BRNO UNIVERSITY OF TECHNOLOGY

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF MECHANICAL ENGINEERING

FAKULTA STROJNÍHO INŽENÝRSTVÍ

INSTITUTE OF MANUFACTURING TECHNOLOGY

ÚSTAV STROJÍRENSKÉ TECHNOLOGIE

OPTIMIZATION OF A SELECTED MANUFACTURING PRODUCTION

OPTIMALIZACE VYBRANÉ VÝROBNÍ TECHNOLOGIE

MASTER'S THESIS

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VEDOUCÍ PRÁCE

BRNO 2021

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
FAKULTA STROJNÍHO INŽENÝRSTVÍ

Zadání diplomové práce

Ústav:	Ústav strojírenské technologie
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Akademický rok:	2021/22

Ředitel ústavu Vám v souladu se zákonem č.111/1998 o vysokých školách a se Studijním a zkušebním řádem V

Optimalizace vybrané výrobní technologie

Stručná charakteristika problematiky úkolu:

Analýza výrobní technologie použité k výrobě vybrané součásti, studium alternativních výrobních strategií, jejich ověření a vyhodnocení výsledků.

Cíle diplomové práce:

Analýza současné výrobní situace.

Návrh progresivních výrobních technologií.

Technologické ověření nových výrobních postupů.

Vyhodnocení výsledků.

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Termín odevzdání diplomové práce je stanoven časovým plánem akademického roku 2021/22

V Brně, dne

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ABSTRAKT

Táto diplomová práca popisuje optimizáciu obrábacieho procesu za účelom zvýšenia produktivity výrobnej linky. Zadanie bolo vypracované v priebehu priemyselnej stáže vo firme Stellantis na obábacej linke blokov valcov motoru DV. Práca vysvetľuje metódy analýzy strát produktivity na výrobnej linke a aplikácii opatrení smerujúcich ku zvýšeniu produktivity, obzvlášť nasadenie nástrojov štíhlej výroby. Najviac boli nasadené nástroje SMED, ktorého cieľom je optimizácia výmeny rezných nástrojov, a TPM, ktorý ma za cieľ zvýšiť spoľahlivosť výrobných prostriedkov.

Kľúčové slová

trieskové obrábanie, automobilový priemysel, rezné nástroje, štíhla výroba, SMED, TPM

ABSTRACT

This thesis describes the optimisation of the machining process in order to increase the productivity of the production line. This assignment has been elaborated during and industrial internship at Stellantis group on the DV engine cylinder block machining line. The thesis explains the methods of analysis of losses of productivity on the production line and application of measures aiming at increasing the productivity, especially the deployment of tools of lean manufacturing. Lean manufacturing tools that were deployed the most were SMED which aims at optimizing the changes of the cutting tools and TPM which has for objective to increase the reliability of the means of production.

Key words

Machining, automotive industry, cutting tools, lean manufacturing, SMED, TPM

ROZŠÍRENÝ ABSTRAKT

Táto práca opisuje optimalizáciu procesu obrábania s cieľom zvýšiť produktivitu výrobnej linky. Zadanie bolo vypracované v súčinnosti s firmou Stellantis na linke na obrábanie blokov válcov motorov DV.

V práci sú vysvetlené metódy analýzy strát na výrobnej linke, aplikácia opatrení zameraných na zvýšenie produktivity, najmä nasadenie nástrojov štíhlej výroby, z ktorých najviac nasadenými metódami sú SMED, ktorého cieľom je optimalizácia výmeny rezných nástrojov, a TPM, ktorého cieľom je zvýšenie spoľahlivosti výrobných strojov.

Úvod

Vynález parného stroja bol veľmi dôležitým vynálezom v dejinách ľudstva. Bol to prvý krok k industrializácii našej spoločnosti. Postupne bol motor nahradený spaľovacím motorom, ktorý využíva rovnaký princíp transformácie translačného pohybu na rotačný, ale pretože má vnútorný spaľovací systém, je kompaktnejší. Spaľovací motor predstavuje vďaka svojej účinnosti a kompaktným rozmerom revolúciu v motorizácii. Spaľovací motor sa od svojho vynájdenia používa ako pohonný systém lodí, lietadiel, automobilov a všetkých typov vozidiel.

Niekoľko rokov po vynáleze motora, ktorý používal ako palivo benzín, vynašiel Rudolf Diesel v roku 1892 nový typ dieselového motora, ktorý mal vyššiu účinnosť ako benzínový. Oba motory sú široko využívané v automobilovom priemysle. Hoci sa podiel spaľovacích motorov na trhu čoraz viac znižuje v dôsledku prísnych emisných noriem, stále zaberajú 85 % automobilového trhu v Európe.

Súbežne s rastúcou kúpnou silou sa zvyšuje aj počet ročne predaných automobilov. Keďže trh s automobilmi je v súčasnosti pomerne veľký a rozvinutý, existuje v tejto oblasti silná konkurencia. Každý výrobca chce vyrábať lepšie, rýchlejšie a predovšetkým lacnejšie ako konkurencia. To vedie k zavedeniu moderných, automatizovaných výrobných prostriedkov. Konkurencieschopnosť na súčasnom trhu však môže zabezpečiť len maximálna účinnosť. V prípade hromadnej výroby sa počíta každá sekunda. Výrobcovia preto robia všetko pre to, aby zefektívnili svoju výrobu.

Metódy neustáleho zlepšovania, najmä z Japonska, sa ukázali ako veľmi účinné pri zvyšovaní efektívnosti výroby. Cieľom týchto techník je zlepšiť produktivitu, ergonómiu, kvalitu a bezpečnosť zavedením štruktúrovanej práce. Už jednoduchá reorganizácia procesov môže mať veľký vplyv na produktivitu. Implementácia týchto metód si často nevyžaduje veľké investície. Sú skôr založené na reorganizácii systémov a stanovení priorít činností. Techniky neustáleho zlepšovania sú v súčasnosti v továrňach veľmi rozšírené, pretože ich cieľom je odstrániť všetky formy plytvania a zlepšiť ich výrobu. Platí to najmä pre automobilový

priemysel, pretože autá sú veľmi zložité stroje, veľmi prísne z hľadiska kvality a bezpečnosti, ale predovšetkým sa vyrábajú vo veľkých sériách.

Prevádzková výkonnosť

Výroba sa vždy meria pomocou ukazovateľa, ktorý umožňuje porovnanie produkcie rôznych výrobných liniek alebo závodov. Jedným z ukazovateľov merania produktivity je prevádzková výkonnosť (PV). Ide o pomer medzi skutočne dosiahnutou výrobou a teoretickou maximálnou výrobou. Poskytuje teda informácie o výkonnosti dielne/výrobnej linky. PV definuje, ako dobre funguje výroba vo vzťahu k jej maximálnej kapacite.

Meranie tejto výkonnosti, a teda stanovenie takéhoto ukazovateľa, je potrebné z týchto dôvodov:

- Vypracovanie a zmena plánov preďalšie zlepšovanie,
- Meranie počiatočnej úrovne výkonu,
- Nastavenie vyčísliteľného cieľa,
- sledovanie vývoja výkonnosti,
- Poskytnúť oficiálne referenčné hodnoty,
- Možnosť porovnávania,
- Vypočítajte technické a ekonomické náklady,
- Určite potenciál výrobnej linky.

TPM

TPM je metóda údržby japonského pôvodu, ktorej cieľom je zvýšiť efektívnosť strojov predchádzaním odstávkam a poruchám a úzkou účasťou operátorov ktorí najlepšie poznajú svoje stroje. Ide teda o participatívnu metódu. Počiatky TPM siahajú do roku 1971. V 80. rokoch 20. storočia sa rozšírila na Západ. V súčasnosti sa využíva najmä v automobilovom priemysle.

Ciele TPM:

- Zvýšenie prevádzkovej výkonnosti,
- Eliminácia strát,
- Zapojenie všetkých oddelení,
- Zapojenie vrcholového manažmentu do práce so zamestnancami,
- Dosiahnuť nulové straty, Zapojiť sa do aktivít v malých skupinách.

SMED

SMED je skratka pre "Single Minute Exchange of Die" (Jednominútová výmena nábojov). V preklade z angličtiny SMED znamená rýchlu výmenu nástrojov. Ide o účinnú metódu, ktorá skracuje čas prestavby výrobnej linky alebo čas výmeny nástrojov tým, že sa najprv reorganizuje proces výmeny nástrojov pred tým než sa do neho investuje.

Ciele SMED :

- Skrátenie prestojov strojov počas výmeny nástrojov,

To potom umožňuje :

- zmenšiť zásoby kvoli zníženiu nákladov,
- Čo najrýchlejšie reagovať na dopyt zákazníkov prostredníctvom rýchlej prestavby linky,
- Zlepšenie kvality prostredníctvom štandardizácie práce,
- Eliminujte improvizáciu prostredníctvom štandardizovanej práce.

Dobrým príkladom nasadenia metódy SMED je zastávka vozidla F1 v boxoch na výmenu opotrebovaných pneumatík a doplnenie paliva. Prestoje sa v priebehu rokov vyvíjali. V 40. rokoch 20. storočia mohol trvať viac ako minútu, ale časom sa optimalizoval a dnes trvá len niekoľko sekúnd. Aktuálny rekord v dĺžke trvania takéhoto zastavenia je 1,82 s. Cieľom je teda urobiť všetko, čo sa dá urobiť počas toho ako formula jazdí aby sa tak minimalizoval čas zastavenia v boxe.

Firma Stellantis

Táto práca vznikla v súčinnosti s firmou Stellantis, ktorá sa zaoberá produkciou automobilov.

Motor DV

Jedná sa o dieselový motor ktorý je najprodukovanejším motorom vo fabrike. Každých 24 sekúnd sa zostaví jeden motor.

Motor je na trhu už niekoľko rokov. V priebehu rokov sa motor vyvíjal v súlade s potrebami trhu. Každá nová verzia motora je navrhnutá tak, aby znižovala spotrebu paliva, a tým aj emisie CO_2. Motor tak spĺňa najnovšie emisné normy Euro (€). V súčasnosti sa v závode Trémery vyrábajú 2 verzie motora DV:

DV5R - v súlade s najnovšou normou (6 EUR). Tento 1,5-litrový vznetový motor HDi má výkon 100 až 130 koní pri nízkej spotrebe paliva (od 3,5 l/100 km). Je tiež známe, že má nízke emisie CO_2 (od 90 g CO_2/km).

DV6 - spĺňa normu 5 EUR. Ide o staršiu verziu motora DV. Je to tiež motor HDi so zdvihovým objemom 1,6 l a výkonom od 100 do 120 koní.

Motor DV je pomerne univerzálny, má vysoký výkon, malý zdvihový objem, nízku spotrebu paliva a nízke emisie CO2. To je dôvod, prečo sa motor DV používa v širokej škále automobilov a značiek.

Kontext stáže

4 typy dielov DV obrábania sa vyrábajú priemernou rýchlosťou približne 2460 dielov/deň. To platí pre kľukové hriadele, ojnice a hlavy valcov. Jediná výrobná linka, ktorá dosahuje horšie výsledky ako ostatné, je linka na obrábanie blokov válcov DV. Priemerný výkon linky na výrobu kľukovej skrine je rádovo 2415 kusov/deň.

Cieľ stáže

Cieľom tejto stáže je optimalizovať výrobu na linke na obrábanie blokov válcov DV.

Blok válcov DV

Táto súčiastka váži 25,380 kg, z čoho 16,37 kg tvorí vrchný blok valcov a 8,1 kg spodný kryt. Zvyšok hmotnosti pripadá na skrutky, tesnenia a zátky.

Hlavná časť bloku válcov je vyrobená zo zliatiny hliníka a kremíka (AlSi9Cu3) s tvrdosťou minimálne 90 HB. Prídavok kremíka do hliníka zlepšuje mechanické vlastnosti materiálu, ako aj jeho odlievateľnosť. To je výhodné najmä pri výrobe odliatkov vo veľkých sériách. Prítomnosť kremíka v hliníku však spôsobuje, že tento materiál je menej obrobiteľný.

V bloku valcov sa vložky valcov vložia počas odlievania v zlievarni. Vložky sú vyrobené z liatiny s lamelárnym grafitom (GLC1) s dobrými mechanickými vlastnosťami a tvrdosťou od 207 do 277 HB.

Obrábanie bloku válcov

Obrábanie bloku válcov je veľmi zložitá úloha. Obrábanie bloku válcov zahŕňa mnoho rôznych obrábacích operácií. Ide najmä o vŕtacie a závitovacie operácie na vytvorenie úchytov pre iné diely, ktoré sa k nim pripevnia. Existujú aj operácie vyvŕtavania otvorov, ktoré si vyžadujú vysokú rozmerovú presnosť. Niektoré povrchy sa obrábajú frézovaním. Ide najmä o spojovacie roviny, ktoré zabezpečujú dokonalé utesnenie medzi rôznymi časťami motora. Okrem toho prebieha proces honovania, ktorým sa dokončujú vložky valcov a ložiská kľukového hriadeľa.

Na obrábanie bloku válcov DV5R sa používa celkom 175 rôznych rezných nástrojov. Vrtáky, rezné závitníky, tvarovacie závitníky, stopkové frézy, čelné frézy, plné vrtáky, stupňovité vrtáky, výstružníky. Používajú sa rezné nástroje z rôznych materiálov: tvrdokov, kubický nitrid bóru (CBN), rýchlorezná oceľ (HSS) alebo polykryštalický diamant (PCD).

Okrem toho môže obrábaný materiál predstavovať určité ťažkosti z hľadiska obrábania. Niektoré časti krytu sú spracované ako dvojmateriál (liatina + hliníková zliatina).

Široká škála obrábacích operácií a materiálov si vyžaduje rôzne typy rezných kvapalín.

Linka na obrábanie bloku válcov DV

Ide o výrobnú linku, ktorá obsahuje niekoľko krokov nazývaných operácie. Jednotlivé operácie sú zapojené do série. Jedna operácia zodpovedá jednému stroju. Výrobná linka pozostáva celkovo z 23 operácií rozdelených takto

- 7 obrábacích strojov
- 2 honovacie stroje
- 2 stroje na montáž
- 3 stanice pre testoanie tesnosti
- 4 odmasťovacie stanice
- 1 laserový gravírovací stroj

Prevádzková výkonnosť na začiatku stáže

Produkcia linky sa vyjadruje prevádzkovou výkonnosťou, ktorá vyjadruje výkonnosť linky. Keďže PV závisí od mnohých faktorov, môže sa v jednotlivých mesiacoch líšiť. Na získanie spoľahlivej referenčnej hodnoty by sa mal použiť priemer PV v rozsahu údajov za minimálne 3 mesiace. Priemerná PV bola na konci roka 2020 na úrovni 80,78 %. Táto hodnota bola vypočítaná ako priemer mesačných hodnôt PV za posledný štvrťrok 2020.

Analýza nízkej produkcie

Napriek kapacitám linky v reálnych podmienkach výroba nikdy nedosiahne 100 % PV. Je nevyhnutné zistiť, prečo je to tak, aby bolo možné zamerať sa na opatrenia v nasledujúcich krokoch. Mali by sa preskúmať rozdiely medzi 100 % PV a skutočne dosiahnutou PV.

Na analýzu situácie na výrobnej linke a identifikáciu príčin nefunkčnosti je potrebné mať k dispozícii spoľahlivé údaje. Prvá analýza bola vykonaná z údajov z terénu, ktoré nahlásili priamo operátori, keďže tí poznajú svoje stroje najlepšie.

Na analýzu sa použil rozsah údajov od 42. týždňa roku 2020 do 08. týždňa roku 2021. Údaje boli zoradené podľa skupiny strát. Zo všetkých údajov viditeľne vyčnievali 3 kategórie strát, zatiaľ čo ostatné boli v porovnaní s nimi skôr zanedbateľné:

- Spoľahlivosť strojov,
- Výmena nástrojov,
- Kvalita.

Okrem týchto troch kategórií strát bolo potrebné pridať ďalšiu :

- Čas cyklu.

Spoľahlivosť strojov bola zodpovedná za väčšinu strát (45 %). Čas cyklu spôsobil približne ¼ strát (26 %). Ďalšou najväčšou skupinou strát bola výmena rezných nástrojov (23 %). Štvrtou najviac znevýhodňujúcou skupinou strát boli straty na kvalite (6 %).

Spoľahlivosť prostriedkov

To je hlavná príčina strát. Takmer polovica strát je spôsobená poruchami a zlyhaniami strojov. Pracovníci údržby robia všetko pre to, aby stroje opravili čo najrýchlejšie. Pravidelne sa vykonáva preventívna údržba, ktorej cieľom je predchádzať budúcim poruchám výmenou opotrebovaných náhradných dielov. Každý týždeň sa celá výrobná linka zastaví na 4 hodiny, aby sa vykonala plánovaná preventívna údržba a cez víkend sa vykonávajú plánované práce.

Napriek tomu je oblasť nedostatočnej spoľahlivosti zdrojov stále na prvom mieste v zozname príčin strát.

Identifikácia bottleneck

Bottleneck je stroj na výrobnej linkem ktorý brzdí všetky ostatné stroje a spôsobuje tak veľa strát. Jedným z výsledkom práce je postup na identifikovanie bottleneck.

Je absolútne nevyhnutné určiť tento bottleneck stroj, ktorý sa stane prioritou.

Na základe analýz sa určilo, že bottleneck je OP90, pretože má najväčší vplyv na výrobu. Keďže stroje na linke sú zapojené do série, zlepšením najslabšieho miesta a zvýšením jeho priepustnosti sa zvýši výkon celej linky.

Rezné nástroje

Široká téma, ktorá sa dotýka každého stroja na linke. Väčšinu práce na výrobnej linke tvoria obrábacie stroje. Na linke je celkom 9 obrábacích strojov a 2 honovacie centrá. Každý stroj obsahuje niekoľko jednotiek, z ktorých každá vykonáva inú operáciu obrábania. Na premenu z odliatku na hotový blok válcov sa dokopy používa 165 rôznych rezných nástrojov.

Veľký počet a rozmanitosť rezných nástrojov znamená, že ich výmena je veľmi častá. Výmeny rezných nástrojov sú jednou z veľkých strát na prevádzkovej výkonnosti.

SMED OP110

Operácia, ktorá bola vybraná na optimalizáciu pomocou SMED, je OP110 z dvoch hlavných dôvodov:

- Výmena nástrojov na OP110 je najčastejšia v celej dielni. Aj keď zmena netrvá dlho, vysoká frekvencia zmien zvyšuje počet manipulácií a pohybov.
- Zadruhé, proces honovanie je najzložitejšou operáciou zo všetkých operácií na linke. Základom pre zvládnutie procesu honovanie je montáž rezných nástrojov. Keďže k výmene nástrojov dochádza často, je dôležité nielen rýchlo namontovať nástroj, ale aj

správne ho namontovať. Zle namontovaný nástroj môže zhoršiť rozmerovú a povrchovú kvalitu obrobku. Nesprávne namontovaný nástroj by mohol zablokovať stroj alebo dokonca poškodiť zariadenie.

Honovaci stroj 110 je obrábací stroj, ktorý obsahuje celkom 6 jednotiek, ktoré vykonávajú honovanie. Z týchto 6 jednotiek obsahuje každá 2 honovacie stroje. Celkovo je teda k dispozícii 12 honovaciech jednotiek.

Honovací stroj pracuje na základe kombinácie dvoch pohybov - rotačného a translačného pohybu. Ide o odstraňovanie materiálu abráziou. Proces abrázie prebieha vďaka prítomnosti abrazivních kameňov. Tie sa rozťahujú a tlačia na vložku valca, keď je honovací nástroj vo vnútri hlavne.

Kamene, ktoré sú v kontakte s obrábaným materiálom, sa opotrebúvajú rýchlejšie ako honovacia hlava. V prípade príliš vysokého opotrebenia ich možno vymeniť bez toho, aby bolo potrebné meniť celý honovací nástroj. V prípade OP je zmena nástrojov rozdelená do 2 kategórií:

Príprava

V prípravnej fáze sa operator natáča počas operacie. Celkovo boli zhotovené 4 videá. Celý proces výmeny sa musel zaznamenať. Už vo fáze prípravy, keď pracovník hľadá osobné ochranné prostriedky, nové náradie, demontážne nástroje vrátane všetkých pohybov, ktoré vykonáva.

Musia sa zaznamenať aj údaje o trvaní a frekvencii vymeny nastrojov. Vďaka aplikácii AMPERE, ktorá sa vypĺňa priamo pracovnikom, je spracovanie tohto typu údajov jednoduchšie a ľahšie sa analyzujú. Keďže údaje o odstávkach strojov získava systém SAPIA automaticky, ich trvanie a frekvencia sú aktuálne. Operator vyplnia iba štítky.

Po zastavení prostriedku vyroby z dôvodu výmeny nástroja sa na dotykovej obrazovke zobrazilo presné trvanie a následne sa charakterizovalo pomocou operatora.

V apliacii AMPERE boly zobrazené štatistické údaje o zmenách nástroja za obdobie jedného týždňa. Vymena nastrojov je rozdelená do niekoľkých kategórií podľa toho, čo operatori identifikovali jako priecinu. Na krivke zobrazene v aplikacii je počet výskytov pre každú kategóriu a v stĺpcoch je celkové trvanie zastavenie. Na získanie priemerného trvania vymeny nastroja sa celkové trvanie a počet výskytov vydelia. Takto sa získali tieto údaje:

Trvanie vymeny honovaciech kameňov: 191/44 = 4,34 min.

Trvanie vzmeny honovaiech hláv: 23/3 = 7,7 min.

Optimalizácia

SMED je participatívna metóda. Cieľom je, aby sa na zmene nástrojov v tejto PO podieľali všetci, ktorí sa na nej podieľajú. Čím viac ľudí sa zapojí, tým viac nápadov sa objaví. Cieľom je aj výmena osvedčených postupov počas vymeny nastroja. Každý má trochu odlišné postupy vymeny nastroja. Na základe diskuse sa môžu vybrať najlepšie postupy, ktoré povedú k vytvoreniu nových noriem pre vymenu nastrojov

Optimalizácia vymeny nastrojov prostredníctvom SMED sa vykonáva v 4 fázach. Toto je znázornené nižšie. Popisy jednotlivých krokov sú vysvetlené nasledovne.

1. Identifikujte

Súbežne so sledovaním videa sa operator dekonštruoval a postupne rozdeľoval na niekoľko fáz. Video je rozdelené na čo najviac fáz. Veľký počet fáz umožňuje vysokú mieru flexibility pri optimalizácii, keďže každú fázu možno presunúť alebo zmeniť. V prípade optimalizácie pražiča CO bolo identifikovaných celkovo 41 rôznych fáz.

2. Oddeliť a zoskupiť

Druhým krokom optimalizácie SMED je určiť, ktoré z fáz možno teoreticky vykonať, keď je zariadenie v prevádzke, a ktoré nemožno vykonať, keď zariadenie v prevádzke nie je. Farby zostávajú rovnaké - žltá pre vonkajšiu operáciu (ktorá nevyžaduje zastavenie prostriedkov) a modrá pre vnútornú operáciu (ktorá vyžaduje zastavenie prostriedkov).

3. Previesť

V kroku konverzie sa maximálne množstvo vnútorných fáz konvertuje na vonkajšie fázy. Zároveň sa externé fázy zoskupujú a presúvajú sa na úplný začiatok alebo koniec vymeny nastrojov, ak to situácia umožňuje. Operácie pozorované na videozázname, ktoré neboli potrebné pre vymenu nastrojov, sú vylúčené.

4. Znížiť

Pokiaľ ide o skrátenie, čas jednotlivých fáz sa skracuje zavedením zlepšení (v prostriedkoch, nástrojoch, úpravách programu atď.).

V tejto fáze je čas vymeny nastrojov rovný 6 minútam a 42 sekundám, z čoho čas zariadenia v pokoji je 5 minút a 6 sekúnd.

To predstavuje nárast o 29 % v čase, keď zarazenie stojí. Úplná optimalizácia vymeny nastrojov je 25 %.

Odstránenie presunov operatora

Okrem zvýšenia času vymeny nastrojov sa navrhovanými úpravami odstránil značný počet presunov a pohybu

Vymena nastrojov pozostávala z 29 ciest pred optimalizáciou, s mnohými cestami medzi hlavným riadiacim pultom, staničným pultom, stolom...

Len pridaním úprav, zmenou umiestnenia nových nástrojov a OOPP, zavedením zlepšení a úprav programu by sa počet presunov mohol znížiť na 6 za predpokladu, že sa vymaže zoznamu činností z pracovného stola.

- Pred optimalizáciou musel operátor prejsť v priemere 53 m na vymenu nastrojov.
- Po optimalizácii musí operátor prejsť len 9 m na vymenu nastrojov.

Akčný plán

Bol vypracovaný akčný plán, v ktorom sú zhrnuté zlepšenia, ktoré boli vybrané počas projektu. Projekt potom monitoruje projektový manažér, ktorý komunikuje s manažérmi jednotlivých činností a je informovaný o pokroku v jednotlivých činnostiach.

Vytváranie noriem

Po dokončení všetkých opatrení a implementácii zlepšení. Ďalším krokom je vytvorenie noriem pre vymenu nastrojov. Tieto normy sú výsledkom pracovného workshopu, na ktorom sa zúčastnil zástupca každého tímu. Normy obsahujú vybrané úpravy a zlepšenia uvedené v akčnom pláne.

Školenie operatorov

Každý operator, ktorého práca ovplyvňuje danú operáciu, je vyškolený v oblasti nových noriem

Školenie IC

Každý IC, ktorého práca ovplyvňuje danú operáciu, je vyškolený podľa nových noriem. Operator si je vedomý každej zmeny v postupu vymeny nastrojov, ktorá bola vykonaná počas optimalizácie SMED.

Monitorovanie lokality

Ukazovatele sa vyberajú na monitorovanie procesu vymeny nastrojov

Nasleduje zoznam opatrení podľa priorít. Tieto činnosti sa používajú na vykonanie zmien navrhovaných v krokoch 3 a 4. Ich priority sa určujú na základe matice 9 políčok, ktorá zohľadňuje 2 premenné: výzvu a náročnosť realizácie.

Následne sa vytvoria normy a operátori sa zaškolia, aby boli oboznámení s najnovšími aktualizáciami a poznali proces vymeny nastrojov, ktorý bol zvolený počas optimalizácie.

Výsledky

Oblasti prezentované v tejto práci a optimalizačné opatrenia v nej opísané mali vplyv na produktivitu, ako aj na charakter príčin strát.

Porovnanie analýz produktivity z obdobia začiatku stáže a z obdobia koncu stáže vykazujú evolúciu.

Vo všetkých kategóriách sa zaznamenáva vysoká miera zmien. Spoľahlivosť strojov sa v období od mája 2021 do júla 2021 v porovnaní s východiskovými údajmi zvýšila o viac ako 50 %. Princíp TPM, ktorý spočíva v odstraňovaní malých opakujúcich sa porúch, a tým v predchádzaní vzniku väčších porúch, sa osvedčil.

Výmena rezných nástrojov sa za rovnaké obdobie zlepšila o viac ako 60 %. Práca v oblasti rezných nástrojov bola systematická a zahŕňala niekoľko tém. Dva konkrétne príklady sú vysvetlené v tejto diploôovej práci.

Vývoj výkonnosti linky, či už v priebehu dní, týždňov alebo mesiacov, je veľmi premenlivý a dynamický. Produktivita je totiž parameter, ktorý závisí od mnohých faktorov. Okrem všetkých rodín strát, ktoré ovplyvňujú produktivitu, závisí aj od mnohých ďalších faktorov, ako je nedostatok energie alebo zásob, počet zamestnancov, prítomnosť obsluhy pri strojoch, motivácia operátorov, rozbeh dielne po odstávke, prestavby linky a podobne.

PV vo výrobe pri obrábaní DV sa meria na zmenu. Na základe toho možno vypočítať dennú, týždennú a mesačnú prevádzkovú výkonnosť.

Priemerná PV za prvé referenčné obdobie je 80,78 %. Ide o priemer mesačných PV za toto obdobie. Priemerná PV za obdobie máj - júl 2021 je 81,46 %. Táto hodnota bola tiež vypočítaná ako priemer mesačných PV.

Tento rozdiel medzi týmito dvoma referenciami zodpovedá nárastu o 0,68 %, čo znamená zvýšenie výroby o 20 kusov denne. Cena jedného bloku válcu je 95 EUR, čo znamená zisk o 1900 EUR za deň.

Napriek zvýšeniu RO a rastúcemu trendu vývoja bola výroba v období od januára 2021 do júla 2021 ovplyvnená vyššími silami, ktoré mali negatívny vplyv na produktivitu. Najmä apríl a jún boli postihnuté:

- Apríl bol ovplyvnený vysokou absenciou spôsobenou pandémiou covid-19 vo Francúzsku.
- Produktivita v júni bola poznačená nedostatkom komponentov v automobilovom priemysle. Závody na montáž automobilov pociťovali nedostatok elektronických čipov. Preto nemohli vyrábať autá. Zastavila sa tým aj výroba v továrňach na motory. Polovicu dní v týždni dielňa stála. Výroba prebiehala nominálne 3-4 dni v týždni. PV sa

nevypočítava v dňoch, keď továreň nevyrába, napriek tomu mali tieto dlhé odstávky nepriamy vplyv na výkonnosť výrobnej linky. Je to spôsobené okrem iného týmito dôvodmi: častejšia prestavba. Na vykonanie takejto prestavby je potrebné najprv vyprázdniť všetky stroje.

Po apríli a júni je automobilový priemysel stále ovplyvnený potrebou energetickej transformácie na zníženie emisií CO2. Hoci naftové motory majú stále významný podiel na automobilovom trhu, dopyt po naftových automobiloch každým rokom čoraz viac klesá.

Závery

V tejto práci bola vykonaná komplexná štúdia produktivity výrobnej linky. Cieľom bolo optimalizovať výrobu linky, pričom sa odhalili najvýraznejšie a najhoršie body. Riešenia boli použité s cieľom optimalizovať výrobu pri vynaložení primeraného úsilia a nákladov.

Výroba sa meria v prevádzkovej výkonnosti (PV). Nikdy nedosiahne svoj maximálny potenciál, pretože v reálnom kontexte vždy existujú faktory, ktoré ho narúšajú a spôsobujú výrobné straty.

V tejto práci sa analyzovali kategórie najviac penalizujúcich strát. Potom boli navrhnuté a uplatnené riešenia. Spomedzi metód použitých na optimalizáciu výroby boli ďalej nasadené nástroje štíhlej výroby. Nakoniec sa posúdil vplyv vykonaných opatrení na produktivitu.

Vplyv prijatých opatrení sa meral na základe 2 hlavných ukazovateľov

- Prevádzkový výkon linky. Tá sa v priebehu projektu vyvíjala z 80,78 % na 81,46 % s dlhodobo rastúcim trendom. Toto zvýšenie je výsledkom optimalizácie opísanej v tejto práci. Nárast produktivity je potom 0,68 %. Toto zvýšenie výroby znamená prírastok 20 kusov denne, čo predstavuje zisk 1900 EUR denne.

- Povaha strát. Rozdelením dôvodov strát, ktoré majú negatívny vplyv na produkciu, je zrejmé, že charakter strát sa počas obdobia projektu zmenil. Kategórie strát, na ktoré sa projekt zameral, sa z hľadiska ich vplyvu na produkciu znížili. Konkrétne ide o oblasť spoľahlivosti zariadení a oblasť rezných nástrojov.

Tento vývoj dokazuje dôležitosť opatrení vykonaných v súvislosti s týmito kategóriami strát, ako aj s celkovou produktivitou. To znamená, že TPM a SMED sa ukazujú ako veľmi dôležité nástroje v súčasnom priemysle a ich správne nasadenie má veľmi dôležitý vplyv na produktivitu.

Diskusia

Aj napriek veľmi uspokojivým výsledkom v takom krátkom čase na linke, ktorá už bola niekoľkokrát optimalizovaná, sú výsledky len čiastočné. V skutočnosti ide o komplexný proces, ktorý prebieha dlhodobo. Mnohé z týchto opatrení sa začali realizovať v období od februára 2021 do júla 2021, ale k dnešnému dňu ich realizácia stále pokračuje. Je preto viac ako pravdepodobné, že zisk z týchto akcií sa v nasledujúcich mesiacoch ešte zvýši.

Veľký potenciál má najmä projekt digitalizácie dielní, keď sa všetci plne oboznámia s jeho fungovaním. Pokračovaním v zavádzaní správnych foriem riadenia prinesie projekt významné výsledky.

Zisky z projektov SMED sú zatiaľ tiež len teoretické a čiastočné. Po dokončení všetkých činností sa PV ešte zvýši.

Pridaná hodnota tejto práce presahuje optimalizáciu výroby, implementáciu nástrojov, ktoré budú naďalej pôsobiť, ako aj školenie tímov, aby sa naučili tieto nástroje používať. To by malo v budúcnosti viesť k zvýšeniu produktivity a efektívnosti linky na výrobu plášťov DV.

RESUME

Ce mémoire décrit l’optimisation du process usinage afin d’augmenter la productivité de la ligne de production. La mission a été réalisée au sein de l’entreprise Stellantis sur la ligne d’usinage des carters du moteur DV. Le moteur La ligne de production des carters

Le mémoire explique les méthodes d’analyse des pertes sur la production, l’application des mesures visant à augmenter la productivité dont surtout le déploiement des outils de l’amélioration continue dont les méthodes les méthodes les plus déployés sont le SMED qui vise à optimiser les changements des outils coupants et la TPM qui a pour objectif d’augmenter la fiabilité des moyens de production. Les points les plus pénalisant et saillants au niveau de la production sont révélés ce qui précède l’optimisation.

Introduction

L’invention de la machine à vapeur a été une invention très importante dans l’histoire de l’homme. C’était le premier pas vers l’industrialisation de notre société. Progressivement, la machine a été remplacée par le moteur à combustion interne, qui lui normalement, utilise le même principe de transformation du mouvement de translation en mouvement de rotation mais comme ce dernier à le système de combustion interne, il est plus compact au niveau de taille. Grâce à son efficacité et sa taille compacte, le moteur thermique fait une révolution dans la motorisation. Depuis son invention, jusqu’à nos jours, le moteur thermique sert comme la propulsion pour des bateaux, avions, voitures et les véhicules de tout type.

Peu d’années après l’invention du moteur qui utilisait l’essence comme carburant, Rudolf Diesel invente en 1892 le nouveau type de moteur thermique à Gazole qui a un rendement supérieur à celui à l’essence. Les deux moteurs sont largement déployés dans l’industrie automobile. Bien que la part des moteurs thermiques sur le marché diminue de plus en plus à cause des normes d’émissions strictes, ces derniers occupent toujours 85% du marché des voitures en Europe.

Parallèlement avec le pouvoir d’achat qui monte, le nombre des voitures vendues annuellement monte également. Puisque le marché automobile est assez grand et développé de nos jours, il y a une forte concurrence dans ce domaine-là. Chaque producteur veut produire mieux, plus vite mais surtout avec un coût de production inférieur à ceux de la concurrence. Cela mène à une mise en place des moyens de production modernes et automatisés. Cependant, seule une efficacité maximale peut assurer la compétitivité sur le marché d’aujourd’hui. Chaque seconde compte beaucoup dans le cas d’une production en grande série. Les producteurs font alors tout pour rendre leur production plus efficace.

Les méthodes de l’amélioration continue provenant majoritairement du Japon ont prouvé leur grande efficacité quant à l’augmentation du rendement de production. Ces techniques ont pour but d’améliorer la productivité, l’ergonomie, la qualité et la sécurité en mettant en place un travail structuré. Rien qu’une simple réorganisation des process peut avoir un grand impact sur la productivité. La mise en place de ces méthodes ne demande souvent pas des grands investissements. Elles se basent plutôt sur une réorganisation des systèmes et une priorisation des actions. Les techniques d’amélioration continue sont aujourd’hui largement déployées dans des usines d’aujourd’hui car celles-ci ont pour but d’effacer toute forme de gaspillages et de rendre leurs productions meilleures. Cela est surtout valable pour l’industrie automobile car les voitures sont des engins très complexes, très stricts au niveau de la qualité et de la sécurité mais surtout, elles sont produites en grande série.

Rendement opérationnel

La production est toujours mesurée par un indicateur qui permet la comparaison entre la production des différentes lignes de production ou des différentes usines. L’un des indicateurs qui permettent de mesurer la productivité est le rendement opérationnel (RO). Il s’agit du ratio entre la production réellement atteinte et la production maximale théorique. Il renseigne alors la performance d’un atelier/ d’une ligne de production. Le RO définit à quel point la production est performante par rapport à ses capacités maximales.

Mesurer cette performance et donc établir un tel indicateur est nécessaire pour des raisons suivantes :

- Guider les plans d’actions de progrès,
- Mesurer le niveau de performance de départ,
- Fixer un objectif chiffré,
- Suivre l’évolution de la performance,
- Constituer la référence officielle,
- Permettre les comparaisons,
- Calculer des enjeux technico-économiques,
- Déterminer le potentiel d’une ligne de flux.

TPM

La total productive maintenance (TPM) est une méthode de maintenance d’origine japonaise qui a pour but d’améliorer le rendement des machines par la prévention des arrêts, des pannes et par une forte implication des conducteurs d’installations (CI’s) qui connaissent le mieux leurs machines. Il s’agit donc d’une méthode participative. Les origines de la TPM datent de 1971. Elle a été ensuite diffusée à l’occident dans les années ’80. Aujourd’hui, elle est déployée surtout dans l’industrie automobile [2].

Objectifs :

Augmentation du rendement opérationnel (RO),

Supprimer les pertes et les gaspillages, les accidents, les pannes,

Implication de tous les départements,

Implication du top management aux employés,

Atteindre zéro pertes, engager les activités en petites groupes.

Le SMED

SMED est un acronyme signifiant « Single Minute Exchange of Die ». Traduit de l'anglais, SMED veut dire changement des outils (CO) rapide. Il s'agit d'une méthode efficace qui réduit le temps de changement de campagne ou le temps de changement des outils (CO) commençant par une réorganisation du processus du CO avant de procéder aux investissements.

Le but du SMED :

• Diminuer le temps d'arrêt des moyens entre 2 pièces bonnes lors d'un changement d'outils (CO) ou un changement de campagne,

Cela permet ensuite de :

• Supprimer les stocks ou les réduire considérablement,

• Répondre au plus vite à la demande des clients via un changement de campagne rapide,

• Améliorer la qualité via la standardisation de travail,

• Supprimer l'improvisation via le travail standardisé.

Un bon exemple du déploiement de la méthode SMED est l'arrêt du véhicule F1 au stand qui a pour but de changer les pneus usés et faire le plein de carburant. Le temps d'arrêt a évolué au fil des années. Il pouvait durer plus d'une minute aux années '40 du 20ème siècle mais il a été optimisé au fur et à mesure et aujourd'hui il ne dure que quelques secondes. Le record actuel de la durée d'un tel arrêt est 1,82s. L'arrêt de voiture étant une opération interne, un maximum des opérations devraient être faites en externe (pendant que la voiture roule). Le but est alors de faire tout ce qui peut être fait dans la phase externe (préparer les nouveaux pneus, préparer les outils, ranger les pneus usés) et ainsi minimiser les opérations internes (changer les pneus).

Groupe Stellantis - Présentation de l'entreprise

Le sujet de ce rapport a été réalisé dans un contexte industriel, au sein de l'entreprise Stellantis. Ce chapitre présente le groupe Stellantis.

Le moteur DV

Le moteur DV est le plus produit sur le site. Un moteur est assemblé toutes les 24 secondes.

Le moteur est sur le marché depuis plusieurs années. Au fil des années, ce dernier évolue suivant le besoin du marché. Chaque nouvelle version du moteur avait pour but de réduire la consommation du carburant et donc réduire les émissions de CO_2. Cela permet, entre-autres, au moteur de respecter les normes d’émissions euro (€) les plus récentes. Actuellement 2 versions du moteur DV sont produites sur le site de Trémery :

DV5R - conforme à la norme la plus récente (€6). Ce moteur diesel HDi de 1,5 l a une puissance allant de 100 jusqu’à 130 CV tout en gardant une faible consommation du carburant (à partir du 3,5l / 100km). Il est aussi connu pour avoir des faibles émissions CO_2 (à partir du 90g CO_2 / km).

DV6 – conforme à la norme €5. Il s’agit de la version plus ancienne du moteur DV. Il s’agit aussi d’un moteur HDi, de la cylindrée 1,6l ayant une puissance allant de 100 à 120CV.

Le moteur DV est assez polyvalent, ayant une haute performance, petit volume cylindrée, basse consommation du carburant et faibles émissions en CO_2. C’est la raison pour laquelle le moteur DV est utilisé dans toute une ribambelle des voitures et des marques automobiles. Un exemple de déploiement du moteur DV5R est visualisé ci-dessous.

Contexte du PFE

Les 4 types de pièces de l’usinage DV sont produites à une cadence moyenne à peu près de 2460 pièces/ jour. Cela est valable pour les vilebrequins, les bielles et les culasses. Le seul atelier qui a une performance inférieure aux autres est la ligne d’usinage des carters DV. Le rendement moyen de la ligne carter est dans l’ordre de 2415 pièces / jour.

Objectif de stage

L’objectif de ce stage est l’optimisation de la production sur la ligne d’usinage des carters de l’atelier DV.

La pièce étudiée – carter du moteur DV

Un carter pèse 25,380 kg dont 16,37 kg le bloc des cylindres et 8,1kg le chapeau carter. Le reste du poids est dû aux vis, joints et bouchons.

La majeure partie du carter est composée en alliage d’aluminium et silicium ($AlSi_9Cu_3$) ayant une dureté de 90 HB minimum. Le fait d’ajouter le silicium dans l’aluminium améliore les propriétés mécaniques du matériau ainsi que sa coulabilité. Cela est spécialement avantageux comme il s’agit de la fabrication des bruts de fonderie en grande série. Néanmoins, la présence du silicium dans l’aluminium rend l’usinabilité du matériau moins bonne.

Dans le bloc des cylindres, les chemises des fûts de cylindre sont insérées dans le carter durant la coulée dans la fonderie. Les chemises sont fabriquées en fonte à graphite lamellaire (GLC1) avec des bonnes propriétés mécaniques dont la dureté varie entre 207 et 277 HB.

Le chapeau-carter est également fabriqué en alliage d’aluminium et silicium avec des inserts en fonte à graphite sphéroïdal (GS400-12). Ceux-ci servent comme le guidage pour le vilebrequin.

Usinage du carter

Usinage du carter est une tâche très complexe. Usinage du carter comprend beaucoup d’opérations d’usinage diverses. Il s’agit surtout des opérations d’alésage et du taraudage pour créer des fixations pour d’autres pièces qui viendront s’attacher à ce dernier. Il y a aussi des opérations d’alésage pour des trous qui nécessitent une grande précision dimensionnelle. Certaines surfaces sont usinées par les opérations de fraisage. Il s’agit surtout des plans des joints d’assurer une excellente étanchéité entre différentes parties du moteur. A cela s’ajoute le process du rodage qui fait la finition des chemises des cylindres et des paliers ligne vilebrequin.

Il y a au total 175 outils coupants différents pour usiner un carter DV5R. Les forets, les tarauds par coupe, les tarauds par déformations, les fraises 2 tailles, les fraises à surfacer, les forets monoblocs, les forets étagers, les alésoirs. Les outils coupants en matériaux différents sont utilisés : le carbure, le nitrure de bore (CBN), l’acier rapide supérieur (ARN) ou le diamant polycristallin (PCD).

En plus, le matériau usiné peut représenter aussi quelques difficultés quant à l’usinage. Certaines parties du carter sont usinées comme bi-matière (fonte + alliage d’aluminium).

Une grande variété des opérations d’usinage et des matériaux usinés nécessitent plusieurs types des liquides de coupe.

La ligne d’usinage des carters DV

Le carter est usiné sur la ligne d’usinage de carter. Il s’agit d’une ligne de production contenant plusieurs étapes appelées opérations. Les différentes opérations sont connectées en série. Une opération correspond à une machine. Au total, la ligne de production est composée de 23 opérations divisées de manière suivante :

- 7 machines transferts
- 2 machines de rodage
- 2 machines d’assemblage carter chapeau/carter et bouchons canaux d’huile
- 3 moyens d’étanchéité

- 4 machines à laver
- 1 machine de gravage laser

Le RO référence

La production de la ligne est exprimée en rendement opérationnel qui exprime la performance de la ligne. Comme le RO dépend de nombreux facteurs il peut varier de mois en mois. Pour obtenir une référence fiable, il faut prendre la moyenne des RO sur une plage des données d'au moins 3 mois. La moyenne du RO était à 80,78% à la fin de l'année 2020. Celle-ci a été calculée comme la moyenne des Ro's mensuels sur le dernier trimestre 2020.

Analyse de la production faible (non-RO)

Malgré les capacités de la ligne, dans les conditions réelles, la production n'atteint jamais le RO de 100%. Il est essentiel d'identifier pourquoi c'est le cas afin de pouvoir bien cibler les actions dans des étapes qui suivent. Les écarts entre le RO de 100% et le RO réellement atteint doivent être étudiés. Ces écarts s'appelleront « non-RO ».

Pour analyser la situation dans l'atelier et identifier les causes du non-RO, il est nécessaire d'avoir des données fiables. La première analyse du non-RO a été faites à partir des données du terrain remontées directement par des opérateurs car ceux-ci connaissent le mieux leurs machines.

Une plage des données depuis la semaine 42 de 2020 jusqu'à la semaine 08 de 2021 a été prise pour l'analyse. Les données ont été triées par famille de perte. 3 Familles du non-RO ressortaient visiblement de toutes les données alors que les autres se montraient plutôt comme négligeables par rapport à celles-ci :

- Fiabilité des moyens,
- Changement d'outils (CO),
- Qualité.

Au-delà de ces 3 familles des pertes, une autre cause du non-RO majeure a dû être ajoutée dans l'équation :

- Temps de cycle (TCY).

La fiabilité des moyens a été responsable pour la majeure partie des pertes du RO (45%). Le TCY hors du nominal causait à peu près ¼ des pertes du RO (26%). La famille des pertes qui suivait était le changement des outils coupants en fréquence (23%). Enfin, la quatrième famille des pertes les plus pénalisantes sont les pertes sur la qualité (6%).

La fiabilité des moyens

Il s’agit de la cause principale du non-RO. Presqu’une moitié des pertes est causée par les pannes et les défaillances des machines. Les effectifs de la maintenance (MAI) font le maximum pour réparer les machines au plus vite. La maintenance préventive qui cherche à effacer l’apparition des futures pannes en remplacent les pièces de rechange usées est déployée régulièrement. Chaque semaine, toute la ligne de production s’arrête pendant 4 heures afin de réaliser les préventifs planifiés (PMP) et les travaux programmés (TP) sont réalisés pendant le weekend.

Malgré cela, le domaine de la fiabilité des moyens insuffisante est toujours en tête de la liste des causes du non-RO.

Identification de la machine bouchon

Une démarche est proposée pour identifier en se basant sur les données factuelles, mesurées automatiquement sur les moyens concernés. Comme il s’agit d’un sujet complexe, la démarche étudie plusieurs facteurs. Elle se base principalement sur 4 piliers qui définissent les étapes de cette démarche :

1. Les arrêts induits dans l’atelier

Dans le raisonnement de la ligne du flux, si les machines sont connectées en série, un endroit bouchon sera celui entouré par l’OP en amont majoritairement saturée et l’OP ou plusieurs OP’s en aval majoritairement en manque de pièce. Si une machine freine le flux, elle cause les arrêts propres des autres machines dans l’atelier en commençant par la machine en aval et la machine en amont, puis se répandant plus loin. Par conséquent, l’endroit bouchon est aussi indiqué par le temps de saturation et manque de pièce le plus petit de l’atelier. Si les durées des saturations et les manques des pièces sont visualisées sur une longue période, les conclusions statistiquement fiables et factuelles peuvent être tirées.

2. Les arrêts propres dans l’atelier

L’un des indicateurs qui caractérisent les points bouchons sont les arrêts propres des moyens. Cela peut évidemment inclure plusieurs types d’arrêts propres tels que les pannes, le changement des outils, le nettoyage copeaux, les réparations, la machine en mode manuel.

Les moyens ayant le temps d’arrêt propre le plus élevé de l’atelier indiquent qu’il s’agit des endroits bouchons. Si les OP’s dans l’atelier sont rangées dans l’ordre décroissant en fonction de leurs temps d’arrêts propres, les endroits bouchons ressortissent en tête de liste.

3. Les débits horaires dans l’atelier

Un indicateur qui a été retenu dans tous les ateliers du groupe Stellantis est la production horaire – c’est-à-dire le nombre des pièces produites pendant une heure. Il s’agit de l’indicateur le plus synthétique qui dépend de toutes les autres familles des pertes. Les valeurs de la production horaire moyenne sont calculées sur période qui dure au moins 415 minutes (le TEP d’une équipe). En tout cas il est conseillé de calculer ces valeurs sur une période nettement plus longue que le TEP d’une équipe car la production horaire peut être biaisée par l’arrêt d’un moyen.

La machine bouchon

OP90 – 2ème machine pénalisante. Le transfert se trouve dans la partie finition de l’atelier. Au-delà d’être la machine pénalisante, celle-ci est problématique aussi au niveau de qualité, TCY lent et un changement des outils hors fréquence qui arrive souvent. C’est pour cette raison-là, qu’il est plus judicieux de se focaliser sur OP90 plutôt que sur OP800.

OP20 – Même si elle . dans cette liste, cela est surtout causé par un défaut récurrent qui est déjà

Il est absolument essentiel de bien identifier la machine bouchon qui deviendra la machine cible car en améliorant celle-ci, tout le flux de production s’améliora.

En employant la démarche spécifiée au-dessus, le choix de machine cible est fait. C’est OP90 qui devient la machine cible car elle pénalise le plus la production. Comme les machines sur la ligne sont branchées en série, en améliorant l’endroit le plus faible et en améliorant son débit, la production de toute la ligne augmentera.

Outils coupants

Le sujet très large qui touche à chaque transfert d’usinage. Les outils coupants font le gros du travail de la ligne de production. Il y a au total 9 machines d’usinage sur la ligne dont 7 transferts d’usinage et 2 machines de rodage. Chaque machine contient plusieurs unités, dont chacune fait une autre opération d’usinage. Ensemble, 165 outils coupants différents sont utilisés pour transformer le brut de fonderie en carter fini.

Un grand nombre et variété des outils coupants signifient des changements d’outils très fréquents. Les changements d’outils représentent une des causes des pertes du RO.

SMED OP110

L'Opération qui a été choisie pour être optimisée par SMED est l'OP110 pour deux raisons principales :

- Le changement des outils sur OP110 est le plus fréquent de tout l'atelier. Même si un changement ne dure pas beaucoup, la fréquence élevée des changements augmente le nombre des manipulations et déplacements.

- Deuxièmement, le process du rodage est le plus complexe de toutes les opérations de la ligne. La base pour bien maîtriser ce process du rodage est le montage propre des outils coupants. Comme les changements des outils se font souvent, il est non seulement important de monter l'outil vite mais aussi le monter correctement. Un outil mal monté peut dégrader la qualité dimensionnel et surfacique du fût. Également, un outil mal monté pourrait bloquer la machine voir endommager l'équipement.

La rodeuse 110 est un transfert d'usinage qui contient au total 6 unités qui font le rodage. Parmi ces 6 unités, chacune contient 2 rodoirs. Il y a donc en tout 12

Un rodoir usine par la combinaison de deux mouvements – le mouvement de rotation et le mouvement de translation. Il s'agit d'enlèvement de matière par l'abrasion. Le process d'abrasion est effectué grâce à la présence des pierres. Ceux-ci s'expandent et s'appuient sur la chemise du cylindre une fois le rodoir se trouve à l'intérieur du fût.

Les pierres, étant en contact avec la matière usinée, s'usent plus vite qu'un rodoir. Ils peuvent alors être changés en cas d'usure trop élevée sans besoin de changer le rodoir entier. Dans le cas de l'OP, Le changement des outils se divise donc en 2 catégorie :

Préparation

Dans la phase de préparation, le CI est filmé lors du CO. En total 4 vidéos ont été prises. Tout le process du changement a dû être enregistré. Dès la phase de préparation quand le CI cherche les EPI's, les nouveaux outils, les outils de démontage y compris tous les déplacements qu'il effectue.

Une prise des données sur la durée et la fréquence du CO doit être faite aussi. Grâce à l'outil AMPERE qui est renseigné directement par le CI, le traitement de ce type des données est plus facile à manipuler et à analyser. Comme les données sur les arrêts des machines sont acquises automatiquement par le système SAPIA, leurs durées et fréquence sont factuelles. Seulement les libellés sont remplis par les CI.

Une fois, le moyen était à l'arrêt en raison du changement des outils, la durée exacte à été remontée dans l'écran tactile et ensuite caractérisée par le CI.

Sur la . 49 les statistiques des changements des outils sont visualisés sur une période d’une semaine. Le CO est divisé en plusieurs catégories en fonction de ce que les CI’s saisissaient. Sur la courbe il y a le nombre d’occurrence pour chaque catégorie et en barres il y a la durée totale. Pour obtenir la durée moyenne du changement, la division de la durée totale et le nombre d’occurrence est faite. Ainsi les données suivantes sont obtenues :

Durée du CO des pierres : 191/44 = 4,34 min

Durée du CO des rodoirs : 23/3 = 7,7 min

Optimisation

Le SMED est une méthode participative. Le but c’est que chacun qui est concerné par le changement des outils à cette OP participe. Plus de personnes participent, plus d’idées sont évoquées. Le but c’est aussi d’échanger des bonnes pratiques lors du CO. Tout le monde a des routines du CO qui sont un petit peu différentes. En échangeant, la meilleure pratique peut être choisie ce qui va mener à la création des nouveaux standards des CO’s.

L’optimisation du CO par le SMED est faite en 4 phases. Ceci est visualisé ci-dessous. Les descriptions de chacune des étapes sont explicitées en bas de l’image.

1. Identifier

En parallèle avec le visionnage de la vidéo, le CO a été décortiqué et progressivement saucissonné en plusieurs phases. La vidéo est décomposée en le plus des phases possibles. Ayant un grand nombre des phases permet d’être très flexible quant à l’optimisation car chaque phase peut être déplacée ou convertie. Dans le cas d’optimisation du CO du rodoir, 41 différentes phases ont été identifiées au total.

2. Séparer et Regrouper

Deuxième étape de l’optimisation SMED consiste à identifier parmi toutes les phases celle qui peuvent en théorie être faites lorsque le moyen est en marche et au contraire celles qui ne peuvent pas être faites qu’avec le moyen à l’arrêt. Les couleurs restent les mêmes – jaune pour une opération externe (qui ne nécessite pas l’arrêt du moyen) et le bleu pour une opération interne (qui nécessite l’arrêt du moyen).

3. Convertir

Dans l’étape de conversion, un maximum des phases internes sont converties en phases externes. En même temps, les phases externes sont regroupées et déplacées au tout début ou à la toute fin du CO si la situation le permet. Les opérations observées dans la vidéo, qui n’était pas nécessaire pour un CO, sont exclues.

4. Réduire

Quant à la réduction, le temps des différentes phases est réduit en mettant en place des améliorations (au niveau du moyen, outillage, modifications des programmes …).

A cette étape, le temps de CO est égal à 6 minutes et 42 secondes dont le temps du moyen à l’arrêt descend 5 minutes et 6 secondes.

Il s’agit alors d’un gain de 29% sur le temps que le moyen est à l’arrêt. L’optimisation du CO intégral est de 25%.

Suppression des déplacements

Au-delà du gain sur le temps de CO, une partie importante des déplacements a été supprimée grâce à des modifications proposées.

Le CO comprenait 29 déplacements avant l’optimisation avec des nombreux déplacements entre le pupitre principal de commande, le pupitre de la station, la table…

Rien qu’en ajoutant des modifications, réorganiser l’emplacements des nouveaux outils et des EPI, mettre en place des améliorations et modifications du programme, le nombre de déplacements pourrait descendre à 6 à condition que la liste d’actions issue du chantier soit soldée.

- Avant l’optimisation, l’opérateur devait se déplacer en moyenne 53m par CO.
- Après l’optimisation, l’opérateur ne doit se déplacer seulement 9m par CO.

Le plan d’actions

Un plan d’actions résumant les améliorations qui ont été retenues lors du chantier a été mis en place. Le chantier est alors suivi par le pilote du chantier qui communique avec les pilotes de chacune actions et se renseigne sur l’avancement de chaque action.

La création des standards

Une fois toutes les actions soldées et améliorations mises en place. L’étape suivante consiste à la création des standards du CO. Les standards sont le résultat du chantier où un représentant de chaque équipe avait participé. Les standards contiennent les modifications et améliorations retenues listées dans le plan d’action.

Formation des CI’s

Chaque CI dont le travail touche à l’opération concernée, est formé selon les nouveaux standards. Le CI est conscient de chaque changement du CO qui a été retenu lors de l’optimisation SMED.

Suivi du chantier

Les indicateurs sont choisis afin de pouvoir suivre le CO.

Une liste des actions rangées par leur priorité suit. Ces actions permettent d’effectuer les modifications proposées lors de l’étape 3 et 4. Leur priorités sont déterminées à partir de la matrice 9 cases qui prend en compte 2 variables : L’enjeu et la difficulté de la mise ne œuvre.

Les standards sont ensuite créés et les opérateurs sont formés afin qu’ils soient familiarisés avec les mises à jour les plus récentes et qu’ils connaissent bien le processus du CO qui a été retenu lors de l’optimisation.

Résultats

Le travail présenté dans ce mémoire et les actions d’optimisation qui y étaient décrites ont impacté la productivité ainsi que la nature des causes des pertes.

La compare la décomposition du non-RO qui a été prise comme référence en février 2021 et la décomposition du non-RO faite pour juillet 2021. Les deux références ont été déterminées comme la moyenne sur plusieurs mois afin d’obtenir les données statistiquement fiables. Pour chaque cas de ., la décomposition du non-RO comprend 4 catégories des pertes qui étaient les plus présentes à l’époque.

Il y a un fort taux de changement pour toutes les catégories. La fiabilité des moyens a été améliorée de plus de 50% pendant la période mai 2021 et juillet 2021 par rapport aux données de référence. Le principe de la TPM étant d’éradiquer les petites pannes récurrentes et ainsi empêcher l’apparition des pannes plus importantes a fait ses preuves.

Le changement des outils coupants a été amélioré de plus de 60% durant la même période. Le travail sur le domaine des outils coupants était systématique et traitait plusieurs sujets. Deux exemples concrets sont expliqués davantage dans ce rapport car il s’agissait des améliorations les plus importantes.

Quant au domaine du temps de cycle, ce dernier s’est dégradé de 1,5 fois de sa valeur de départ. Désormais, le TCY est responsable de plus de 63% des pertes dans l’atelier. Ce travail ne touchait que marginalement au Temps de cycle à cause de la grande complexité du sujet. Il y avait néanmoins des actions menées sur la problématique du TCY tout au long de la période entre février et juillet 2021.

Il est également remarquable que la quatrième catégorie soit différente pour les 2 périodes citées au-dessus. Lors de première analyse faite entre octobre 2020 et févier 2021 il y a le sujet de la qualité qui s’ajoute aux 3 autres familles des pertes majeures tandis que pour la période entre le mai 2021 et le juillet 2021, c’est la famille des pertes nettoyage copeaux qui émerge.

L’évolution du RO

L’évolution de la production que ce soit au cours des jours, des semaines ou des mois est très volatil et dynamique. C’est parce que la productivité est un paramètre qui dépend de beaucoup de facteurs. En plus de toutes les familles des pertes qui influencent la productivité, celle-ci dépend aussi de tout un tas des autres facteurs tels que le manque d’énergie ou d’approvisionnement, manque des stocks, le nombre des effectifs, la présence des opérateurs à côté des moyens, la motivation des opérateurs, les démarrages de l’atelier après un arrêt, le changement de campagne et autres.

L’évolution du RO pendant la période d’août 2020 – juillet 2021 est visualisé sur La période d’octobre 2020 à décembre 2020 qui correspondant au calcul du RO de référence est visualisée en rouge. La période marquée en vert représente les 3 derniers mois du stage chez Stellantis (mai – juillet 2021).

Le RO dans la production à l’usinage DV est mesuré par équipe / par tournée. En partant de ça, le RO journalier, hebdomadaire et mensuel peut être calculé.

Afin de proposer les résultats synthétiques, les RO’s mensuels sont visualisés sur le graphique.

Le RO moyen sur la première période de référence est 80,78%. Il s’agit alors de la moyenne des RO’s mensuels de cette période. Le RO moyen pendant la période de mai – juillet 2021 est 81,46%. Il a été calculé également comme la moyenne des RO’s mensuels.

Cette différence entre ces 2 références correspond à un gain de 0,68% ce qui signifie une augmentation de production de 20 pièces par jour. Le prix d’un carter moteur étant à 95€, l’augmentation se traduit par un gain de 1900€ par jour.

Malgré l’augmentation du RO et une tendance croissante d’évolution, la production sur la période de janvier 2021 à juillet 2021 a été touchée par des forces majeures qui ont eu un impact négatif sur la productivité. Les mois d’avril et de juin ont été particulièrement touchés :

- Le mois d’avril a été touché par un taux d’absentéisme élevé causé par la pandémie covid-19 en France.

- La productivité du juin a été marquée par un manque des composants dans l’industrie automobile. Les usines d’assemblage terminale ressentaient une pénurie des puces électroniques. Elles ne pouvaient donc pas produire des voitures. Comme toutes les usines du PSA travaillent en flux tiré, cela a arrêté la production aussi dans des usines de mécanique. L’atelier était à l’arrêt la moitié des jours de la semaine. La production fonctionnait au nominal pendant 3-4 jours de la semaine. Le RO n’est pas calculé sur les jours où l’usine ne produit pas, néanmoins ces arrêts longs ont eu un impact indirect sur la performance de l’atelier. Cela est causé notamment par des raisons suivantes : le changement de campagne est plus fréquent. Pour effectuer un tel changement, il est tout d’abord nécessaire de vider tous les stockeurs et tous les transferts. Le vidage des stockeurs prend du temps et une fois vidés, les arrêts de la ligne ne seront pas facilement amortis. Chaque arrêt va alors avoir un grand impact sur la production. Deuxièmement, les transferts d’usinage ont été conçus pour travailler en continu. Chaque arrêt et vidage de la machine perturbe ce fonctionnement nominal.

Au-delà des mois d’avril et de juin, l’industrie automobile reste affectée par le besoin d’une transition énergétique afin de réduire les émissions de CO2. Même si le moteur diesel a toujours une part importante sur le marché automobile, la demande des voitures diesel diminue chaque année de plus en plus.

Conclusions

Dans ce rapport une étude complexe de la productivité d’une ligne de production a été faite. Le but étant optimiser la production de la ligne, les points les plus saillants et pénalisants ont été révélés. Des solutions ont été appliquées afin d’optimiser la production tout en dépensant un effort et un coût raisonnable.

La production est mesurée en Rendement opérationnel (RO). Elle n’atteint jamais son potentiel maximal car dans le contexte réel, il y a toujours des facteurs qui la perturbe et causes des pertes de la production.

Ce travail a analysé des familles des pertes les plus pénalisantes. Ensuite, des solutions ont été proposées et appliquées. Parmi les méthodes appliquées pour l’optimisation de la production, les outils du lean manufacturing ont été déployés davantage. Enfin, l’impact des actions menées sur la productivité a été évalué.

L’impact des actions menées a été mesuré sur 2 indicateurs principaux :

- Le rendement opérationnel de l’atelier. Ce dernier a évolué au cours de ce projet en passant de 80,78% à 81,46% avec une tendance croissante sur le long terme. Cette augmentation est le résultat de l’optimisation décrite dans ce mémoire. L’augmentation de la productivité est alors 0,68%. Cette hausse de production signifie un gain de 20 pièces par jour ce qui sa traduit par un gain de 1900€ par jour.

- La nature des pertes. En décomposant les raisons des pertes qui impactent négativement la production, il est évident que la nature des pertes a évolué durant la période du projet. Les catégories des pertes ayant été le sujet du projet ont diminué en termes de leur impact sur la production. Plus précisément il s’agit des domaines de la fiabilité des moyens et le domaine des outils coupants.

Cette évolution prouve la pertinence des actions menées sur ces catégories des pertes ainsi que sur la productivité au global. C’est-à-dire que la TPM et le SMED se révèlent comme des outils très pertinents dans l’industrie d’aujourd’hui et leur bon déploiement a un impact très important sur la productivité.

Discussion

Même avec des résultats très satisfaisants sur une période aussi courte au sein d’une ligne qui avait déjà été optimisée plusieurs fois, les résultats ne sont que partiels. En réalité, il s’agit d’un processus complexe qui se passe sur le long terme. Beaucoup des actions ont démarré pendant la période entre le février 2021 et le juillet 2021 mais en ce date, l’avancement de ces actions est toujours en cours. Il est alors plus que probable que le gain de ces actions augmentera encore plus dans les mois à venir.

En particulier, le projet de la digitalisation de l’atelier, a un grand potentiel, une fois tout le monde sera entièrement familiarisé avec son fonctionnement. En continuant à déployer les bonnes formes du management, le projet apportera des résultats importants.

Les gains issus des projets SMED sont aussi pour le moment seulement théoriques et partiels. One fois, toutes les actions complétées, le RO augmentera encore plus.

La valeur ajoutée de ce travail au-delà de l’optimisation de production, la mise en place des outils qui continueront à agir, ainsi que les formations des équipes pour qu’ils apprennent à se servir de ces outils. Cela se devrait traduire par une future hausse de productivité et l’efficacité de la ligne de production des carters DV.

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KOLENIČ, Michal. *Optimalizace vybrané výrobní technologie.* Brno, 2022. Dostupné také z: https://www.vutbr.cz/studenti/zav-prace/detail/137031. Diplomová práce. Vysoké učení technické v Brně, Fakulta strojního inženýrství, Ústav strojírenské technologie. Vedoucí práce Miroslav Píška.

AFFIRMATION

I declare that this master’s thesis is result of my own work, led by my supervisor, and all used sources are duly listed in bibliography. I proclaim that all presented information is true and valid to the best of my knowledge.

31.08.2021

Date

Michal Kolenič

POĎAKOVANIE

V prvom rade by som sa chcel poďakovať skupine Stellantis za to, že mi poskytla príležitosť zúčastniť sa na ich projektoch a poverila ma takou dôležitou úlohou, ktorej výsledky sú opísané v tejto správe.

Osobnejšie by som chcel poďakovať:

-môjmu nadriadenému a riaditeľovi oddelenia DV Mathieu NICOLASOVI,
-vedúcemu oddelenia DV pre obrábanie Danielovi MENGOZZIMU,
-vedúcemu údržby Olivierovi WALTEROVI.

Ďalej by som chcel poďakovať všetkým technikom, údržbárom a výrobcom, ktorí mi neváhali poradiť a ktorí ma usmerňovali počas celej stáže v spoločnosti Stellantis.

Ďakujem aj svojim nadriadeným z akademickej sféry:

- prof. Ing. Miroslavovi Píškovi, CSc. z Vysokého učení technického v Brne,

- Ing. Frédericovi ROSSI, Ph.D. z univerzity Arts et Métiers de Cluny.

Na záver by som chcel poďakovať svojej rodine a priateľom za podporu počas celého štúdia.

ACKNOWLEDGMENT

First, I would like to thank the Stellantis Group for giving me the opportunity to participate in their projects and for entrusting me with such an important mission, the results of which are described in this report.

More personally I would like to address myself to:

- My supervisor and the director of the DV department - Mathieu NICOLAS

- The DV department's machining manager - Daniel MENGOZZI

- The head of maintenance - Olivier WALTER

I would then like to thank all the technicians, maintainers and manufacturers who did not hesitate to give me advice and who guided me throughout my internship at Stellantis.

I also thank my supervisors from the academic world:

- prof. Ing. Miroslav Píška, CSc. from the Brno University of Technology

- Ing. Fréderic ROSSI, Ph.D. from the Arts et Métiers de Cluny

Finally, I would like to thank my family and my friends for their support throughout my studies.

CONTENTS

INTRODUCTION

The invention of the steam engine was an important milestone in human history. Being the first step towards the industrialisation of our society. Gradually, this engine was replaced by the internal combustion engine, which also uses the principle of transforming translational motion into rotational motion, but because it has an internal combustion system, it is more compact in size. Thanks to its efficiency and compact size, the internal combustion engine was a revolution in motorisation. Since its invention, the internal combustion engine has been used as a propulsion system for boats, aeroplanes, cars and other types of vehicles.

A few years after the invention of the internal combustion engine that used gasoline as fuel, Rudolf Diesel invented in 1892 the new type of internal combustion engine that has a higher efficiency than gasoline. Both engines are widely deployed in the automotive industry[1]. Although the market share of internal combustion engines is increasingly decreasing due to strict emission standards, they still occupy 85% of the car market in Europe[2].

As purchasing power rises, so does the number of cars sold annually. Since the car market is quite large and developed nowadays, there is a strong competition in this field. Every producer wants to produce better, faster, but above all at a lower production cost than the others. This leads to the implementation of modern, automated production methods. Only maximum efficiency can ensure competitiveness in today's automotive market. Every second counts in the case of mass production. Producers therefore invest heavily to make their production lines more efficient.

Continuous improvement methods, mainly from Japan, have proven to be very effective in increasing production efficiency. These techniques aim to improve productivity, ergonomics, quality and safety by implementing structured work. Just a simple reorganisation of processes can have a big impact on productivity. The implementation of these methods often does not require large investments. Rather, they are based on a reorganisation of systems and a prioritisation of actions. Continuous improvement techniques are now widely deployed in today's factories because they aim to eliminate all forms of waste and make their production better. This is especially true for the automotive industry as cars are very complex machines, very strict in terms of quality and safety, but above all, they are mass-produced.

1 THEORETICAL ANALYSIS

This chapter includes a basis of the elements and topics widely discussed in this thesis. For ease of understanding, it is necessary to define and explain them.

1.1 OVERALL EQUIPEMENT EFFECTIVENESS

Production is always measured by an indicator that allows comparison between the outputs of different production lines or plants. One of the indicators that allow to measure productivity is the Overall equipment effectiveness (OEE). OEE is the ratio between the production achieved and the theoretical maximum production. It therefore provides information on the performance of a workshop/production line[3]. The OEE defines how well the production is performing in relation to its maximum capacity. Measuring this performance and therefore establishing such an indicator is necessary for the following reasons:

- To guide progress action plans,
- To measure the initial level of performance,
- To set a numerical target,
- To monitor the evolution of performance,
- To provide an official benchmark,
- To enable comparisons of productivity between different periods of time and its evolution
- Calculate the technical and economic stakes,
- Determine the potential of a production line[3, 4]

In order to understand how to calculate Overall equipment effectiveness (OEE) under real industrial conditions, it is necessary to define the following points:

- shift length (ST),
- planned production time (PPT),
- Fully productive time[5].

1.1.1 Shift length time

The shift length (ST) is the total time in one week (7 days multiplied by 24 hours) minus the non-requirement of production (for different reasons), major renovations, changeovers. In other words, it is the time that manufacturers are physically present on the site in course of one week. ST is measured in hours.

$$\mathrm{ST} = (7 * 24) - (\mathrm{NonRequirement} + \mathrm{Renovations} + \mathrm{Changover}) \tag{1}$$

1.1.2 Planned Production Time

The Planned Production Time (PPT) is the time during which the manufacturer/operator is present on the facility, i.e. the time during which he is likely to produce. PPT is based on the ST minus the meal breaks and planned maintenance stops.

$$\text{PPT} = \text{ST} - \text{meal breaks} - \text{planned maintenance} \quad (2)$$

1.1.3 Fully productive time

Runtime also called good production time is the time when the resources are working without disturbances or breakdowns. Runtime is therefore computed as the PPT minus the induced downtime, own downtime, quality losses, cycle time losses[5].

$$\text{Fully productive time} = \text{PPT} - \text{induced downtime} - \text{own downtime} - \text{quality loses} - \text{cycle time losses} \quad (3)$$

1.1.4 Calculation of Overall equipment effectiveness

The OEE varies between 0 and 1, where 0 means 0 pieces produced and 1 expresses the maximum possible production. It is often expressed in % which is easier to handle and interpret[3–5].

$$OEE = \frac{good\ count}{maximum\ theoretical\ production} = \frac{good\ count * ideal\ cycle\ time}{planned\ production\ time} = \frac{fully\ productive\ time}{planned\ production\ time} \quad (4)$$

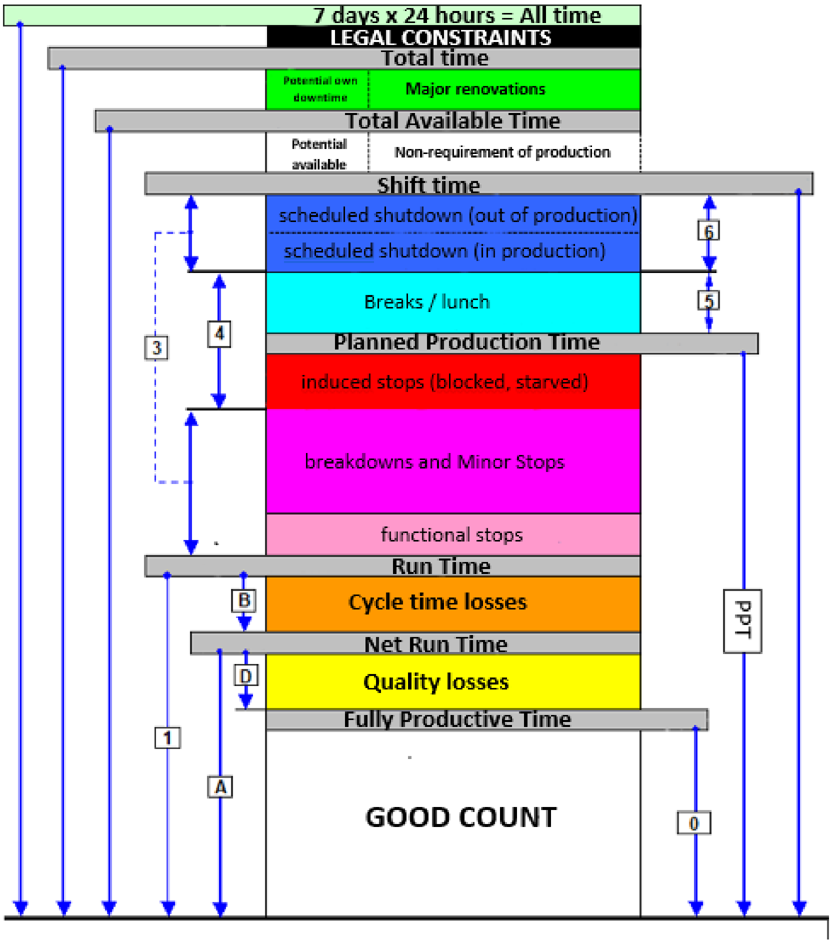


Figure 1.1.4.1 Various types of work periods [6].

The OEE is always linked to PPT. The PPT of a workshop is then composed of the OEE which varies between 0 and 1 as explained before. The rest between 1 and OEE will be called the no-OEE. Sometimes there is also a part that cannot be calculated and belongs neither to the OEE nor to the no-OEE.

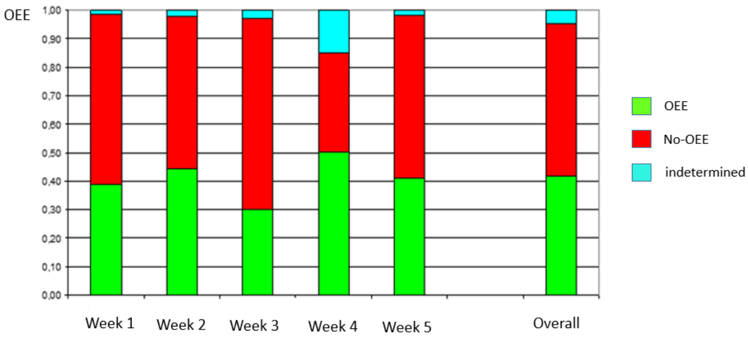


Figure 1.1.4.2 Example of weekly OEE/ no-OEE [6].

1.2 STANDARDISED WORK & KAIZEN

To increase the production of a workshop and to be able to control it, various methods have been deployed over the years. Most of them originate from Japan where they started to be widely deployed in the 1960s. The common name for such methods is continuous improvement or Kaizen (the Japanese word for continuous improvement)[7].

One of the key ideas of Kaizen is to implement standardised work in such a way that the work is repeatable and waste-free. This allows for predictable results, increased safety, increased quality, minimising costs and eliminating waste.

Making the work standardised also makes it possible to better organise production and to better know the needs in terms of staffing, costs, tools required and time needed to perform the operation. Once the work is standardised and formalised by creating a work standard, any discrepancies between the standard and the observed reality can be easily identified and then corrected.

Everyone is involved in Kaizen, especially those employees who carry out the standards on a daily basis.

Waste can be eliminated very easily, just by applying the standards and checking them. Just by organising the processes within the company, work can become more efficient, and waste can be reduced or eliminated. Standardisation also prevents problems from returning if they have arisen[7, 8].

1.3 VISUAL MANAGEMENT

The aim of visual management is to make visible everything that is in the OK or NOT OK state so that all anomalies in the field are easily recognisable in real time.

The aim is to visually recognise what is normal or abnormal, to identify the causes of the anomalies. The ease with which anomalies can be recognised directly in the field means that we can react as quickly as possible [9, 10].

Figure 1.1.4.1 Example of visual management on workshop floor[11].

1.4 ELIMINATION OF WASTE AND THE CONCEPT OF ADDED VALUE

The cost of a product or process is made up of value added and non-value added (also called waste).

- Value added - the means needed to transform a product. That is, what the customer is willing to pay for the product or service (examples: machining operations, drilling, milling, assembling several parts together),
- Non-value added – the part of the expenditure that does not add anything to the product synonym to non-value is waste (examples: moving parts from one place to another, putting guards on a part).

Waste is therefore all work that does not add value to the products and all artificial price increases that do not benefit the customer. Waste can be classified into the following families:

- MURA (non-value added to the process): irregularity, variability, imbalance,
- MURI (non-value added to the resources): tediousness, illogicality,
- MUDA (non-value added to the product or service): overproduction, stocks, transport, waiting, movement, unnecessary operations, defects.

It is possible and important to eliminate waste by identifying it and seeking improvements to reduce it. As a rule, firstly MURA waste is reduced or eliminated, followed by the elimination or reduction of MURI and MUDA[7, 12, 13].

1.5 JUST-IN-TIME WORK

The just-in-time philosophy means producing just what is needed, when it is needed, and with the minimum resources necessary. The aim is to produce just what the customer consumes. This means working at a pace that suits the customer’s needs, with a continuous flow.

Continuous flow means that the produced part is constantly moving forward at a continuous "takt time" without stopping, whether in a production line or in a larger scale factory. In the case of a mechanical plant, the part should spend the least time possible as raw material input before being transformed to finished part output to avoid or minimise inventory costs.

In the case of a production line, takt time can be equated with cycle time (TCY). It is the time of an operation on the line. In the context of the last station on the line, the cycle time will be the rate of this line. The TCY is an important concept in production management. It is in the interest of all those involved in production to monitor it[12].

1.6 PROBLEM SOLVING

In practice, during an execution of a process such as in production, problems always occur. The frequency of their occurrence can be reduced but they can never be totally eradicated. Problems are to be seen as a means of progress, especially if they are solved by relevant methodologies that are part of continuous improvement.

1.6.1 PDCA

The PDCA approach describes the reasoning behind continuous improvement. It consists of 4 steps, hence the 4-letter acronym:

- P = plan – study the problem, define the objective, plan, set up an action plan, calculate the necessary resources,
- D = do – execute what was planned in the previous stage, adjust it, and monitor the progress,
- C = check – check the impact of the actions taken, evaluate the results,
- A = act – countermeasures, standardisation if the improvement was successful, kaizen[12, 14].

1.6.2 TPM

Total Productive Maintenance (TPM) is a maintenance method of Japanese origin which aims to improve the efficiency of machines by preventing stoppages and breakdowns, by strongly involving the plant operators (POs) who know best their machines. It is therefore a participative method. The origins of TPM date back to 1971. TPM method spread to the West in the 1980s. Today, it is mainly used in the automotive industry [2].

Meaning:

- Maintenance: keeping equipment in good condition by cleaning, repairing, lubricating,
- Productivity: Doing maintenance with the least possible impact on production,
- Total: everyone gets involved[15].

Objectives:

1. Increase in overall equipment effectiveness (OEE),
2. Eliminate losses and waste, accidents, breakdowns,
3. Involvement of all departments,
4. Involvement of top management and communication between top management and all other employees.
5. Achieving zero waste, engaging in small group activities.

-All objectives of TMP that were listed above should ultimately aim to achieve, maintain and improve the nominal performance of production facilities[15, 16].

The treatment of breakdowns is based on three major pillars:

- The analysis and elimination of the causes of breakdown/failure,
- The development of self-maintenance,
- The development of programmed maintenance.

According to TPM, the failures of an installation can be divided into several categories according to the severity of the failures and their number of instances. All these categories of failures can be visualised using the TPM pyramid. The TPM pyramid shows, among other things, that each category is strongly related to the others.

At the bottom of the TPM pyramid, there are failures that occur most often but cause only minor downtime. This type of breakdown is called "malfunction precursors". If breakdowns in this category are ignored, they may cause more serious failures to occur. These are to be displayed in the layers above the "malfunction precursors". Despite higher severity of failures that fall into layers above the "malfunction precursors", they appear less often. In this way, the other categories of faults can also be arranged in the same way, knowing that each level of the pyramid is closely related to the others[17].

Figure 1.6.2.1 The TPM pyramid [11].

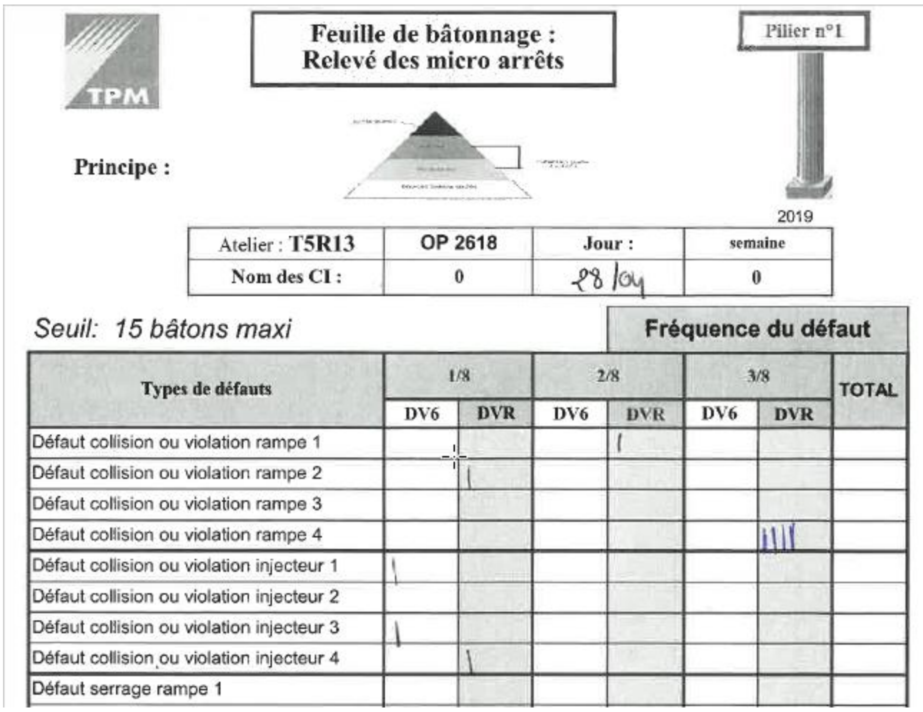
1.6.3 Check sheets: Data collection

Check sheets are a tool for collecting data on events such as breakdowns, machine defects or quality problems.

Depending on the number of occurrences of a defect, the operator puts a "stick" in the line corresponding to the defect concerned. This system makes it possible to visualise the means of production that cause the most problems. The check sheets are displayed in front of each means of production, each containing a list of defects specific to the means. Following each intervention on the means of production, the plant operator who carries out the repairs must specify on the check sheets which defect there was on the means. These sheets are then entered into Excel and processed statistically. In this way, the most defective and problematic means of production can be visualised, which makes it possible to know which means of production need to be worked on to improve productivity. Check sheets are therefore an important indicator for maintenance[18, 19].

The aim of check sheets is:

- To prioritise problems so that we know where to act,
- Repair small problems and thus avoid the occurrence of larger ones,
- Increase the OEE by eradicating recurrent breakdowns[11].



TPM

Feuille de bâtonnage :
Relevé des micro arrêts

Pilier n°1

Principe :

2019

Atelier : T5R13	OP 2618	Jour :	semaine
Nom des CI :	0	28/04	0

Seuil: 15 bâtons maxi

Types de défauts	1/8		2/8		3/8		TOTAL
	DV6	DVR	DV6	DVR	DV6	DVR	
Défaut collision ou violation rampe 1				|			
Défaut collision ou violation rampe 2		|					
Défaut collision ou violation rampe 3							
Défaut collision ou violation rampe 4						||||	
Défaut collision ou violation injecteur 1	|						
Défaut collision ou violation injecteur 2							
Défaut collision ou violation injecteur 3	|						
Défaut collision ou violation injecteur 4		|					
Défaut serrage rampe 1							

Fréquence du défaut

Figure 1.6.3.1 Example of a check sheet.

1.6.4 Pareto

Pareto is an abbreviation for "Pareto's law", otherwise known as the "80-20 law". The name implies that 20% of the factors are responsible for 80% of the results. Data can be plotted using a Pareto chart, which ranks phenomena in order of relative importance when quantitative data are available.

The aim is then to distinguish between important and less important problems, which makes it possible to prioritise the actions to be taken. The graphic representation of the Pareto (in this case it is called a Pareto diagram), visualises the relative importance of the data studied and allows the prioritisation of the treatment of the causes[20].

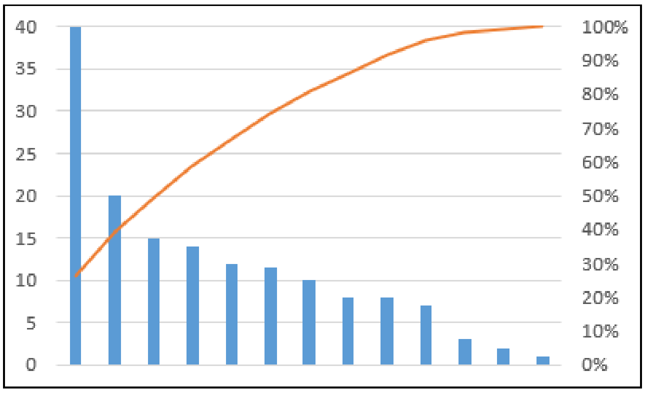


Figure 1.6.4.1 Example of a Pareto chart.

1.6.5 SMED

SMED is an acronym for "Single Minute Exchange of Die". That means fast tool change (TC). It is an effective method of reducing production line changeover time or TC time, starting with a reorganisation of the TC process before making investments[21].

The aim of SMED is:

- To reduce the downtime of the means of production between 2 good parts during a tool change (TC) or a line changeover,

This then allows to:

- Respond as quickly as possible to customer demand via a rapid change of campaign,
- Improve quality through work standardisation,
- Eliminate improvisation through standardised work,
- Eliminate stocks or reduce them considerably.

The reduction of stocks and the ability to respond quickly to customer demand allows a move towards continuous flow (just-in-time) production.

The SMED method is based on the concept of value added (VA). During a line changeover, the concept of VA is operations requiring the stopping of the means of production. In the SMED method, this concept is called internal operation. There are also operations that do not justify stopping the means of production. These operations are called external operations. The objective of an optimised TC is to minimise internal operations by replacing them with external operations. The objective of the SMED method is also to identify and eliminate waste[22, 23].

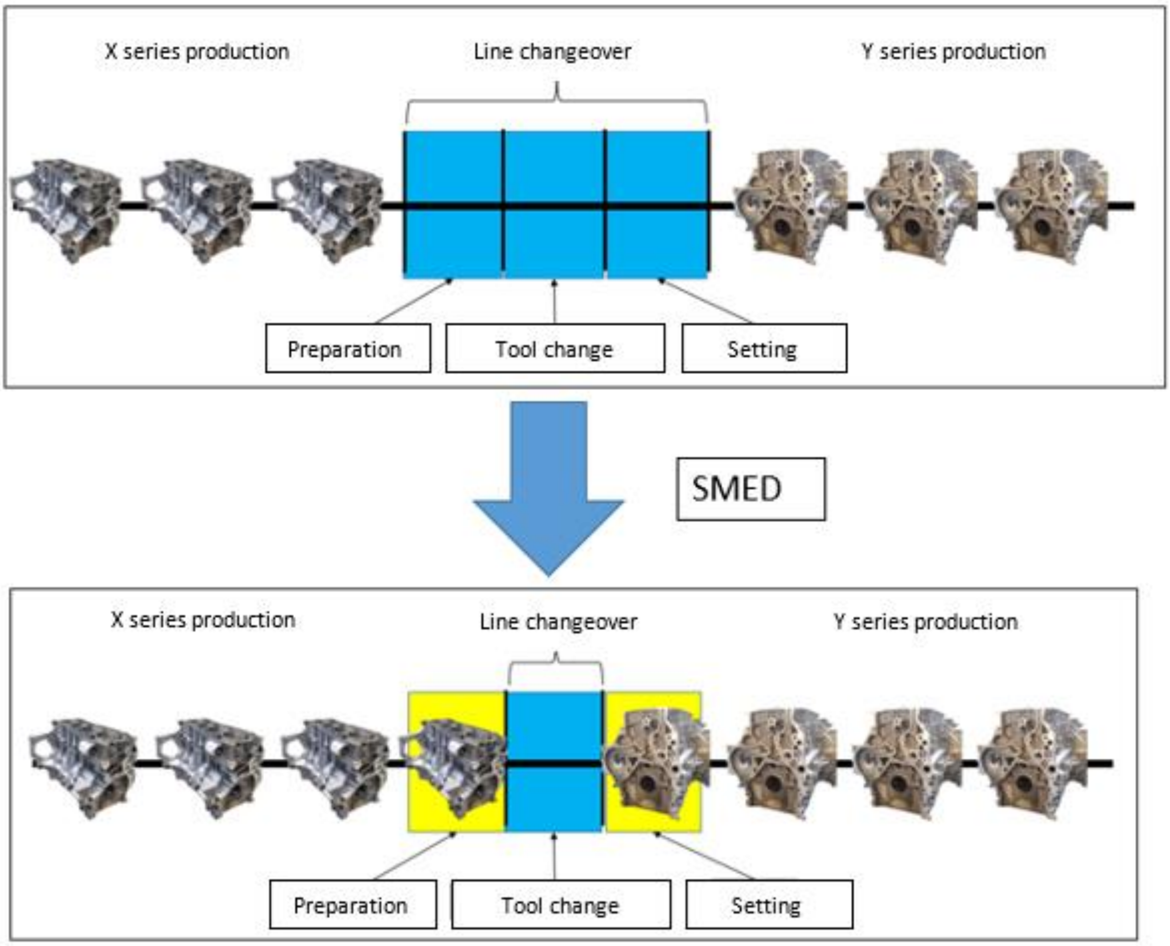


Figure 1.6.5.1 Reduction of line changeover time by using SMED.

In an industrial context, the SMED method is often implemented in the form of a workshop. It consists of 4 phases, preceded by a preparation phase (phase 0).

The phases of SMED method are following:

0. Observe (preparatory phase),
1. Identify,
2. Separate,
3. Convert,
4. Reduce

The phases of SMED are explained in detail below[24].

0. Observe (preparatory phase) - This phase consists of taking the data needed to carry out the other phases. First, an observation of the change is made. The PO is filmed during the manipulation. The film is then analysed in the following phases.
1. Identify - In TC, several operations can be identified. The film is broken down into several operations.

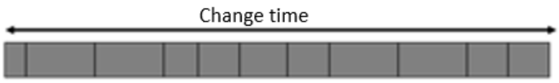


Figure 1.6.5.2 Identification phase of SMED.

2. Separating and grouping - identifying internal and external operations.

Figure 1.6.5.3 Separation phase of SMED.

3. Convert – transform internal operations into external operations. We need to find out how to make internal operations external.

Figure 1.6.5.4 Conversion phase of SMED.

Practical example of the conversion phase of SMED is shown in the figure below.

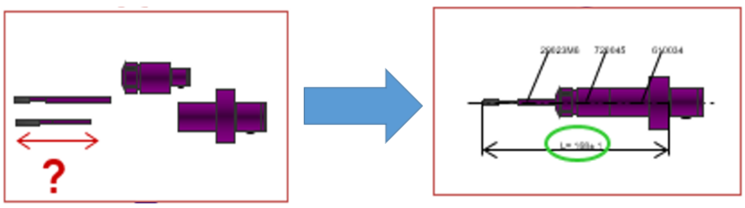


Figure 1.6.5.5 Example of the conversion of internal operations to external operations: presetting a drill.

4. Reduce - first reduce internal operations, and then external operations by reducing their complexity and eliminating waste.

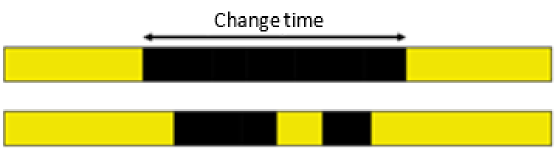


Figure 1.6.5.6 Reduction phase.

A good example of SMED deployment is the F1 car pit stop to change worn tyres and refuel. The stopping time has evolved over the years. It could last more than a minute in the 1940s, but it has been optimised over time and today it lasts only a few seconds. The current record for the duration of such a stop is 1.82s. As the car stop is an internal operation, a maximum of operations should be done externally (while the car is running). The aim is then to do everything that can be done in the external phase (prepare new tyres, prepare tools, put away used tyres) and thus minimise the internal operations (changing tyres).

Figure 1.6.5.7 Formula 1 at the pit stop [25].

1.6.6 The manager's role and mission

The manager's mission is primarily to give vision and meaning. In an industrial context, this is extremely important because each actor in the production process must adhere to the same vision in order for things to move forward. The manager must also encourage the emergence of problems and ensure that they are received in a positive and constructive state of mind. It is very important that team members see meaning in what they do. Therefore, in addition to explaining how to do it, you need to explain why you are doing it. Also, it is important to get feedback on the work they are doing. That's how the workforce adheres to the tasks that are asked of them[11, 26].

2 STELLANTIS GROUP – COMPANY PRESENTATION

The content of this report was carried out in an industrial context, within the company Stellantis. This chapter presents the Stellantis group.

2.1 PRESENTATION OF THE COMPANY

The Stellantis group is the result of a recent merger between the PSA group (Peugeot société anonyme) and the FCA group (Fiat Chrysler Automobiles). The group was created on 16 January 2021. The Stellantis group is currently ranked 6th worldwide in the automotive sector. On a European scale, Stellantis is in first place (vehicle sales in Q1 2021) with a 20.7% share of the European automotive market.

Diverse automotive companies in Stellantis group are displayed in the figure below.

Figure 2.1.1 Breakdown of companies included in Stellantis groups[27].

After the merger, a policy of sharing know-how between the two automotive groups was established. This also resulted in an optimisation of the factories, as one factory could specialise in the production of one type of part. Thus, the change of production campaigns and the problems of stocks are reduced. This merger has made it possible to get the best out of both groups and thus reduce costs, improve technologies and be more efficient

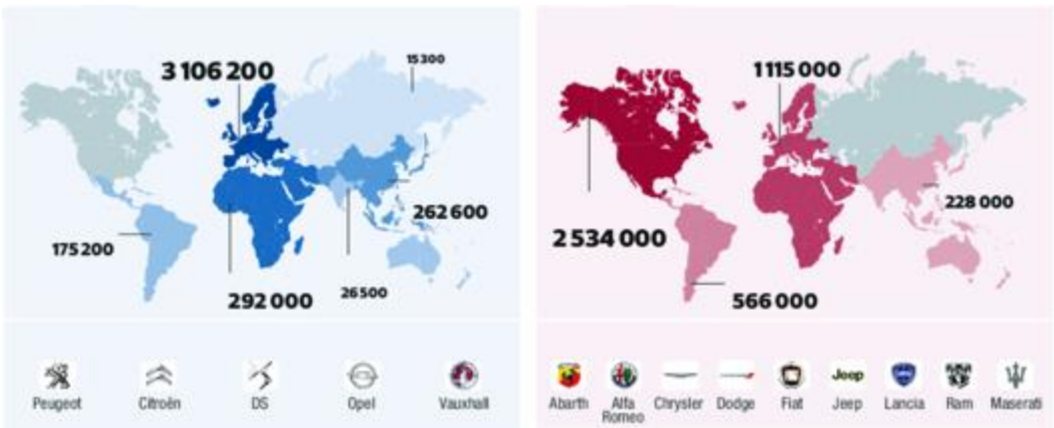


Figure 2.1.2 PSA and FCA group car sales in 2018 (before the merger)[27].

The PSA group was very well established in the European market, while the FCA group sold most of its cars in the American region. After the merger, the markets of both groups are combined.

During the time of the internship that was subject of this diploma work, Stellantis comprised of 14 automotive brands and 2 mobility brands (Free2Move and Leasys). The Stellantis portfolio covered a whole range of products, from general cars to commercial vehicles, from premium cars to luxury cars. The oldest brand is Peugeot, founded in 1896, and the most recent brand is DS automobiles, created in 2014. Stellantis has more than 1000 years of accumulated experience. All Stellantis trademarks are listed chronologically according to their creation dates in the figure below.

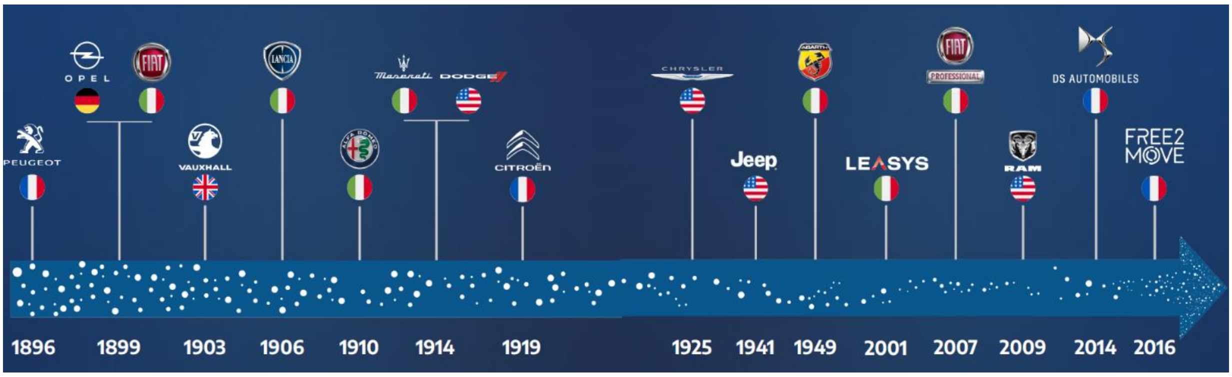


Figure 2.1.3 All Stellantis trademarks arranged chronologically[27].

2.2 PRESENTATION OF INTERNSHIP LOCATION

This project was carried out at the Trémery manufacturing plant. The plant is located in the north-east of France, in the Lorraine region, near the border with Germany and Luxembourg.

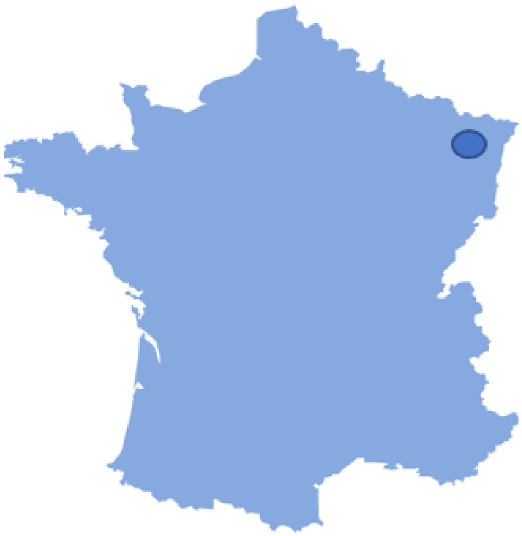


Figure 2.2.1 The position of the Stellantis manufacturing factory on the map of France[27].

The plant began operating in 1979. Since its creation, the factory has produced more than 50 million engines. In 2020, 1091,600 engines were produced, including 718,500 diesel engines, 284,900 petrol engines and 88,200 electric engines.

The Trémery site is an engine factory. The engines are manufactured from parts from the foundry and the forge. Once the engines have been manufactured by machining and assembly, they are delivered to the final assembly plants where they are fitted into the cars.

In total, 4 different types of engines are produced in Trémery. The distribution of the workshops by sector is shown in figure below. The following figure shows the EB workshop in green, the DW in purple, the DV in yellow and the MEL1 in blue. Each workshop has assembly lines and the DW, DV and EB workshops also have machining lines.

Figure 2.2.2 the Trémery plant with the breakdown by sector of activity[27].

2.2.1 Key figures about the manufacturing site

The Trémery plant has produced more than 50 million engines since it opened in 1979. In 2020, 1,091,600 engines were produced at the site. Most of the engines produced are sent to the Stellantis terminal plants. Currently, about 7,000 engines are produced at the site every day.

40 trucks loaded with engines leave the site every day, of which they head to:

- 35% to Spain,
- 27% to France,
- 19% to Slovakia,
- 9% to Italy,
- 5% to England,
- 5% to Germany, Argentina, Morocco, Russia.

To produce so many engines, the factory needs to be supplied with raw materials and components. There are a total of 378 suppliers, more than half of which come from France. On average, 83 trucks a day deliver components to Trémery. This number can vary according

to production needs in order to respect the pull system.
The plant is constantly innovating and becoming increasingly automated in order to increase its performance and to be able to meet the new needs of the automotive market. In 2020, 32.9 million euros were invested in Trémery.

2.3 PRODUCT RANGE [27]

On the Trémery site, four types of engines are produced. Three of those four types are thermal engines, two of which are diesel engines (DW and DV) and one is petrol (EB). The fourth product type is an electric motor e-GMP. Their specifications of all four engines are given in the table below.

Table 2.2.1 Product range of the Trémery factory.

name	DW	DV (DV5R)	EB (EBDT)	e-GMP
				
Fuel	Diesel	Diesel	Petrol	Electric
Engine category	2 - 2.2 l	1.5 -1.6 l	1.2 l	Permanent magnet synchronous motor
Number of cylinders	4	4	3	-
Power	110 – 180 CV	100 – 130 CV	110 – 130 CV	Max torque: 260 Nm Puissance max.: 90kW Continuous power: 47 kW @ 13000 rpm
Emissions	116 g CO2/km	90g CO2/km	105g CO2/ km	-
Consumption	4.4 l / km	3.5 l / km	4.5 l / km	
Average consumption	7,1 l / km	5 l / km	6.8 l /km	
Engines produced per day at Trémery	1350	2200	1450	660

2.3.1 The DV engines

The DV engine is the most produced engine on the site. An engine is assembled every 24 seconds.

The engine has been on the market for several years. Over the years, the engine has evolved according to the needs of the market. Each new version of the engine is designed to reduce fuel consumption and thus reduce CO2 emissions. This allows the engine to meet the latest Euro (€)

emission standards. At the time of this thesis and internship, the two versions of the DV engine were produced at the Trémery site:

- DV5R,
- DV6.

The DV5R version complies with the latest CO_2 standard (€6). This 1.5 litre HDi diesel engine has a power output of 100 to 130 hp while keeping fuel consumption low (from 3.5l / 100km). It is also known to have low CO_2 emissions (from 90g CO_2 / km).

The DV6 version is compliant with the €5 standard. This is the older version of the DV engine. It is also an HDi engine, with a displacement of 1.6l and a power ranging from 100 to 120hp.

The DV engine is quite versatile, having high performance, small displacement, low fuel consumption and low CO_2 emissions. This is the reason why the DV engine is used in a wide range of cars and car brands. An example of the DV5R engine application is shown in the figure below.

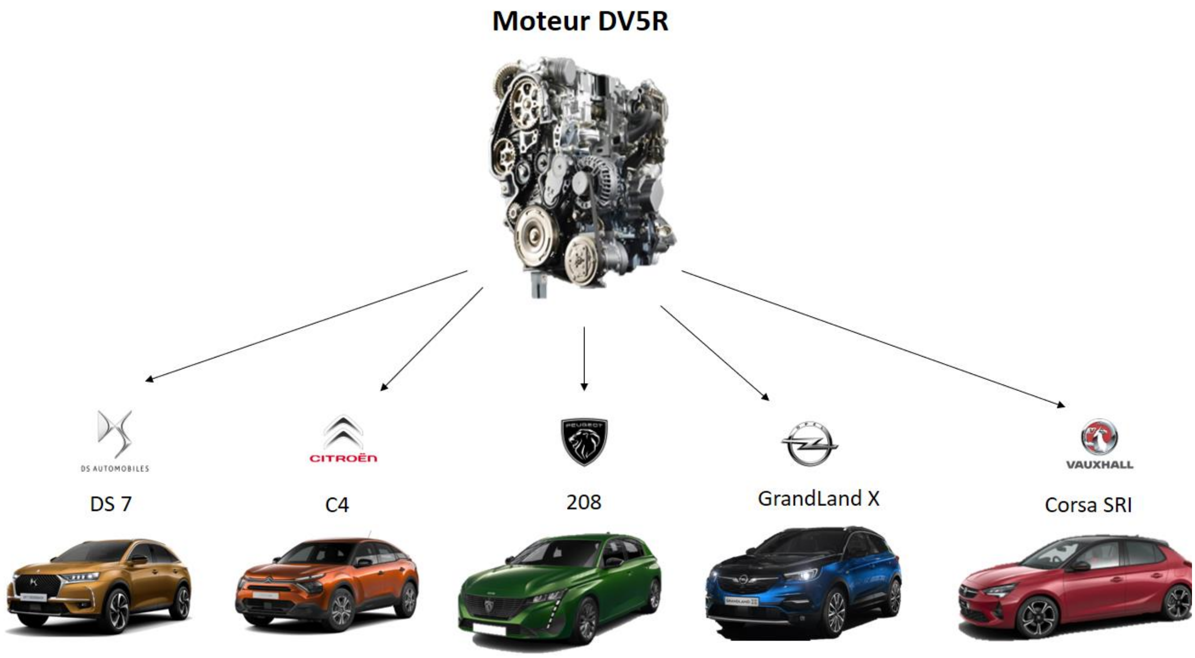


Figure 2.3.1.1 Examples of application of the DV5R engine[27]

2.4 THE DV WORKSHOPS

The DV engine is currently the most produced of all the engines at the Trémery site, with a production of 2,500 engines per day (of which there are 2,200 DV5R and 300 DV6). One DV engine is assembled every 24 seconds at the facotry. The engine consists of approximately 300 components, 4 of them are machined on the site. The DV section is divided into 2 workshops: the assembly workshop and the machining workshop. In total, there are 6 production lines in the DV sector:

- 5 machining lines,
  - 1 engine casing line (aluminium + cast iron),
  - 1 crankshaft line (cast iron + steel),

    - 1 connecting rod line (steel),
    - 2 cylinder head lines (aluminium + cast iron),
- 1 assembly line.

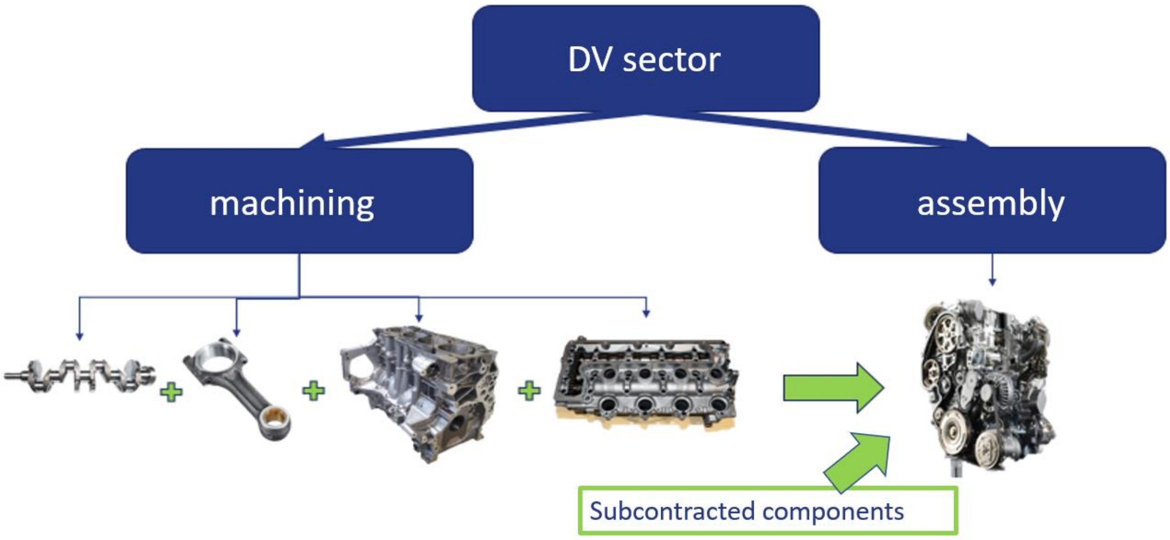


Figure 2.4.1 Production lines in the DV sector of the workshop.

2.4.1 DV machining lines

Among the four parts machined at the Trémery site, there are two fixed parts (the cylinder block and the cylinder head) and two moving parts (the crankshaft and the connecting rod). The photos of the machined parts are displayed in the following figure. The photographs were taken during the internship.

Moving parts


a) b)

Figure 2.4.1.1 Moving parts machined in the workshop, a) crankshaft and b) connecting rod.

Moving parts


a) b)

Figure 2.4.1.2 Fixed parts machined in the workshop, a) cylinder block and b) cylinder head.

2.4.2 Organisational structure and work schedule

The flow manager FM (also called the production manager - PM) is a direct subordinate of the plant manager in Tremery. He delegates duties to the group managers (GMs). There is one GM for the machine shop and one for the assembly shop.

The machining GM is then responsible for 5 production lines. At the head of each production line, there is a Unit Manager (UM). Each UM is responsible for a production team called an effective production unit (EPU).

The organizational structure is displayed in the following figure.

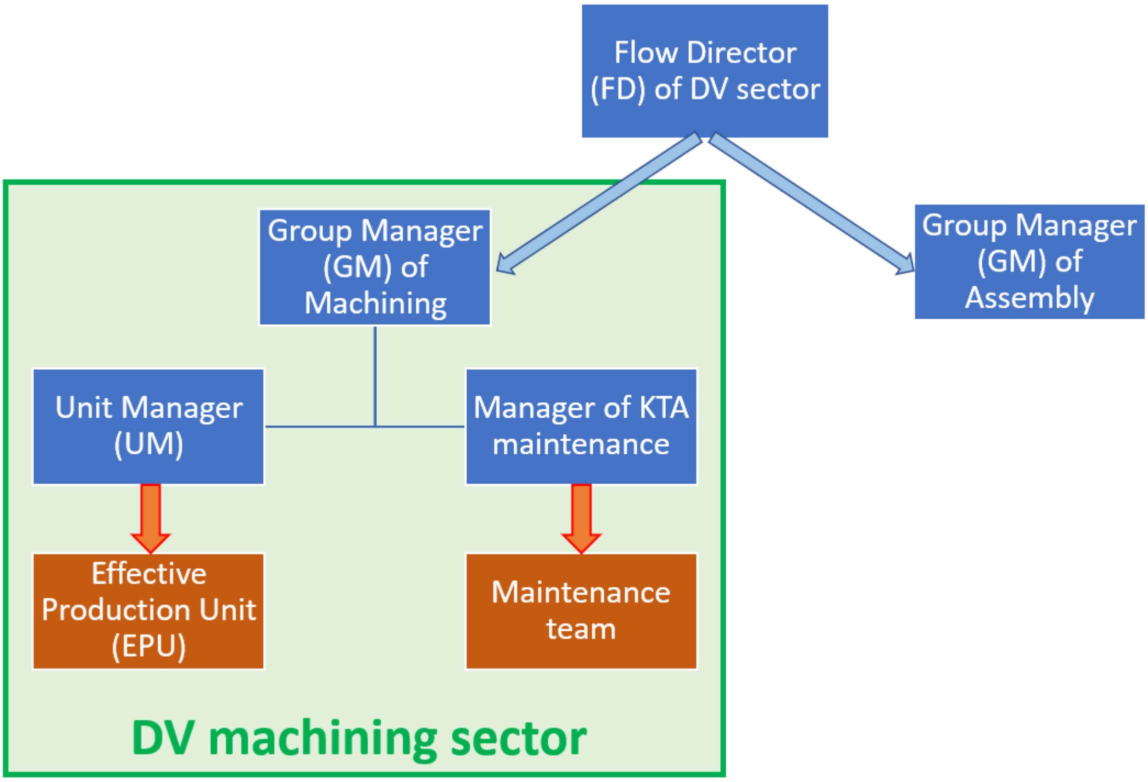


Figure 2.4.2.1 Organisational structure of DV sector in Theremy manufacturing site.

The workshop functioned in four shifts/tours during the duration of the internship: A,B,C, SD.

- Shift 1 – morning. 5:30 - 13:00 (team A or B),
- Shift 2 – afternoon. 13:50 - 21:20 (team A or B),
- Shift 3 – night. 22:13 - 5:30 (team C),
- Shift 4 – weekend. Saturday (5:30 - 17:30 / 17:30 - 5:30) & Sunday (5:30 - 17:30 / 17:30 - 5:30). (SD team).

2.4.2.1 **Organisation of the elementary production unit**

The idea of an EPU (effective production unit) is to be an autonomous group in the manufacturing of parts, troubleshooting and quality control.

The EPU team consists of 11 people, including one Unit Manager. The unit is led by the UM who ensures that the whole team produces enough parts to fill the quota and maintain the stock at a nominal level. The UM is also responsible for safety at work, compliance with standards, the quality of the parts produced and the cleanliness of the working environment.

Plant operators (POs) are primarily responsible for the production of parts and their quality. They are also capable of performing level 1 maintenance, which consists mainly of small, simple repairs. An operator works on several machines. The whole workshop is divided into islands and each island contains several operations. The OPs are distributed according to the islands in the workshop. A PO then has 3 or 4 machines for which they are responsible, and they are able to perform Level 1 maintenance, which consists mainly of small, simple repairs.

The production system pilot specialist (PSPS) is more versatile than a normal operator. They do the same work as an PO but can work anywhere on the shop floor. If an PO needs help or needs to leave for a break, the PSPS temporarily takes over their role.

Finally, there are electrical and mechanical technicians. These are responsible for complex maintenance (level 2 & 3). They intervene in case of serious breakdowns. They are also able to do manufacturing and therefore take over the role of the PO if necessary.

Table 2.4.2.1 Typical job functions in an effective production unit.

Job functions	**effective**
Unit Manager	1
PSPS	2
Operators	6
Mechanic technician	1
Electric technician	1

3 CONTEXT OF THE INTERNSHIP

The 4 types of parts of the DV machining were produced at an average rate of about 2460 parts/day. This applied to crankshafts, connecting rods and cylinder heads. The only shop that performed worse than the others was the DV cylinder block machining line. The average output of the cylinder block line was in the order of 2415 parts/day.

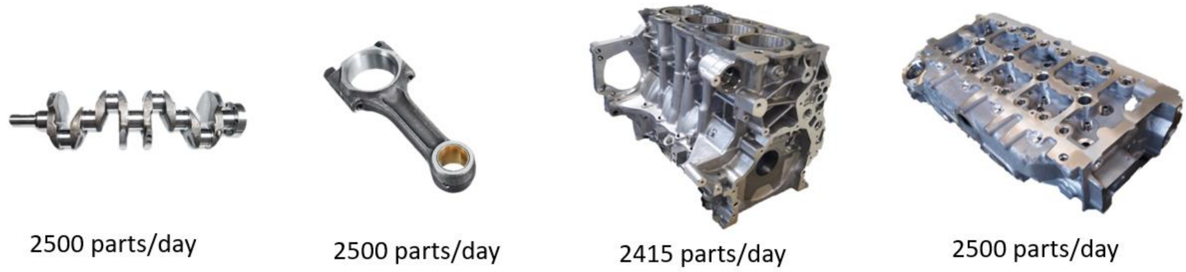


Figure 2.4.2.1 Average daily production at Tremey factory.

3.1 OBJECTIVES OF THE INTERNSHIP

The objective of this internship was the optimization of the production on the machining line of cylinder blocks of the DV workshop.

3.2 STUDIED WORKPIECE – DV ENGINE CYLINDER BLOCK

As mentioned in the previous chapter, the engine cylinder block was one of the 4 parts machined in the DV workshop in Trémery. Of these, the cylinder block was the largest. It was a fixed part, which means that the engine casing did not move in relation to the vehicle frame during operation.

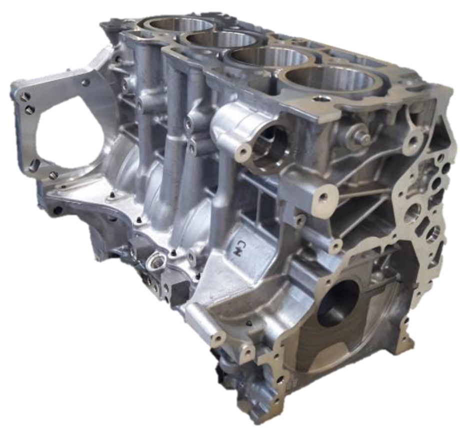


Figure 2.4.2.2 Studied workpiece – cylinder block of DV5R engine.

The cylinder block serves as a place for other parts such as the crankshaft, connecting rods, pistons, cylinder head, water pump, oil pan etc. It then has the role of a frame in the engine.

The DV5R (1.5l) and DV6 (1.6l) cylinder blocks have a very similar architecture with some slight differences.

The DV6 cylinder block is 12mm higher than DV5R, it has a different water pump location and some holes that were placed differently. Currently, the DV5R motor was the most produced motor on site. The DV6 engine was produced less and less, knowing that its production was going to end soon. For the sake of simplicity, the DV5R engine was studied next in this thesis.

The cylinder block was made up of 2 parts which first enter the production process separately as foundry blanks and are then joined together in the cylinder block processing line. These 2 parts were:

- Upper cylinder block,
- camshaft bearing cap

a) b) c)

Figure 2.4.2.3 Workpieces a) Unmachined upper cylinder block workpiece a) Unmachined camshaft bearing cap c) Machined cylinder block

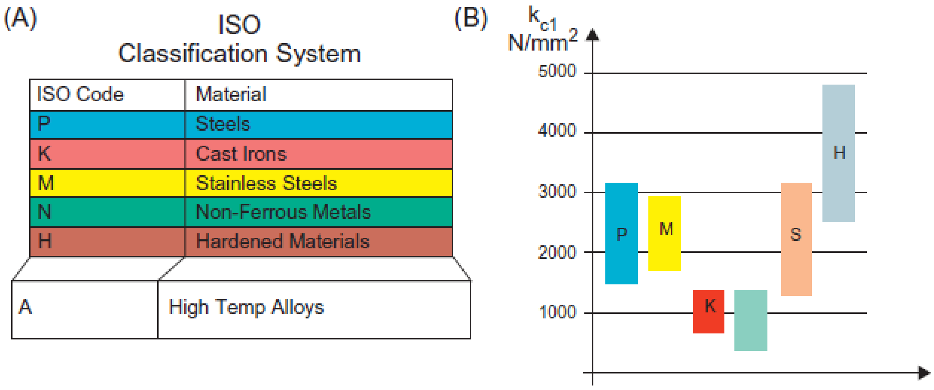
A cylinder block weighted 25.38 kg, of which 16.37 kg was the upper cylinder block and 8.10 kg was the camshaft bearing cap. The rest of the weight was due to screws, gaskets and plugs.

The main part of the upper cylinder block was made of aluminium-silicon alloy (AlSi9Cu3) with a hardness of 90 HB minimum. The addition of silicon to the aluminium improved the mechanical properties of the material as well as its castability. This was especially advantageous when it came to the production of castings in large series. However, the presence of silicon in aluminium made the material less machinable.

In the cylinder block, the liners of the cylinder were inserted into the upper cylinder block during the casting process in the foundry. The liners were made of lamellar graphite cast iron (GLC1) with good mechanical properties and a hardness ranging from 207 to 277 HB.

The camshaft bearing cap was also made of aluminium-silicon alloy with inserts of spheroidal graphite cast iron (GS400-12). These served as a guide for the crankshaft.

All those machined material – aluminium-silicon alloy, lamellar graphite cast iron GLC1 and spheroidal graphite cast iron (GS400-12) are standard machined materials and are relatively easy to machine compared to steels used for workpiece materials.



(C)

ISO	MC	Material
P	P1	Unalloyed steel
	P2	Low-alloyed steel (≤5% alloying elements)
	P3	High-alloyed steel (<5% alloying elements)
	P4	Sintered steels

ISO	MC	Material
M	P5	Ferritic/Martensitic stainless steel
	M1	Austenitic stainless steels
	M2	Super-austenitic, Ni≥20%
	M3	Duplex (austenitic/ferritic)

ISO	MC	Material
K	K1	Malleable cast iron
	K2	Gray cast iron
	K3	Nodular SG iron
	K4	CGI
	K5	ADI

ISO	MC	Material
N	N1	Aluminium-based alloys
	N2	Magnesium-based alloys
	N3	Copper-based alloys
	N4	Zinc-based alloys

ISO	MC	Material
S	S1	Iron-based alloys
	S2	Nickel-based alloys
	S3	Cobalt-based alloys
	S4	Titanium-based alloys
	S5	Tungsten-based alloys
	S6	Molybdenum-based alloys

ISO	MC	Material
H	H1	Steel (extra hard)
	H2	Chilled cast iron
	H3	Stellites
	H4	Ferro-TiC

Figure 2.4.2.4 Materials regrouped by a) System of Classification of basic groups of construction materials according to ISO b) values of specific cutting pressure c) material subgroups according to CMC system[28].

The cast iron is great to be used for the workpiece material because it can be casted creating complex internal shapes of the cylinder block and then finished by machining due to its great machinability. The machinability of cast iron is due to presence of graphite in the structure that serves as auto-lubricant during the machining.

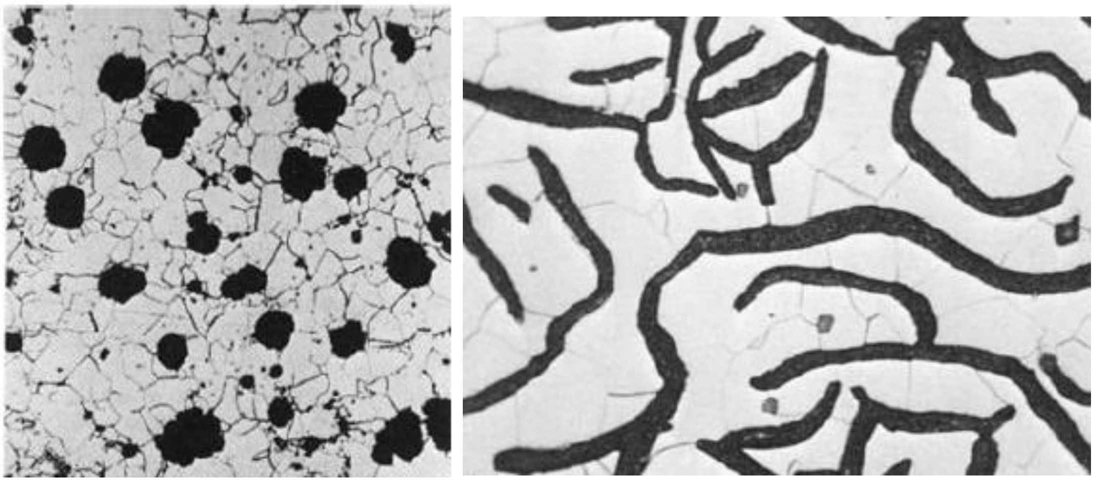


Figure 2.4.2.5 graphite in grey cast irons a) spherical and b) laminar [29].

Gray cast iron can usually be machined dry or with an oil free coolant. If a coolant is used, it is important that it be oil-free. Machining gray cast iron gives particularly good results with ceramic cutting tools Gray cast iron can usually be machined dry or with an oil free coolant. If a coolant is used, it is important that it be oil-free. Machining gray cast iron gives particularly good results with ceramic cutting tools [29].

3.3 MACHINING OF THE CYLINDER BLOCK

Machining of the cylinder block was a very complex task. Machining the cylinder block included many different machining operations. These were mainly drilling and tapping operations to create fasteners for other parts that were attached to it. There were also boring operations for holes that required high dimensional accuracy. Some surfaces were machined by milling operations. These were mainly the planes of the joints to ensure an excellent seal between different parts of the engine. In addition, the honing process was used to finish the cylinder liners and crankshaft bearings.

There were a total of 175 different cutting tools for machining a DV5R cylinder block. Drills, cutting taps, deforming taps, milling cutters, face milling cutters, monobloc drills, step drills, reamers. Cutting tools made of different materials are used: carbide, boron nitride (CBN), high speed steel (HSS) or polycrystalline diamond (PCD)[30].

In addition, the material being machined may have presented some difficulties in machining. Some parts of the cylinder block were machined as two-material (cast iron + aluminum alloy).

A wide variety of machining operations and materials required different types of cutting fluids.

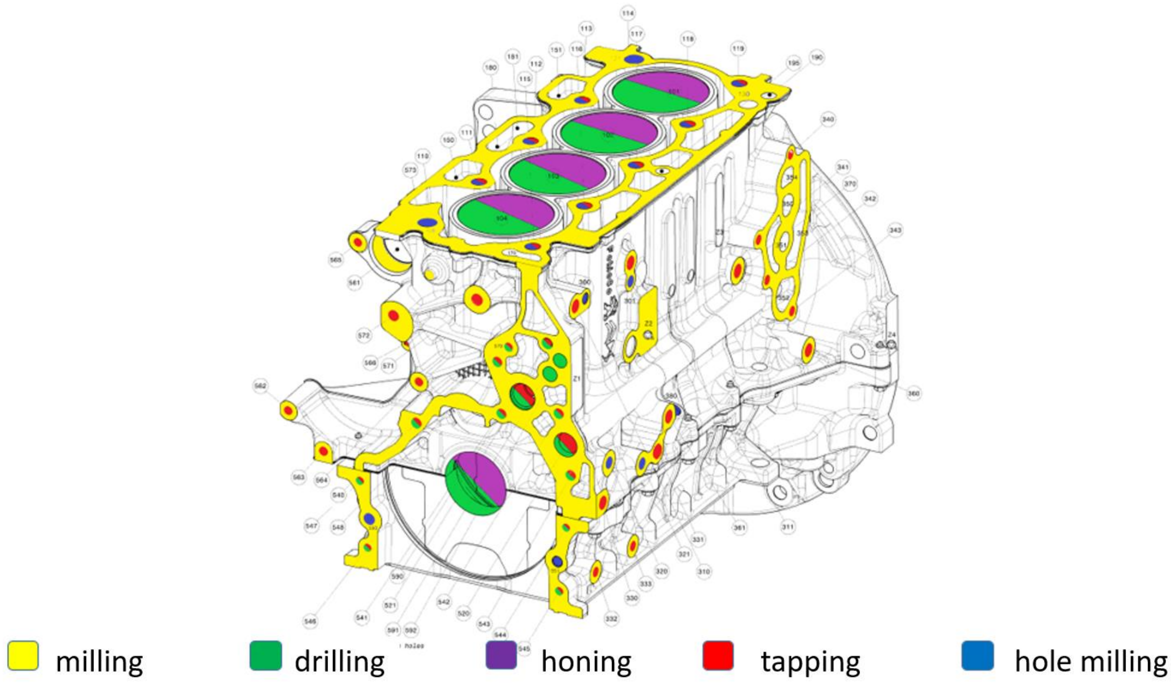


Figure 2.4.2.6 Different machined operations on the cylinder block workpiece.

The specificity of the cylinder block machining was the honing of the cylinder liners. The aim was to ensure the highest quality of surface and shape. The cylinders served as the location for the pistons.

The pistons had to go through tens of millions of cycles. The cylinders therefore had a high dimensional and surface quality.

The tool used was called the honing tool. It was a cylindrical grinding tool that laps the cylinder liners by a combination of translation and rotation. The result of this process was a typical grooved structure. This structure was extremely important for the good lubrication of the cylinders in the future engine. A well grooved structure allowed to maintain an oil layer between the cylinder and the piston rings. The process was so complex that it had to be done in 3 steps: roughing, semi-finishing and finishing knowing that at each step the material removal was of the order of a few microns.

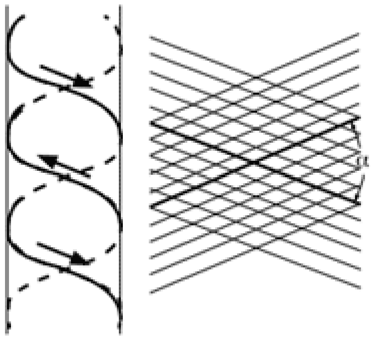


Figure 2.4.2.7 Typical surface structure after honing[31].

a) b) c)

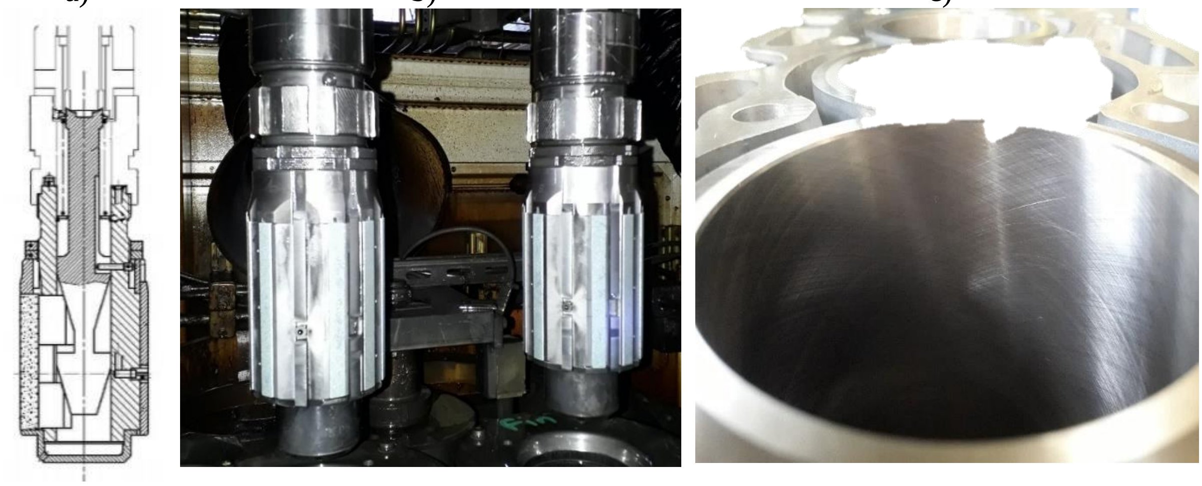


Figure 2.4.2.8 a) honing tool, b) honing tools mounted in machine, c) cylinder’s surface after honing

In addition to all the points concerning the machining of the cylinder block, another challenge was added. In the industrial context, it was a part produced in large series (2400 parts/day in the case of the DV cylinder block). In addition to quality, it was therefore important to ensure high production rates with reasonable costs.

3.4 MACHINING PRODUCTION LINE OF DV CYLINDER BLOCKS

The housing was machined on the housing machining line. This was a production line containing several steps called operations. The different operations were connected in series. One operation corresponds to one machine. In total, the production line consisted of 23 operations divided as follows

- 7 transfer machines,
- 2 honing machines.
- 2 machines for camshaft bearing cap assembly and oil system plugs
- 3 air leak test machines
- 4 washing machines

The production line is divided into a main flow line (blue background on picture) and a secondary line (yellow background on picture). The operations are organised as follows:

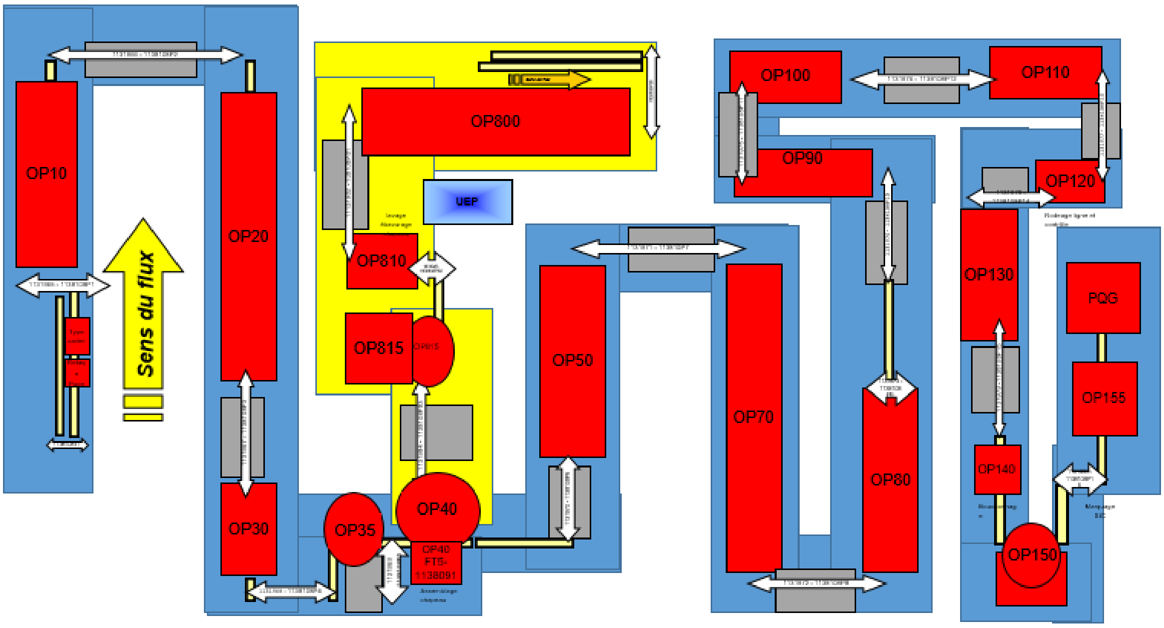


Figure 2.4.2.9 Layout of the workshop.

The upper cylinder block, before going to the OP10, is loaded onto the conveyor where it is fitted with a microchip that ensures its traceability throughout the production line. The part follows the production line marked in blue.

The camshaft bearing cap is loaded onto the conveyor at OP800 (the yellow line). After passing through machining, washing and leakage tests, the camshaft bearing cap arrives at OP40.

At OP40 the two parts (upper cylinder block and camshaft bearing cap) are assembled together and continue on to the rest of the production line as a single part - the cylinder block. Thus the cylinder block goes through several machining operations, washing, honing etc.

The cylinder block comes out as a finished product ready to be assembled in the engine after operation 155. This place is called the GQS (general quality station). Here the operator checks the quality of the part for a final time. The parts are then sent to the production lines.

Each machine is divided into several stations or units. Each of them does a specific task.

Each operation on the line should work at the same speed. To describe this, the reverse concept of frequency is used. This is called the cycle time. It is the time needed to perform an elementary operation on a unit

The designed cycle time (TCY) of the line is 24s. This means that in normal conditions, every 24s, a machined part leaves the line. However, this is never the case. This problem will also be studied in this thesis. In total, it takes 3 hours and 30 minutes for the part to pass through the entire production line.

Table 2.4.2.1 Description of the OP's of the DV cylinder blocks machining line.

OP	Description
05	Identification and loading of parts
10	Machining start, cylinder head and crankshaft face machining,
20	machining of manual gauge, thrust bearing, fix. Nozzles, roughing Ø cylinder liners, drilling between cylinders
30	Deburring - washing
35	Leakage control
40	Assembly of upper cylinder block and camshaft bearing cap, marking
50	Machining of intake, exhaust and oil pan faces. Machining of accessory mountings
70	Machining of cylinder head face, clutch face and gearbox face. Machining of starter face.
80	Crankshaft line boring, pin holes
90	Roughing and finishing boring of cylinder liners
100	Deburring - washing
110	Honing of cylinder liners
120	Honing of crankshaft line
130	Deburring - washing
140	Pressfit of plugs
150	Leakage control
155	Gravage des données process
GQS	General Quality Station
800	Roughing and finishing of crankshaft face
810	Deburring - washing
815	Leakage control

4 ANALYSIS OF INITIAL STATE

In the context described above, the problematic mentioned were studied. The cylinder block production line produced on average fewer parts than the other production lines of the DV department. The performance of the cylinder block production line were the subject of the following study.

4.1 THE BENCHMARK OEE

The production of the line was expressed in operational efficiency which expresses the performance of the line. As the OEE depended on many factors it could vary from month to month. To obtain a reliable reference, it was necessary to take the average of the OEE over a data range of at least 3 months. The average OEE was 80.78% at the end of 2020. This was calculated as the average of the monthly OEEs over the last quarter of 2020.

Table 2.4.2.1 Average monthly OEE for last quarter of 2020.

Q4 2020	October	81,87 %
	November	78,73 %
	December	81,75 %
	average	80,78 %

4.2 THE POTENTIAL OF THE WORKSHOP

First, it was important to define the line's capacity. That was, the theoretical maximum production. Based on the formula explained earlier in this report, the production corresponding to 100% of the OEE could be evaluated.

ted. To do this, the shift time length (ST) was divided by the nominal TCY of the line. The daily planned production time PPT was the sum of the PPT's of the 3 shifts because the workshop produces on 3 shifts.

4.2.1 Planned production time in cylinder block production line

The planned production time (PPT) was calculated as the shift time length (ST) minus the breaks. The ST of a shift during the week was 450min. After taking into account operator breaks, the following PPTs were defined:

Table 4.2.1.1 PPT at cylinder block line during week.

	Morning shift (1/8)	Afternoon shift (2/8)	Night shift (3/8)	Total PPT per day
Monday, Tuesday, Thursday, friday	400	400	396	1196
Wednesday	390	390	386	1166

Table 4.2.1.2 PPT at cylinder block line during weekend.

	Total PPT per day [min]
Saturday	594
Sunday	624

4.2.2 Nominal cycle time of the line

The cycle time of the line was defined from the production requirement to respect the pull work. The production line was designed for a TCY of 24s (0.40 min).

This TCY was the working time of one unit of a machine on the line. Once the unit finished machining, it passed the part to the next unit and so on. As the machines were connected in series, it was important to have the same cycle time in each unit.

4.2.3 Theoretical maximal production

The theoretical maximum production output is calculated from the nominal cycle time TCY and the PPT as follows:

$$theoretical\ maximal\ production = OEE_{max} = \frac{PPT\ [min]}{TCY\ \ [min]} \quad (5)$$

Example of calculation of theoretical maximal production can be seen below.

$$theoretical\ maximal\ production = OEE_{max} = \frac{PPT\ [min]}{TCY\ \ [min]} = \frac{(400+400+396)}{0{,}40} = 2990\ parts/day \quad (6)$$

Applying this calculation on all days in the week, the maximum production outputs equal 100% OEE were calculated as follows:

- Monday, Tuesday, Thursday, Friday: 2990 parts/day,
- Wednesday: 2915 parts/day,
- Saturday: 1485 parts/day,
- Sunday: 1560 parts/day.

4.3 LOW PRODUCTION (NON-OEE) ANALYSIS

Despite the capacities of the line, under real conditions, production never reached the OEE of 100%. It was essential to identify why this was the case in order to be able to target the actions in the following steps. The gaps between the 100% RO and the RO actually achieved should be investigated. These gaps were be called "non-OEE".

To analyse the situation on the shop floor and identify the causes of the non-OEE, it was necessary to have reliable data. The first analysis of the non-OEE was made from field data reported directly by operators as they knew their machines best.

The system of data feedback from the workshop was set up. Every day, the Unit manager filled in the Excel file where they specified the production they made during their shift, as well as all the important reasons for the non-OEE). The information was progressively fed back from the operator, through the monitors to the unit manager who registered all the information in specially designed files. A diagram of the information flow from the workshop to the unit manager is shown below.

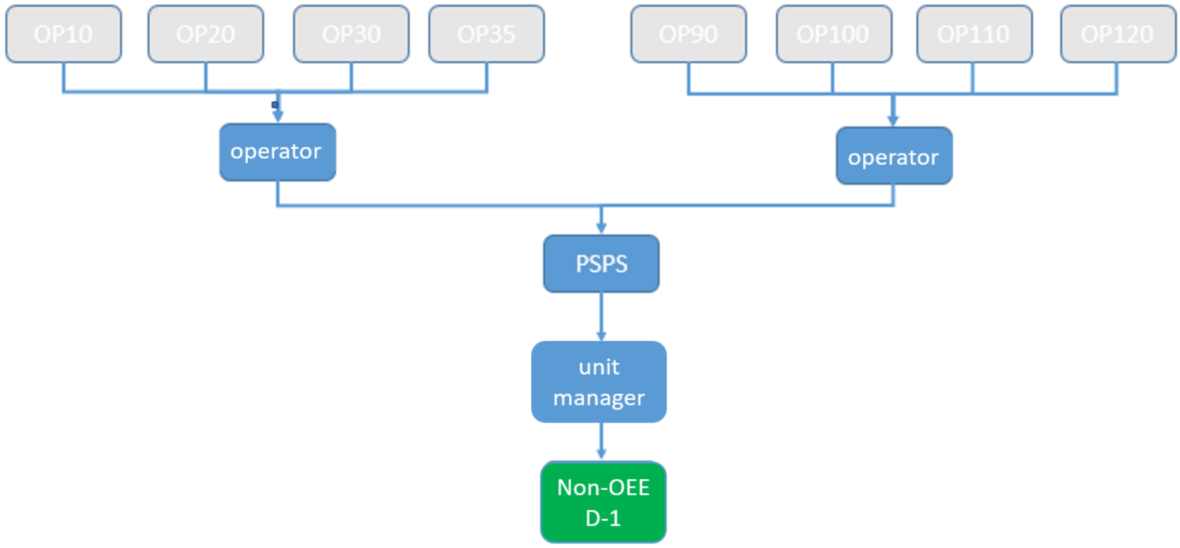


Figure 4.2.3.1 Feedback pattern diagram of daily non-OEE.

In the non-OEE file, the UM had to specify the date, his team, the operation concerned, the description of the problem and the loss category (Figure 23). It was precisely this categorisation of losses that enabled the OEE losses to be classified and analysed.

Date	Equipe	OP	mach ine	Durée	Durée	Validation des incidents	Pertes	Famille	Impact RO	Temp de
	3/8									
23/10/20	1/8	020	1	00H30'	30	GH VIDE ATTENTE GRAISSEUR	75	Mq Energie	100	0,4
23/10/20	1/8	070	1	00h15'	15	DEFAUT COHERENCE MODE TRANSFERT FAIT RECY	38	Panne	100	0,4
23/10/20	1/8	070	1	00H30'	30	COF 21 + COPEAUX	75	Chgt outil prévu	100	0,4
23/10/20	1/8	P8	1	00h15'	15	DEPOSE CASIER NC (BLOQUE PAR 1 PIECE AU SOL ?)	38	Panne	100	0,4
23/10/20	1/8	080	1	00H45'	45	COF BE + BF + COPEAUX	113	Chgt outil prévu	100	0,4
23/10/20	1/8	090	1	00h15'	15	COF TOURTEAUX	38	Chgt outil prévu	100	0,4

Figure 4.2.3.2 Screenshot of an example of a non-OEE file.

A range of data from week 42 of 2020 to week 08 of 2021 was taken for analysis. The data was sorted by loss family. 3 families of the no-OEE stood out visibly from all the data, while the others were rather negligible in comparison to them:

- Reliability of means of production,
- Tool change (TC),
- Quality.

Beyond these 3 families of losses, another major cause of the no-OEE had to be added into the equation:

- Cycle time (TCY)

To obtain the quantified results, the following approach was used:

In a first step, the share of the no-OEE related to TCY was calculated. The TCY for each OP was measured in hundredths of a minute. The deviations between nominal TCY (24s = 40cmin) and the measured TCY were calculated. The production line operations were ranked according to the deviations in descending order (table below). The OP with the largest TCY deviation and located in the production flow was designated as the leading machine. From the TCY of the slowest machine, the TCY of the line could be calculated.

Table 4.2.3.1 Cycle times of each OP of the production line.

OP [-]	TCY [cmin]	difference [cmin]	difference [%]
800	47,18	7,18	17,94%
810	46,03	6,03	15,07%
050	42,11	2,11	5,26%
090	41,67	1,67	4,17%
100	41,26	1,26	3,15%
110	40,71	0,71	1,77%
130	40,26	0,26	0,66%
120	40,15	0,15	0,37%
155	40,00	- 0,00	0,00%
070	39,38	- 0,62	-1,54%
035	39,29	- 0,71	-1,78%
150	38,99	- 1,01	-2,53%
815	38,95	- 1,05	-2,61%
080	77,82	- 2,18	-2,72%
030	38,40	- 1,60	-3,99%
040	38,38	- 1,62	-4,05%
140	37,98	- 2,02	-5,05%
020	36,82	- 3,18	-7,94%
010	35,87	- 4,13	-10,33%

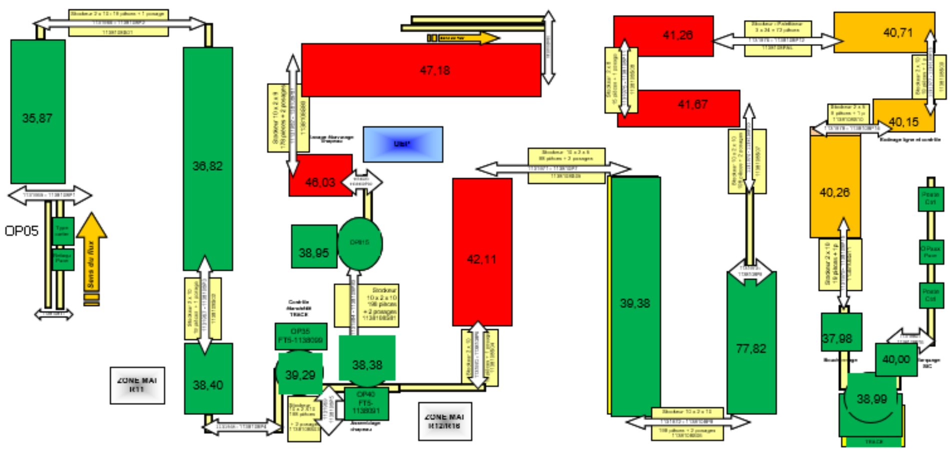


Figure 4.2.3.3 – OP's cycle times shown in the production line [min].

Reasoning in the logic of the production flow, OP50 becomes the leading machine with the highest TCY (even though OP800 has the highest TCY, it is not in the main flow and its impact on total production is lower than that of the machines in the flow). The cycle time of OP50 was 42.11 cmin (February 2021 - week 8). The share of the no-OEE due to TCY can be estimated:

$$noOEE_{TCY} = 100 - \left(\frac{ideal\ TCY\ [min]}{TCY\ of\ the\ slowest\ OP\ [min]}\right) * 100 = 100 - \left(\frac{0{,}4000}{0{,}4211}\right) * 100 = 5\% \quad (7)$$

For the remaining 3 categories, the durations of the events in each category were aggregated and compared.

Table 4.2.3.2 Cumulative duration [in min] of reported events in each category (W42/2020 - W08/2021).

Cutting tools	Reliability of means of production	Quality (rework, sorting)
14990	30260	3815

From these data, adding the TCY parameter, the values of the no-OEE are evaluated:

Table 4.2.3.3 OEE losses [in %] (w42/2021 - w08/2021) absolute values

TCY	Cutting tools	Reliability of means of production	Quality	sum : no-OEE
5,00 %	4,35 %	8,77 %	1,10 %	19,22 %

In order to isolate just the part corresponding to the no-OEE, the values are compared relatively to each other:

Table 4.2.3.4 Decomposition of the no-OEE [in %] (w42/2021 - w08/2021) relative values.

TCY	Cutting tools	Reliability	Quality	sum
26,02	22,61	45,62	5,75	100

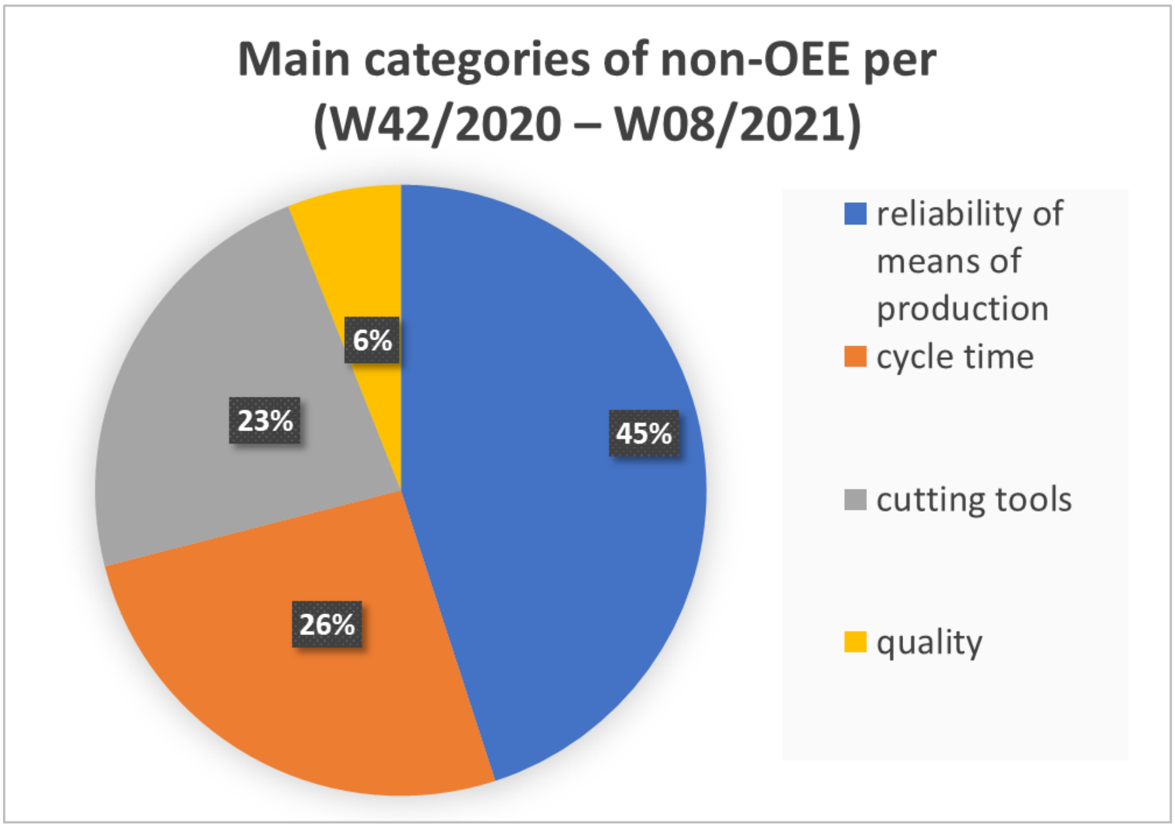


Figure 4.3.4 Main categories of non-OEE.

Summary:

Reliability of the means of production was responsible for most of the OEE losses (45%). TCY outside the nominal range caused about ¼ of the OEE losses (26%). The next largest family of losses was the change of cutting tools (23%). Finally, the fourth most penalising loss family was quality losses (6%).

4.4 ANALYSES VIA SAPIA TOOL

In order to analyse the no-OEE of the production line even more accurately, the SAPIA tool is deployed.

SAPIA (from French) is the acronym for: Système d'Aide au Pilotage des Installations d'Atelier.

It is a system whose objective is to reveal the weak points of the production line in order to target the interventions and establish the maintenance plan.

This system was developed by the PSA group. It was implemented on the crankcase production line in the 2000s.

The software, in spite of its complexity, starts from a simple idea: to determine in which state a machine (e.g. machining centre, machining transfer, robot...) is and to be able to acquire this data in real time.

Each machine was connected to this system by 8 wires. The system then worked with a format of 8 bits = 1 byte. Depending on the state the machine is in, the different bits are either enabled (1 boolean) or disabled (0 boolean).

By activating one bit or a combination of several bits, the machine state changes in the SAPIA system.

The 8 possible states of a machine can be divided into 3 main categories:

- Production,
- Induced stop,
- Own stop.

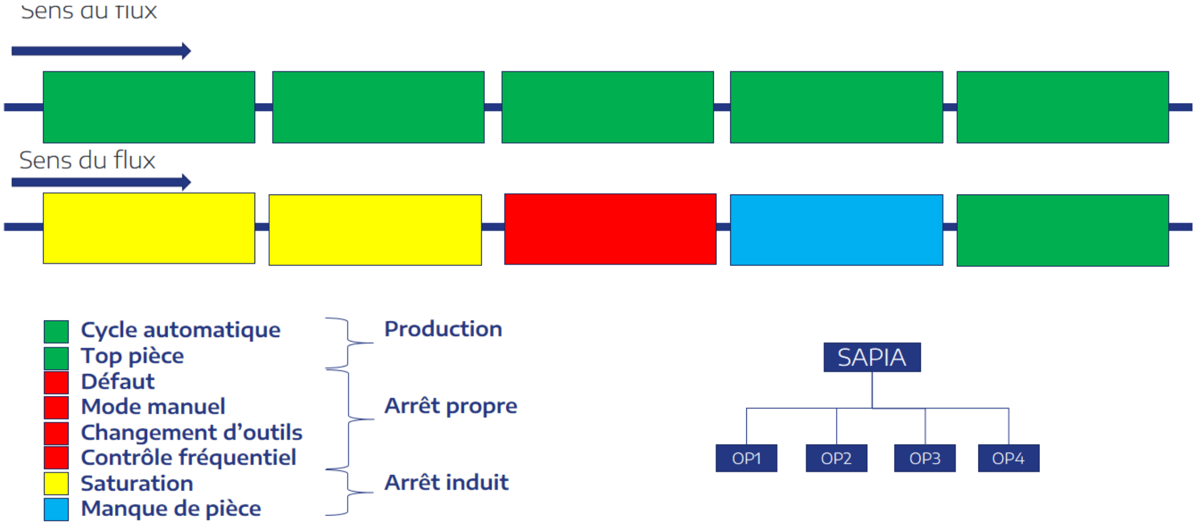


Figure 4.4.1 The states of the means of production classified by class and distinguished by the colours.

Production:

When the machine is in normal operation and producing parts, it is in an automatic cycle.

Each time it finishes machining a part, it sends a "top part" signal, which is coded as bit 4. This allows to count how many parts the machine has produced during a given period. Statistically, this can be used as an indicator (hourly production). Sapia allows the visualisation of production evolution with the "activity curve" tool (Figure below).

The production-related status is always associated with the colour green.

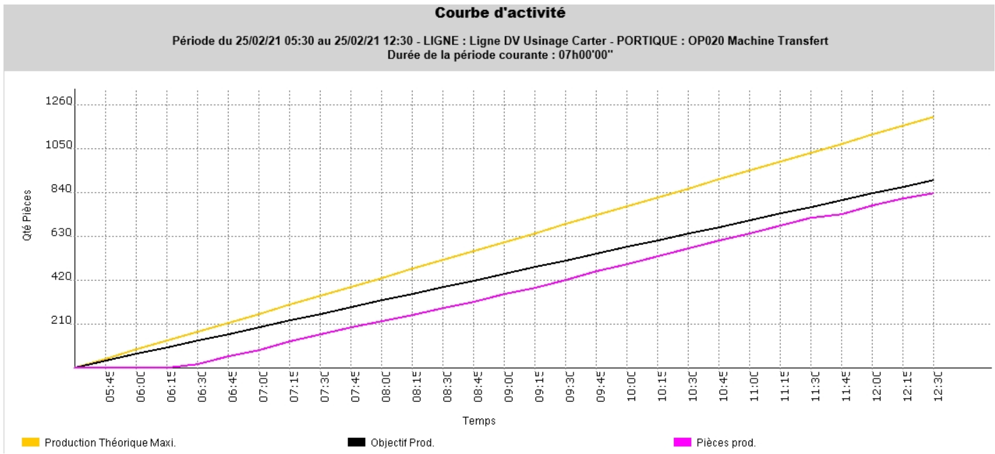


Figure 4.4.2 – Activity curve.

Induced stops: These are stops for which the machine is not responsible. It is a stop induced by another machine in the flow. There are two possible scenarios:

- blocked: the machine has finished working but cannot pass the part to the downstream machine because the flow is blocked (for example, the downstream machine has broken down). The blocked machine does not show any failure but it is stopped because of the downstream machine. blocked status is indicated by the colour yellow.
- starved: The machine has finished machining the workpiece and is ready to receive a new workpiece. But the part does not arrive. The machine is not supplied. It is therefore stopped because of one of the machines in the upstream flow. The lack of part status is associated with the colour blue.

Own stops: all machine own stops.

- breakdown: the machine has failed. It can be any kind of failure.
- Manual mode: a very large family of own stops. It can hide any type of intervention/failure. Manual mode is always initiated by a PO voluntarily. It can happen following a breakdown, during troubleshooting, tool change, machine cleaning with the mean of production stopped...
- Tool change: if the PLC is well programmed, the machine should recognise if it is stopped because of the tool change.
- Frequency control: at a defined frequency, the machine stops automatically in order to alert the PO that it is necessary to check the part in the means of production. As the cutting tools wear out over time, frequency control allows the quality of the parts produced to be checked.

Colour differentiation allows for better production line control. As the data acquisition takes place in real time, the machine states of the entire line can be visualised on a synoptic.

On the production lines, there are several screens, with a live overview of the production line. The POs are then able to see a machine stop even if they are not next to it. The screens are mounted next to the control stations, for example, as this can take several minutes. Thus, the PO is able to intervene during a machine stop and continue its frequency control later.

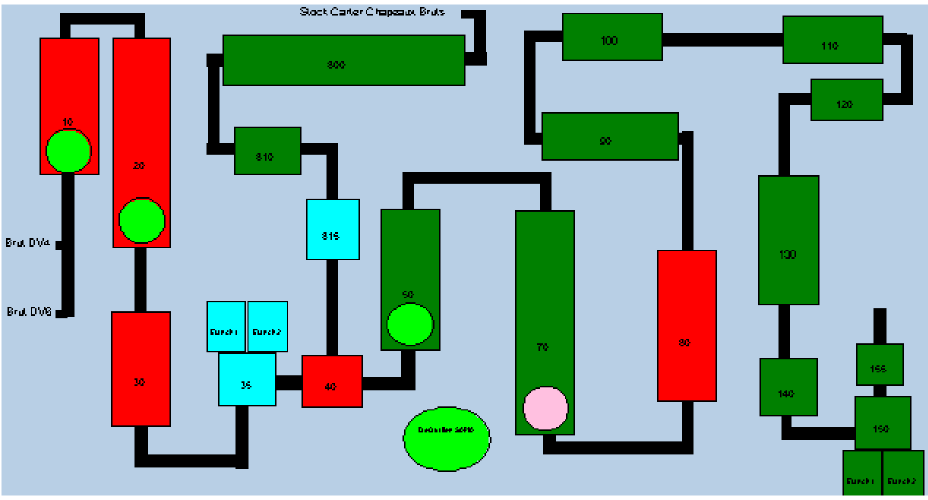


Figure 4.4.3 All Ops statuses in real time.

4.5 BUFFERS

The buffers were designed to cushion machine downtime, whether it be due to tool changes, breakdowns, or campaign changeovers. Even such a major intervention as campaign changeover could be done without really disrupting the production of the line provided that the campaign changeover on different operations is done in a well thought out manner.

The buffers are distributed in the production line over several locations.

In a production line optimisation approach, the position and capacity of the buffers should be taken into account.

Figure 4.5.1 High-capacity buffer.

5 PROPOSED SOLUTIONS

After identifying the main causes of the no-OEE, solutions to optimise the problem areas were proposed. As the issues in production and their resolution and optimisation of production were a very complex task, activities had to be prioritised. To do this, 2 factors were considered:

- the impact of the action group on the no-OEE,
- the difficulty of the implementation of the topics.

Priorities were assigned using the 9-box matrix which takes into account the 2 variables mentioned above.

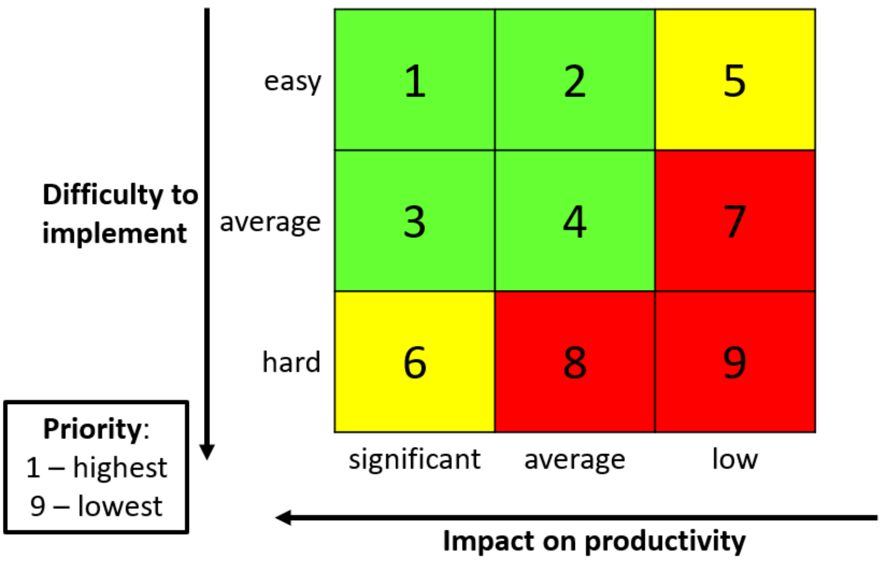


Figure 5.1 Priorities assigned to action group depending on their ease of implementation and impact on productivity.

Priority in the graphic above were evaluated from highest priority being 1 to lowest priority being 9. The action group with the highest priority was the one that was the easiest to implement with the most impact.

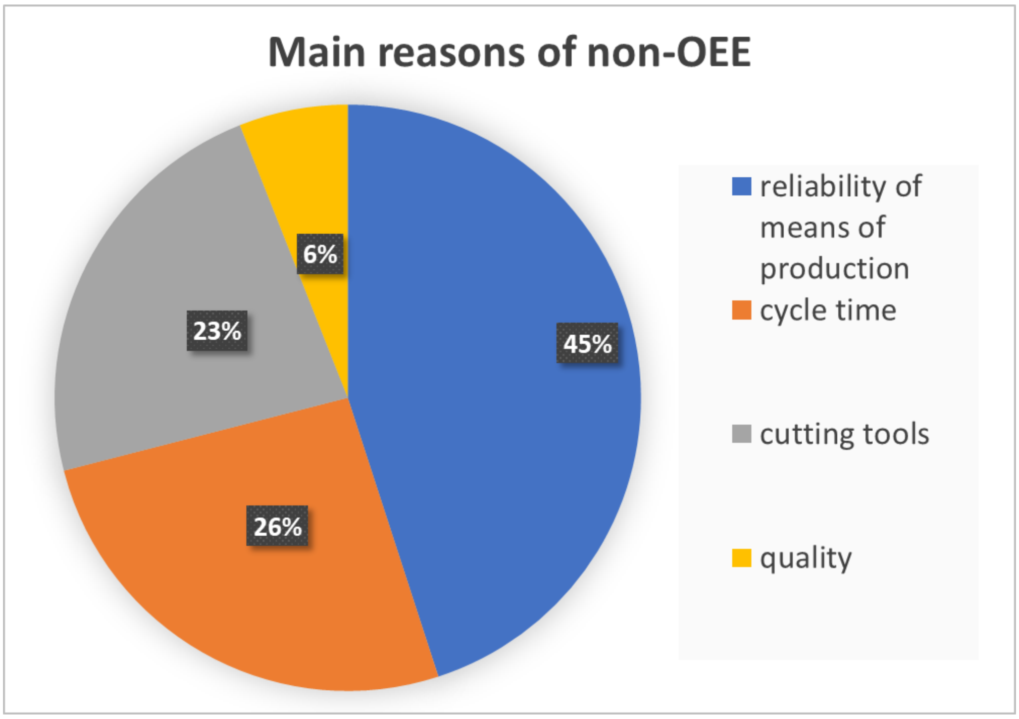


Figure 5.2 Reasons for non-OEE categorised.

The reliability of the means became the number one priority as it had potentially major impact on the no-OEE of the line. Being able to improve the area of reliability could increase the OEE faster than other areas. Even though it was a complex issue and troubleshooting had to be done be done by the highly specialised staff, there were actions that could be easily implemented. Working on the area of reliability of resources did not mean managing all the topics belonging in this category, but further choosing among them the most relevant ones.

Cycle time had the second greatest potential to impact the no-OEE of the production line. This was a subject of great complexity. Although it had been a subject of study by technicians for a long time before beginning of this intern ship, the progress made was small in comparison to the efforts made. Therefore, this topic was determined to have a lower priority. Actions to improve the derived cycle time ere nevertheless still be carried out during the internship.

Quality deviations were often caused by collisions between the machine and the workpiece or the cutting tools and the workpiece. Similarly, worn or incorrectly pre-set tools could be the cause of quality problems. By solving the other areas and organising the work in the production line correctly, the quality of the parts produced was also expected to rise. Beyond that, among the causes of the no-OEE mentioned above, the quality problem had a minor impact on the OEE of the production line. This topic therefore had the lowest priority in the efforts to increase OEE. Quality was still an important budgetary issue, but which was not the subject of this diploma work.

Following the selection of priorities, the areas of reliability and cutting tools were further developed in this report in the following chapters.

Even if the areas of optimisation were chosen, it was then necessary to find the most relevant topics in each of them.

5.1 THE RELIABILITY OF THE MEANS OF PRODUCTION

The reliability of the means of production was the main cause of the no-OEE. Almost half of the losses were caused by machine breakdowns and failures. The maintenance staff did their best to repair the machines as soon as possible. Preventive maintenance, which sought to prevent future breakdowns by replacing worn spare parts before critical usage, was carried out regularly. Every week, the entire production line stopped for 4 hours to carry out planned preventive maintenance (PMP) and scheduled work was carried out during the weekends.

Despite this, the area of insufficient resource reliability was still at the top of the list of causes of no-OEE.

5.1.1 Breakdowns on the production line

On a production line, breakdowns were often preceded by malfunction precursors. These were sometimes not handled for various reasons:

- Often it was a sign of a malfunction that is not very serious. As a result, operators did not pay attention to them,
- To keep the production good in the short term, small malfunctions are often shunned with the best intentions.
- In the case of numerous breakdowns, teams were forced to prioritise the most important ones so that production did not come to a standstill,
- The budgetary aspect could also influence the prioritisation of interventions.

5.1.2 Check sheets in the production line

Malfunction precursors predict the appearance of the most penalising stoppages and as they appear most often, they are most easily detected.

This is why there were a system of check sheets put in place. However, the logistics behind it were complicated for the following reasons:

- complicated data processing,
- only partial information gathered,
- possible data loss due to difficulty processing,
- dependency on too many factors.

Complicated data processing was the first possible complication. Small failures were recorded on check sheets. These had to be collected manually, entered into a database, analysed and published. Then, through statistical processing, results and conclusions can be drawn.

Partial information was the second possible complication. The information on a check sheet only gave information on the number of occurrences of small breakdowns. Even though these breakdowns were generally of short duration, information on their duration was missing from the information on the check sheets.

Possible loss of data due to difficult processing was the third challenge. Given the complexity of the data reporting chain, there was increased probability that part of the data was lost.

Lastly, the reliability of the check sheets was strongly dependent on several factors. Reliability depended on the manufacturers on the production line - the plant operators (POs), their fill rate

(Number of events taking place/Number of events entered in the sheet) and the accuracy of the information entered. Similarly, the reliability of the check sheets depended on all the data processing figure as on the that follows.

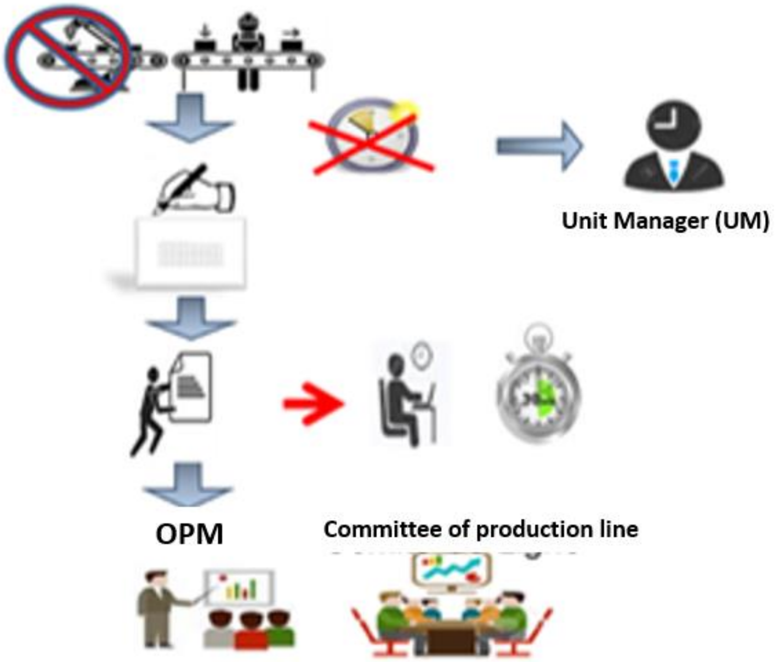


Figure 5.1.2.1 Data processing of the check sheets in the factory.

To facilitate this reporting from the production line, the AMPERE project had digitised the production line and is elaborated in the following chapter.

5.1.3 The AMPERE project

The AMPERE project was a project made to improve check sheets by digitalizing the production line. AMPERE stands for "**A**cceleration **M**anagement **PER**formance **E**quipment".

The AMPERE project represented one of many steps taken to modernise the Trémery plant. Numerous improvements to automate production and make it more efficient were increasingly being implemented. This project allowed us to obtain and visualise real, factual information at any time. The aim was to consult the information in real time, which allowed quick action to be taken. In this context, the AMPERE tool had been put in place.

In case of breakdowns, whether small recurring breakdowns or serious breakdowns, were stoppings production, the AMPERE project worked with them as input data. The idea was simple: to be aware of the origin of the machines' stops on the production line so they could be analysed.

All own stops were automatically reported via the SAPIA system. The AMPERE project complemented this existing system.

For this purpose, touch screens were mounted and connected to the machines in the production line. They were then programmed to filter only the own stops of the means.

Figure 5.1.3.1 AMPERE interface at the workshop.

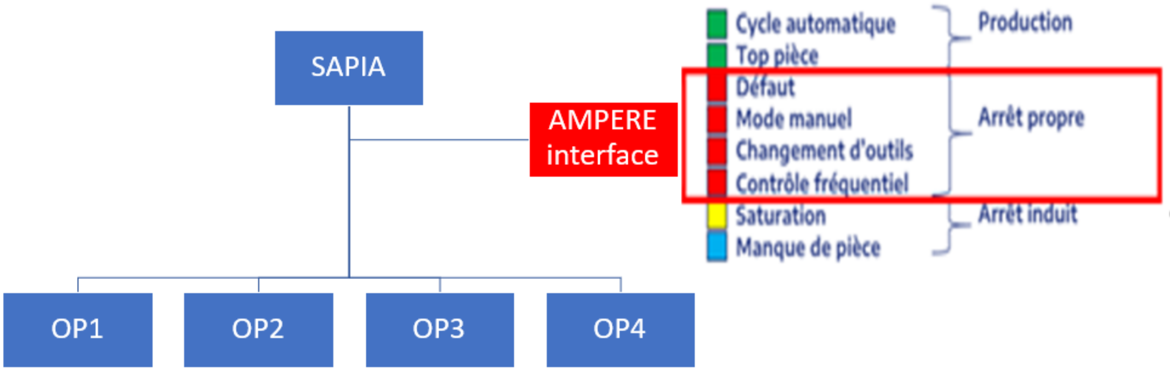


Figure 5.1.3.2 AMPERE connection to the SAPIA.

After the mean of production went into stoppage, exceeding the threshold, an event was automatically brought up on the screen with the time stamps of the start and end of an event as well as its duration. The means of production affected by the shutdown were automatically linked to this event.

Figure 5.1.3.3 AMPERE screenshot.

The operator then had to characterise this event by clicking on the "to be entered" box. Then, they would be directed to the page of the characterization of the families of losses. Here they could find all the families of losses corresponding to the stops of the means of production.

Figure 5.1.3.4 Screenshot of categories of losses in the AMPERE interface.

Once the loss family were chosen, it was sufficient to specify the cause of the losses. The operator only needed to select from the database of loss cause category that had been customised for the mean of production concerned.

Figure 5.1.3.5 Screenshot of categories of causes of loses an OP commentaries in the AMPERE INTERFACE.

All the teams were trained to characterise the losses of their installation. It was thanks to the involvement of each operator in the production line that the data could be processed and sorted. Thus, the most recurrent and penalising breakdowns were identified.

5.1.4 AMPERE data processing

After the losses were entered via an AMPERE screen, they were recorded and processed by the PowerBi software. This was a Microsoft program that was able to visualise data and filter it statistically via dynamic graphs.

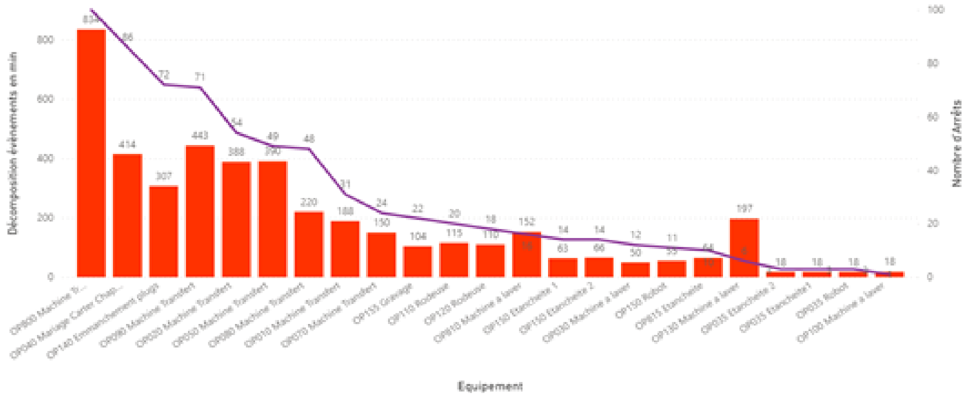


Figure 5.1.4.1 Example of dynamic graph in PowerBi software.

Using Pareto's law, the top 5 recurring defects were selected and communicated to the maintenance teams. This was done regularly, every 2 weeks. An example of such a processing of the data reported by the AMPERE system is shown in the picture above. The fault labelled "lubrification defect" was reported 42 times over a period of 2 weeks, causing downtime of 267 minutes in total.

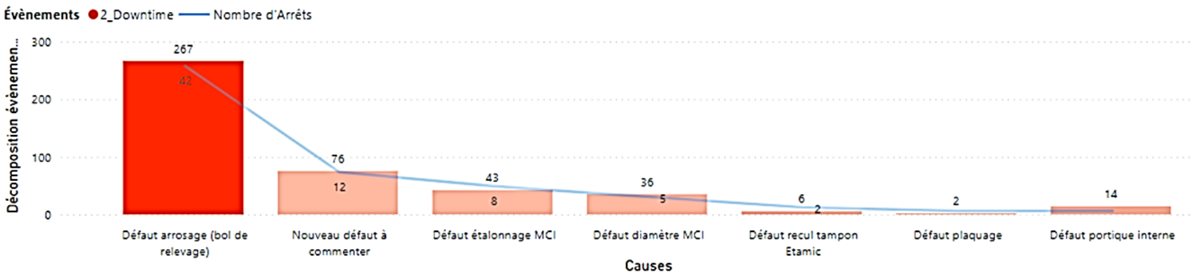


Figure 5.1.4.2 Pareto diagram of reoccurring defects over two week period of time extracted thanks to PowerBi software.

All problems were discussed at the no-OEE meetings where technicians, maintainers and operators all participated. This way, everyone tried to identify the causes of problems and, following this analysis, an action planner was put in place to solve the problem. For each action, a task manager and a deadline were assigned.

5.1.5 Reporting of results

An important part of this work was ensuring good communication of the results to each employee involved in the project. Operators who characterised the causes of losses on a regular basis needed to get feedback. The operators needed to be aware that the maintenance teams were processing what they characterised on the screens.

For the project of this type to continue, every player must be involved. This is why the desire to participate must be created. A clear vision must be established. This is why the results of the AMPERE analyses were then communicated to the EP|U. Each member of the EPU was aware of the defects identified in the production line and the actions taken to resolve them. The results and feedbacks were also displayed on printed dashboard placed for viewing in the workshop as shownin the following figure.

Figure 5.1.5.1 Dashboard with updated feedback put on display in workshop.

5.1.6 Bottleneck

The bottleneck is the designation for the machine that has the greatest impact on production. The bottleneck slows down production on the production line. As the machines in a production line are connected in series, the bottleneck defines the flow rate of the entire line. The product flow cannot go faster than the throughput of the bottleneck machine.

However, the identification of such a machine is not simple as it depends on many factors such as the machine's own stops, induced machine stops, position in the flow, cycle time, tool change time, hourly production rate.

It is important to identify the bottleneck machine in the production line because by identifying it, the efficiency of the whole line is improved. Working on the bottleneck is a priority in terms of improving the production of the line.

5.1.7 Identification of the bottleneck machine

The SAPIA tool was used to identify the bottleneck. The data was visualised via the Microsoft PowerBi display and processing tool. An approach was proposed to identify the bottleneck based on factual data, automatically measured on the means of production concerned. As this was a complex problem, the approach considered several factors. It was mainly based on 4 pillars that defined the steps of this approach:

1. induced stops in the production line,
2. own stops in the production line,
3. hourly production in the production line,
4. summary of bottleneck.

5.1.7.1 **Induced stops in the production line**

In the reasoning of the flow line, if the machines are connected in series, a bottleneck will be the one surrounded by the mostly blocked upstream operations (OPs) and the mostly part-starved downstream OP or several OPs. If a machine slowed down the flow, it would put the other machines in the production line in induced stop, starting with the downstream machine and the upstream machine, and then spreading further. Therefore, the bottleneck location was also indicated by the smallest blockage and part-starvation downtimes in the production line. If the blockage and part-starvation downtimes are visualised over a long period, statistically reliable and factual conclusions can be drawn.

According to the upstream resources that were mostly blocked and the downstream resources that were starved. TOP bottleneck machines, depending on the induced stops, can be identified.

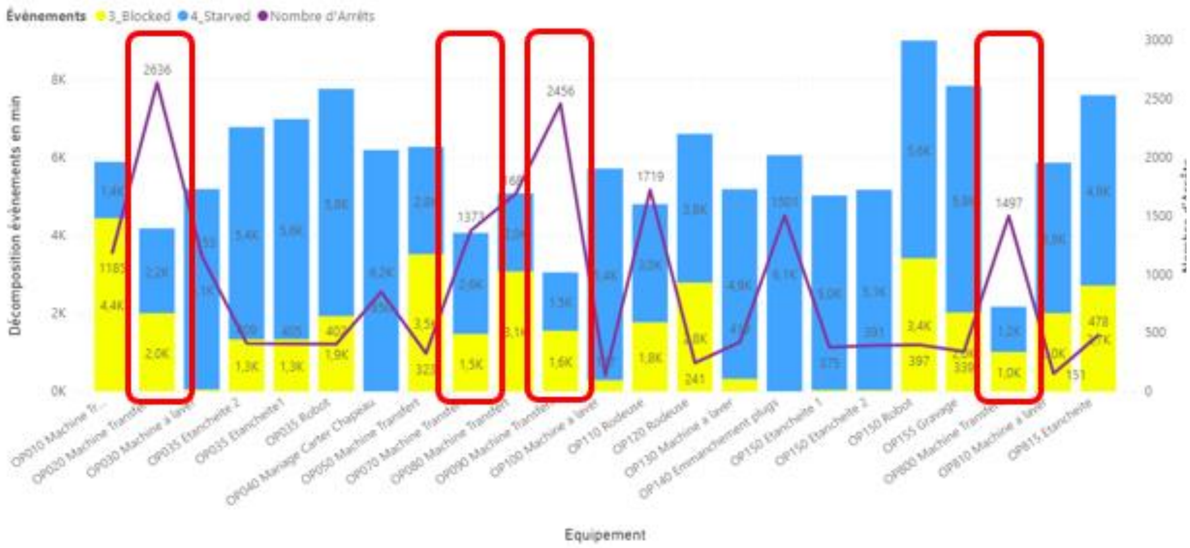


Figure 5.1.7.1 – Bottleneck machines identified - blockage (yellow) and starvation (blue) downstream.

In the figure above, the blockages and starvation downtimes are shown for each machine in the production line. These durations were measured in minutes. The operations were arranged in the same order as the machines in the production line. Four of these machines stand out from the rest. To explain this via an example: the first machine circled is the OP20. It was surrounded by OP10 upstream. This one was mostly blocked. The downstream machines were mostly starved. This means that OP20 was one of the bottlenecks. The same logic applies to the other machines, circled by a red tile.

Similarly, the same machines would be identified if the methos used was based on the lowest induced downtime. If the OP's were arranged in ascending order, the same machines identified earlier would be at the top of the list.

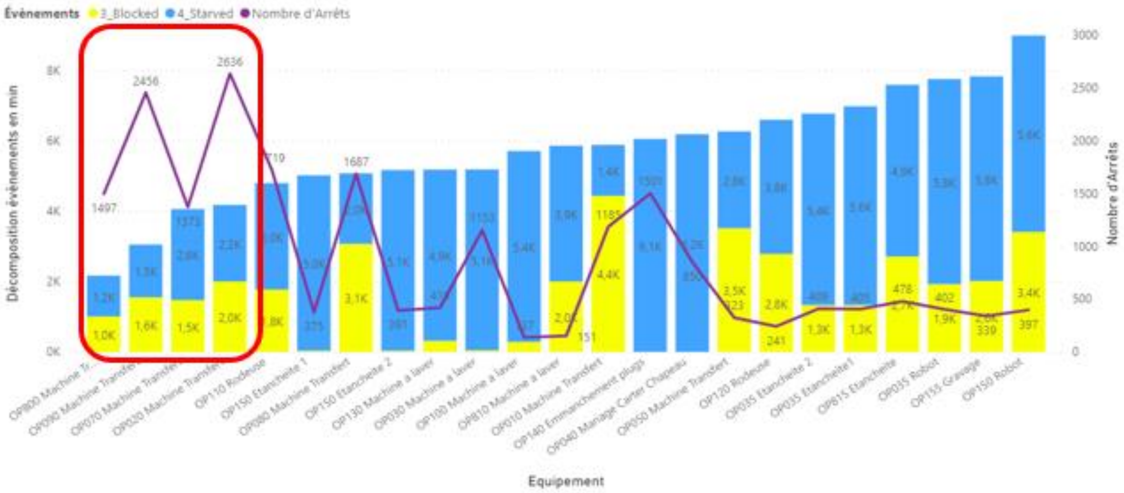


Figure 5.1.7.2 Method of lowest induced downtime to identify the bottleneck – blockage (yellow) and starvation (blue) downtimes.

For both graphs, the data were visualised over a period of one month. In the columns, the saturation and shortage downtimes are displayed. The curve represents the number of stops during the same period.

5.1.7.2 **Own stops in the production line**

One of the indicators that characterise the bottlenecks are the own stops of the means of production. This can obviously include several types of own stops such as breakdowns, tool changes, chip cleaning, repairs, machine in manual mode.

The means of production with the highest own stop time in the production line indicate that they are the bottleneck locations. If the OPs in the production line are ranked in descending order according to their own stop times, the bottlenecks are at the top of the list.

It is remarkable that the top 4 POs in the list below are the same as those at the level of induced stops.

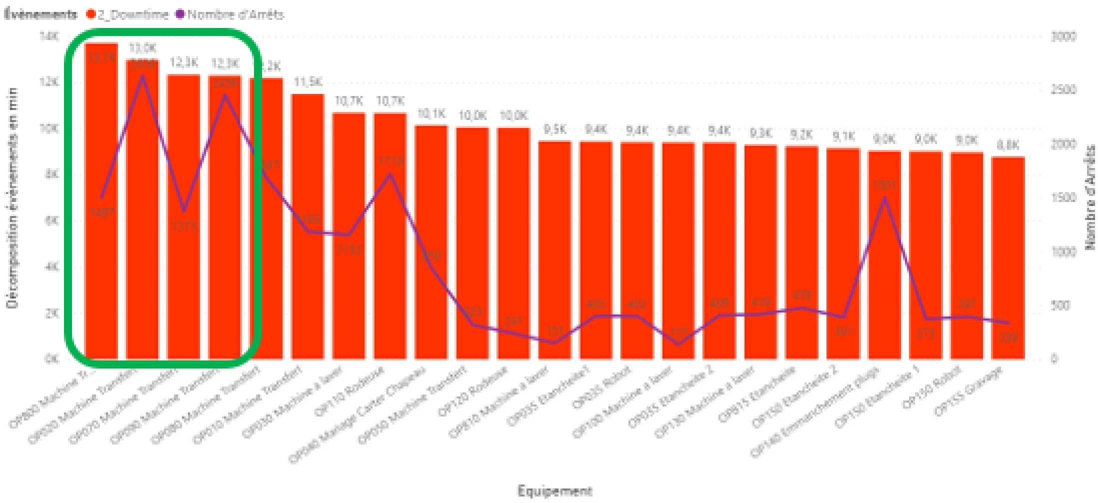


Figure 5.1.7.3 Own downtimes.

5.1.7.3 **Hourly production in the production line**

The SAPIA software was able to record when the mean of production produced a part. This data was recorded with the time stamp. Thus, it was possible to determine how many parts have been manufactured during a certain period.

An indicator that had been adopted in all the production lines of the Stellantis Group wasthe hourly production - i.e. the number of parts produced in one hour. This was the most synthetic indicator and depended on all the other loss families. The values of the mean of production per hour were calculated over a period of at least 400 minutes (the PPT of one shift). In any case, it was advisable to calculate these values over a much longer period than a shift's PPT, as the hourly production may be biased by the shutdown of a means of production.

For this thesis, the mean of production per hour has been calculated over a period of one month. Using such a long period for hourly throughput calculations gives statistically reliable values. In Figure below, the 5 machines with the lowest hourly production of the whole production line are shown (May 2021). The values of the mean of production per hour are shown in columns. The objective hourly production is shown in the red line. It was calculated from the maximum hourly production [f(TCY line)] and was adjusted for the target OEE. The green line shows the maximum hourly production of each machine [f(TCY mean)].

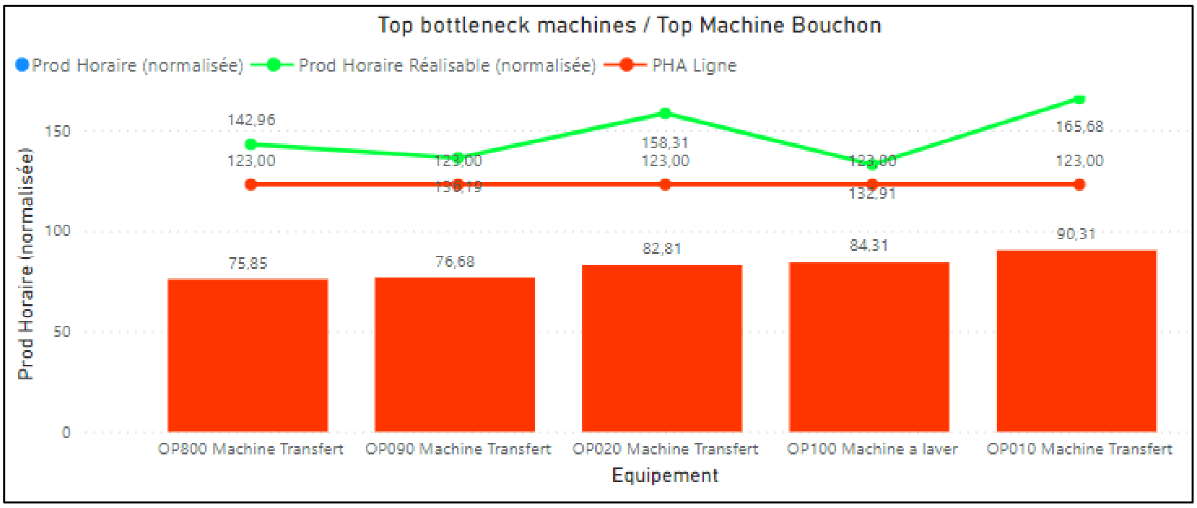


Figure 5.1.7.4 – 5 machines having the lowest production per hour

In the graph above, the 5 machines with the lowest average hourly production are shown. The data was calculated over a period of one month. The columns represent the average hourly production. The green curve represents the maximum achievable hourly production for each OP. This was calculated according to the cycle time of this machine. The red curve shows the objective hourly production of the production line. It was calculated according to the ideal cycle time. It is adjusted in relation to the target OEE.

The data displayed must be interpreted. Among the TOP 5 bottleneck machines (the machines with the lowest hourly production are OP800, OP90, OP20, OP100, OP10. Knowing that OP10 and OP20, as well as OP90 and OP100 are juxtaposed. It was then each time a single machine that caused the low production of the other.

Note: the accuracy of the hourly production measurements depended on the calendar information in the SAPIA software. If, for example, the production line did not produce on a given day, but this information was not properly entered in the calendar, the hourly production on that day will be 0. This would cause the values even over a longer period to be biased.

5.1.7.4 **Summary**

Based purely on hourly throughput, induced stops and own stops, the following data would be derived from the analyses:

Table 5.1.7.1 Determination of bottleneck

rank	Hourly production	Own stops	Induced stops	points assigned
1st	OP 800	OP 800	OP 800	5
2nd	OP 90	OP 20	OP 90	4
3rd	OP 20	OP 70	OP 70	3
4th	OP 100	OP 90	OP 20	2
5th	OP 10	OP 80	OP 110	1

In the table above, higher is the rank, worse was machine placed.

By ranking the results obtained starting with the most penalised machines, the above table was obtained. Then, depending on the position of the means of production in the ranking, points can be attributed to them as shown in the table below.

Summarising the points awarded, the new more synthetic ranking was obtained as per in following table.

Table 5.1.7.2 Total points obtained per OP.

OP	Total Points
800	15
90	10
20	9
70	6
100	2
10	1
110	1

Using the results in Table above, the first bottleneck was then OP800, followed by OP90 and OP20. The fourth was OP70 and the last stopper in the TOP5 was OP100.

The position of the means of production in the production flow

The 3 factors that have been mentioned before are calculated from what was measured. This was then factual data which nevertheless must be analysed behind it in order to identify priorities.

One of the key factors in identifying priorities (= identification of the bottleneck machine) is the position of the means of production in the production flow.

The five previously identified bottleneck machines are visualised in the production flow on the picture below.

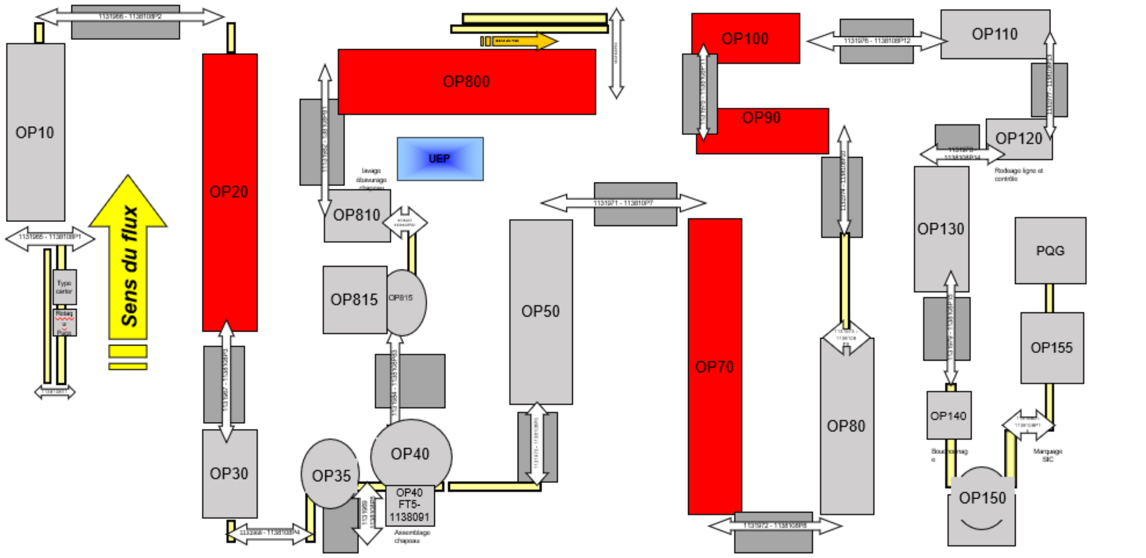


Figure 5.1.7.5 – TOP 5 bottlenecks visualized in the production flow

OP800 - 1st penalizing machine. A very complex machining transfer that does both: rough machining and finishing machining. This machine was not on the main flow line but was separate. It was possible to run it independently and if it was stopped, this did not necessarily disrupt the production of finished cylinder blocks.

OP90 - the second machine to suffer from the bottleneck. The transfer was located in the finishing part of the production line. In addition to being the penalising machine, this one was also problematic in terms of quality, slow cycle time and a change of tools that often occurs out of frequency. For this reason, it makes more sense to focus on OP90 rather than OP800.

OP20 - Even though it was on this list, it was mostly caused by a recurring defect that was already known. The measures have been applied and the corrections have been put in place. It was then a problem that was fixed separately. In addition to this, this machine was overcapacity because its cycle time was lower than the ideal cycle time of the line. This was one of the few cases.

OP70 - the machine where most of the long stops are caused by tool changes. This problem will be addressed separately in this thesis (SMED OP) and was not the reason for the machine to become the target machine.

OP100 - this was a washing machine that does not perform complex operations. It did not use any cutting tools to add value to the part. This machine was included in the list because it was held back by OP90 which was the upstream machine.

It was absolutely essential to identify the bottleneck machine that would become the target machine because by improving the bottleneck machine, the whole production flow would improve.

Using the approach specified above, the target machine was chosen. OP90 becomes the target machine as it had the greatest impact on production. As the machines on the line were connected in series, by improving the weakest point and improving its throughput, the production of the whole line will increase.

5.1.8 OP90 - the target operation

The OP90 operation consists of machining and transfer machines of the cylinder liners. These had already been roughened in the OP20. This first roughing was also called "peeling" because it removed the top layer of the cylinders. This top layer had a higher hardness than the rest of the drums. It was also irregular in terms of its thickness. The clean removal of this layer in OP20 was the basis for a clean processing of the OP90.

The OP90 transfer does the semi-finishing and finishing of the cylinder holes. The transfer contains 6 machining units and 1 dimensional control unit.

Table 5.1.8.1 – Target operation breakdown.

	Control	**Finishing**			**½ Finishing**		
Unit	13.2	11.2	10.2	8.2	5.2	3.2	2.2
cylinder no.	1, 2, 3, 4	3	2	1,4	1,4	3	2

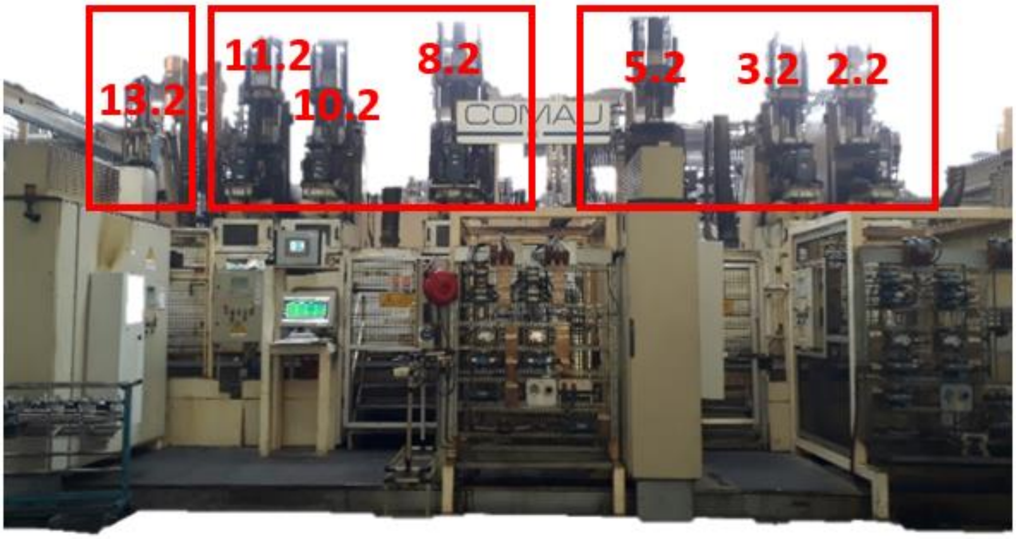


Figure 5.1.8.1 – transfer machine OP90

5.1.9 OP90 Proposed Maintenance Meetings

Some problems identified were not trivial and needed to have a synthesis of several opinions. This approach was chosen to deal more closely with the bottleneck. As the bottleneck was the weakest and most penalising point of the whole flow, it was important to target actions on this element as a priority.

Operation 90 being the bottleneck became the focus of this meeting. The meeting was managed in such a way that everyone familiar with the machine was brought together and could express their knowledge on the subject: the POs working with the machine on a daily basis, their hierarchical superiors, the technicians, etc.

5.1.10 Monitoring the bottleneck machine

The bottleneck machine was monitored more closely through meetings and also through the animation that had been set up in the production line. To monitor the progress and results of the work done on this OP, it was possible to monitor the same indicators as those used for its identification. That is, own stops, induced stops and hourly production. The bottleneck machine was identified on the basis of data from May. By comparing this data with the data for the following weeks/months. OP90 being the bottleneck machine should be monitored very closely. Everyone should be aware of the importance of this issue. Management had been deployed to take this forward.

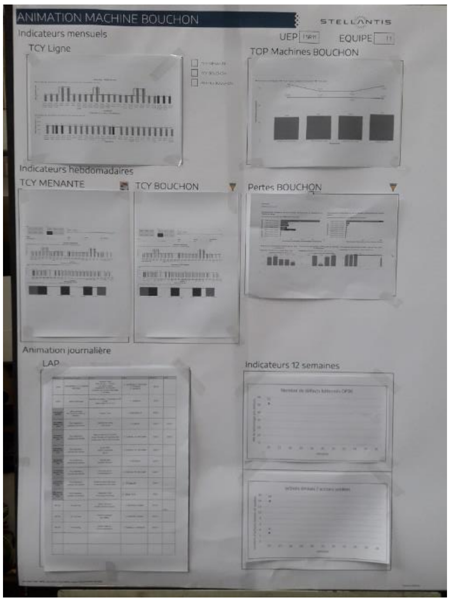


Figure 5.1.10.1 – monitoring of bottleneck directly in production line

In the picture above, there is the bottleneck monitoring standard shown. This contained several indicators that were intended to determine the vitality of the bottleneck. This was updated regularly on a weekly basis. The standard contained:

- Cycle time of the bottleneck machine
- The hourly production of the bottleneck machine
- the schedule of actions
- Indicators:
    - Number of defects reported on the check sheets during the week
    - Number of actions closed during the week

5.2 CUTTING TOOLS

Cutting tools are a broad subject that touches every machining operation. The cutting tools do the majority of the work on the production line. There were a total of 9 machining operations on the line, including 7 machining transfer machines and 2 honing machines. Each machine contained several units, each of which did another machining operation. Together, 165 different cutting tools were used to transform the casting blank into the finished cylinder block.

The large number and variety of cutting tools means that tool changes were very frequent. Tool changes were one of the causes of OEE losses.

An important element in the organisation of the cutting tools in the production line is 5S and visual management. Good orientation means that the operator does not have to waste a lot of time looking for new tools. A visual management system that distinguishes between used and adjusted tools avoids confusion between tools. This prevents confusion between used and adjusted tools, which could potentially lead to catastrophic consequences. An example of the organisation of the tools in the production line is shown in the image below.

Figure 5.1.10.1 - Worn cutting tools (on the left) , pre-set cutting tools (on the right)

In order to save time and to minimise the downtime of the means of production, the cutting tools were preset in a specialised department for this purpose (tool management centre - TMC). The tools were sharpened and preset on special stands, in order to meet the specifications. The tools were then deposited in the production line near the means of production. Once the tools were worn, they were taken by the TMC and the cycle was repeated.

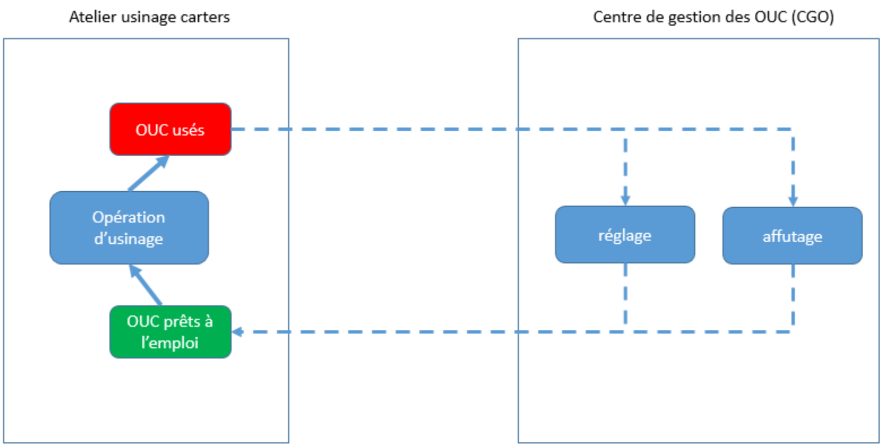


Figure 5.1.10.2 – cutting tool's pre-setting cycle

The tools were changed at a given frequency which was defined according to the machining material, the material being machined and the cutting conditions. However, it sometimes happened that tools had to be changed outside this frequency.

There were several causes for off-frequency tool changes:

- Equipment problems - locatings used for positioning the workpiece, bad clamping of the workpiece.
- Mechanical problems - slack belt, incorrect clamping
- **Poor presetting - wrong cutting tool length, wrong insert positioning**
- **Incorrect sharpening - cutting angles not respected, insufficient sharpening**
- **cutting tool transport - broken inserts during transport**
- **Blank problems - poor microstructure/hardness, poorly positioned holes**
- **Wrong cutting tool - wrong inserts fitted, different reference**
- Coolant problems - misaligned nozzles, clogged hoses, coolant breakage
- Program changes - wrong machining speeds (Va, Vc)
- **Power interruptions -cutting tool stops in the material while machining**

A significant proportion of the out-of-frequency changes were caused by factors outside the production line. The causes in the list above that were highlighted in bold were not production line related. Most of the rest could be classified in other categories, such as reliability of means of production and maintenance-related issues. It was in these categories that the root cause of these problems should be sought.

Whether it was TC in frequency or TC out of frequency, the number of changes and the losses that TC causes are very high. TC's account for 23% of OEE losses. For this reason, an optimisation of the tool changes was carried out. The SMED method was used for this.

5.2.1 SMED OP110

The Operation OP110 that has been chosen to be optimised by SMED for two main reasons:

- The tool change on OP110 was the most frequent in the production line. Even if a change does not last long, the high frequency of changes increases the number of manipulations and movements.
- Secondly, the honing process was the most complex of all operations on the line. The basis for mastering the running-in process was the clean mounting of the cutting tools. As tool changes occur frequently, it was not only important to mount the tool quickly but also to mount it correctly. A badly mounted tool can degrade the dimensional and surface quality of the cylinder. Also, an incorrectly mounted tool could block the machine or even damage the equipment.

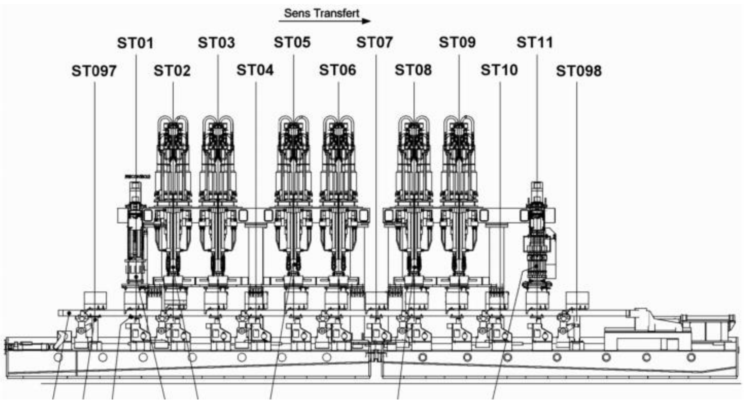


Figure 5.2.1.1 – OP110 – the honing machine

a) b) c)

Figure 5.2.1.2 - honing equipment of OP110 : a)honing tool, b)honing stones, c) honed surfaces

A honing tool works by a combination of two movements - rotational and translational. This is material removal by abrasion. The abrasion process is carried out by the presence of stones. These expand and press against the cylinder liner once the honing tool is inside the liner.

The stones, being in contact with the machined material, wear out faster than a honing tool itself. They can then be changed if the wear is too high without the need to change the whole honing tool. In the case of the OP, the change of tools is divided into 2 categories:

- Change of honing tool,

- Change of honing stones.

Preparation

In the preparation phase, the PO was filmed during the TC. In total 4 videos were taken. The whole changeover process had to be recorded. Already in the preparation phase when the PO was looking for the personal protective equipment’s (PPE's), the new tools, the dismantling tools including all the movements he makes.

Figure 5.2.1.3 - a sequence of a video from the TC in OP110

Data on the duration and frequency of TC should also be collected. Thanks to the AMPERE tool, which was filled in directly by the PO, the processing of this type of data was easier to handle and analyse. As the data on machine stoppages are acquired automatically by the SAPIA system, their duration and frequency are factual. Only the labels are filled in by the POs.

Once, the mean of production was stopped due to tool change, the exact duration was brought up in the touch screen and then characterized by the PO.

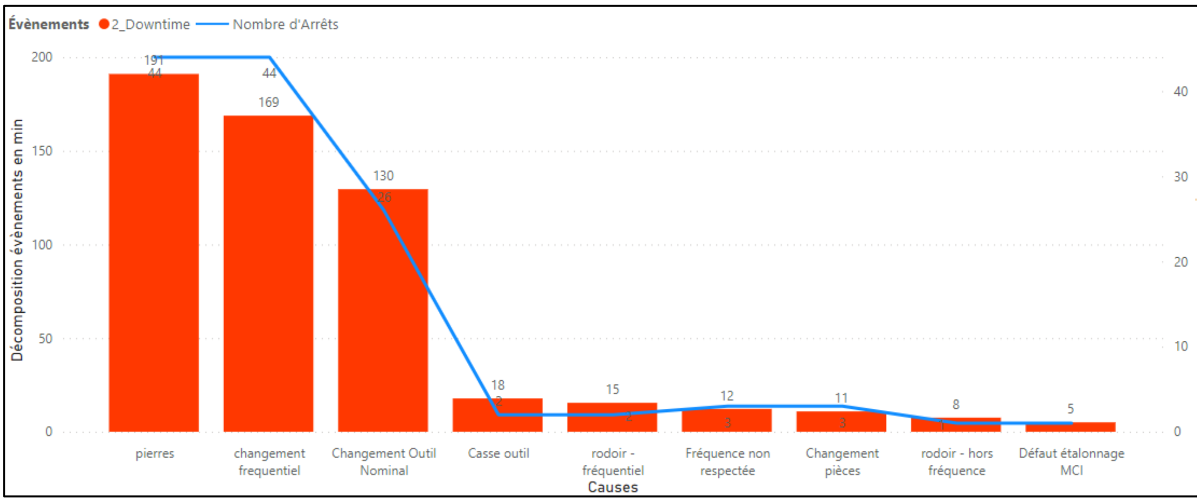


Figure 5.2.1.4 Tool change statistics on OP110

In the Figure above, the statistics of the tool changes are shown over a period of one week. The OC was divided into several categories according to what the POs were reporting via touch screens. On the curve there is the number of occurrences for each category and in the bars there is the total duration in minutes. To obtain the average duration of the change, the total duration and the number of occurrences were divided. Thus, the following data were obtained:

- TC time of stones: 191/44 = 4,34 min
- TC duration of the rods: 23/3 = 7,7 min

Optimisation

SMED is a participatory method. The aim is that everyone who is involved in changing the tools at this OP participates. The more people participate, the more ideas are brought up. The aim is also to exchange good practices during the TC. Everyone has TC routines that are a little bit different. By exchanging, the best practice can be chosen which will lead to the creation of new TC norms.

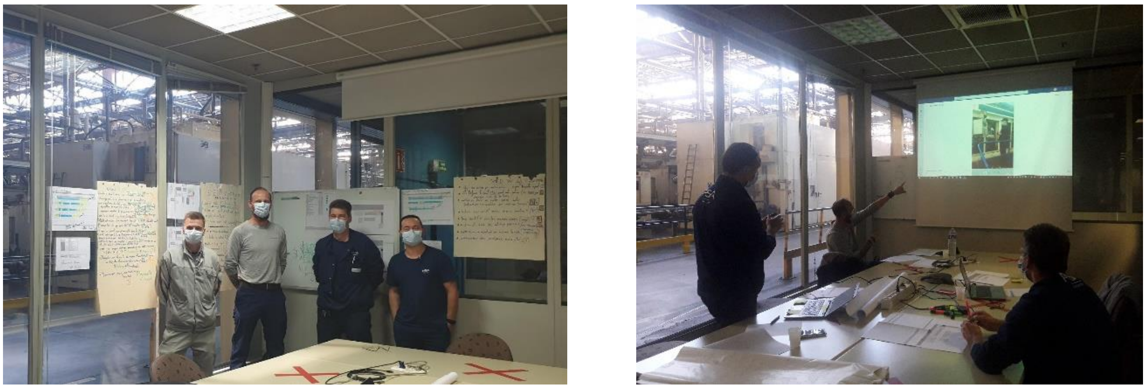


Figure 5.2.1.5 – SMED project with participants

The optimization of TC by SMED was done in 4 phases. This is visualised below. The descriptions of each of the steps are explained at the bottom of the picture.

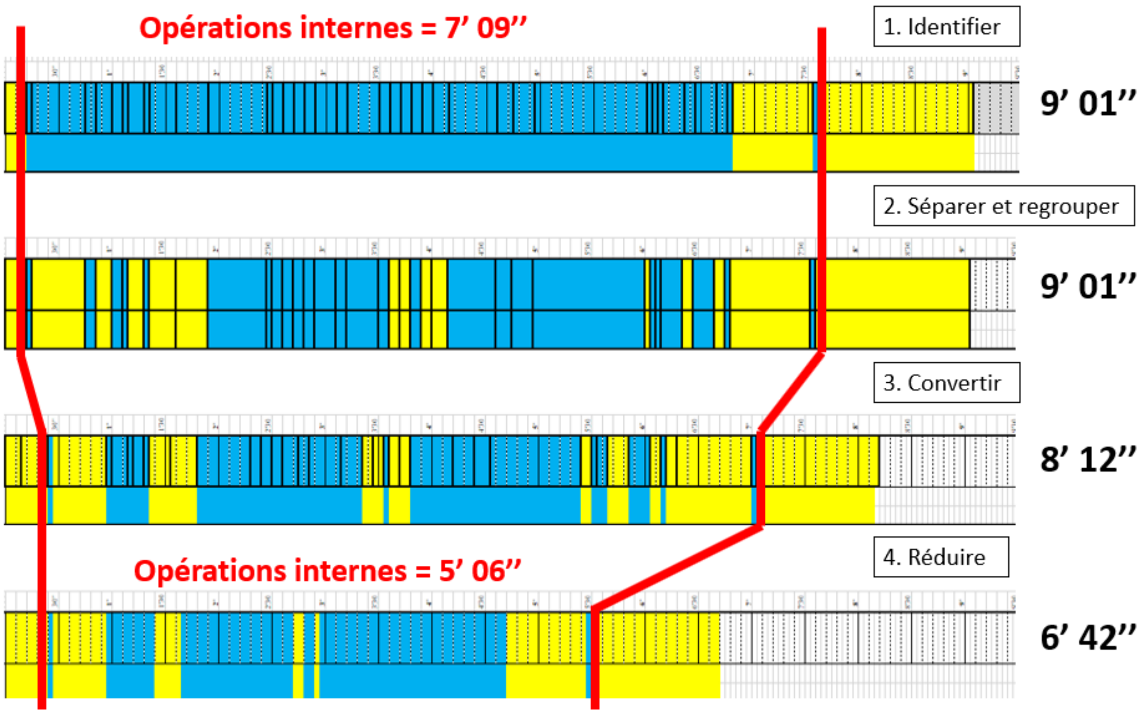


Figure 5.2.1.6 - SMED optimization

1. Identify

In parallel with the viewing of the video, the TC was deconstructed and gradually broken down into several phases. The video was broken down into as many phases as possible. Having a large number of phases allows for a high degree of flexibility in the optimisation as each phase can be moved or converted. In the case of the TC optimization of the honing tool, a total of 41 different phases were identified.

Each of them was recorded on the operation graph. They were then distinguished by colour:

- In blue, internal operations = the mean of production is stopped.
- In yellow, the external operations = the mean of production is running.

The TC initially lasted a total of 9 minutes and 1 second, of which the time during which the means of production was stopped lasted 7 minutes and 9 seconds.

The time during which the mean of production was stopped was calculated from the moment when the machine stops for the first time until the moment when it starts producing parts again.

2. Separating and grouping

The second step of SMED optimisation is to identify which of the phases can theoretically be done when the means of production is running and which cannot be done unless the means is stopped. The colours remain the same - yellow for an external operation (which does not require the means of production to be stopped) and blue for an internal operation (which requires the means of production to be stopped).

3. Convert

In the conversion stage, as many of the internal phases as possible are converted to external phases. At the same time, the external phases are grouped together and moved to the very beginning or the very end of the TC if the situation allows. Operations observed in the video, which were not necessary for a TC, are excluded.

4. Convert

As for the reduction, the time of the different phases is reduced by implementing improvements (in the means of production, tooling, programme modifications, etc.).

At this stage, the TC time is equal to 6 minutes and 42 seconds, of which the time of the mean of production is 5 minutes and 6 seconds.

This represents a gain of 29% on the time that the means of production is at a stop. The full CO optimisation is 25%.

Elimination of displacements

In addition to the savings in TC time, a significant number of trips had been eliminated thanks to the proposed modifications.

Before the optimisation, the TC consisted of 29 moves with many moves between the main control desk, the station desk, the table...

Just by adding modifications, reorganising the location of new tools and PPE, implementing improvements and modifications to the programme, the number of moves could be reduced to 6, provided that the list of actions from the project is completed.

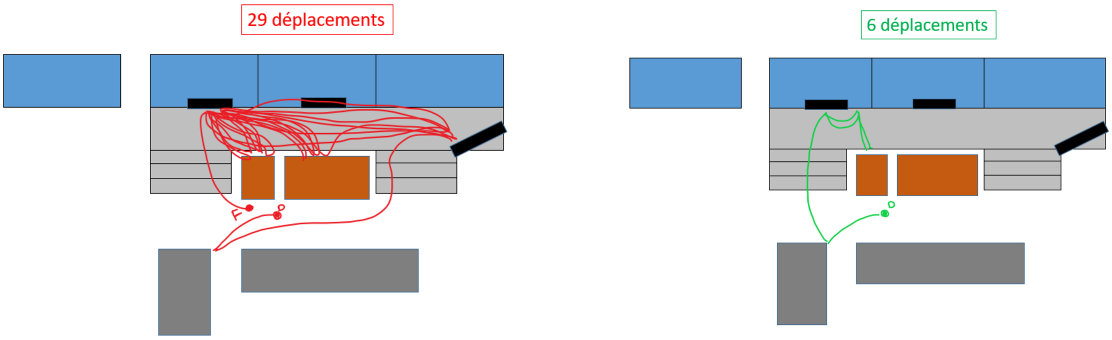


Figure 5.2.1.7 Optimization of movements during TC at OP110 reduced from 29 to 6.

- Before the optimisation, the operator had to move an average of 53m per TC.
- After the optimisation, the operator only has to move 9m per TC.

The action planning process

An action plan summarising the improvements that were selected during the project was put in place. The project is then monitored by the project manager who communicates with the managers of each action and enquires about the progress of each action.

The creation of standards

Once all the actions have been completed and improvements implemented. The next step is to create the TC standards. The standards are the result of the project where a member of each team participated. The standards contain the selected changes and improvements listed in the action planning.

Training of POs

Each PO whose work affects the relevant operation is trained according to the new standards. The PO is aware of every TC change that has been retained during SMED optimisation.

Follow-up of the project

The indicators are chosen to be able to monitor TC following by PDCA where some modifications cad be done.

5.2.2 SMED OP70

The second means of production where tool change was optimised was the OP70 machining transfer. Specifically, the optimisation was targeted at a single problematic station - st.21.

After an observation of the CO's in the production line, the tool change on OP70 st.21 turned out to be the most time consuming in the whole production line.

Firstly, a TC on OP70 st.21 took an average of 40 minutes knowing that there were 3 TC's per day. This made a daily changeover time of 120 minutes. The losses on the OEE were then significant. With the nominal cycle time of 0.40 minutes the production losses reached 300 parts/day.

Secondly, the TC time deviated considerably from the standards that were created during the last optimisation. The internal operations of the TC should have taken only 10 minutes.

a) b) c) d)

Figure 5.2.2.1 TC on OP70 st.21 .

a) location of face milling cutters: worn milling cutter (left) and new set milling cutter (right), b) milling cutter grip on the hoist, c) milling cutter transfer between table and machine, d) attachment (HSK) of milling cutter to the spindle

A more detailed TC analysis was done by observation and timing of the process. The TC time can be broken down as follows:

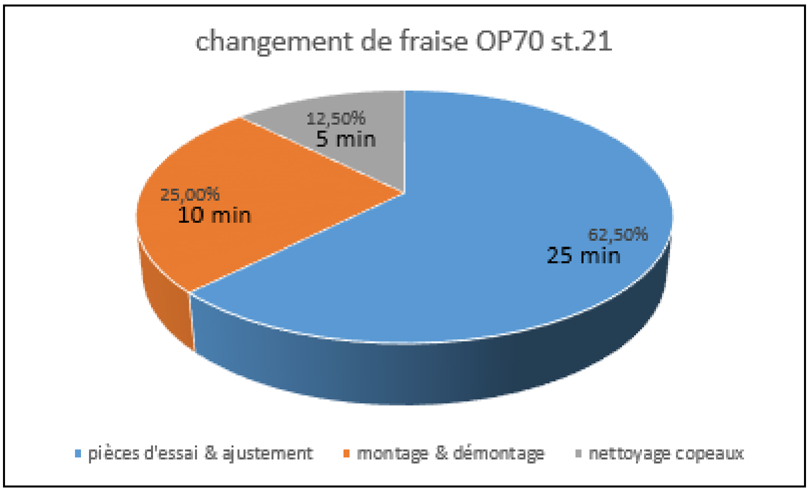


Figure 5.2.2.2 Various phases during the TC at OP70 st.21

The change of face milling cutter concerned st.21, i.e. the second unit of the transfer from the beginning in the direction of flow. Knowing that the transfer had a total of 25 units. When the PO changed the milling cutter, he had to make sure that the inserts were properly adjusted so that the tool produced parts correctly. At the time of the creation of the standards, the correct setting of the cutter was guaranteed by the TMC department (cutting tool management centre). However, today it was the role of the manufacturers to validate the correct setting of the tool. This was done by checking the dimension (height of the cylinder block) (Figure 54) after the first part was machined by the new tool. As the TC was concerned with the 2nd station of the 25-station transfer, the PO was constrained to take the part out through the rest of the mean of production. This then takes the time equivalent to passing through 23 stations (25 - 2). It was impossible to take the part out directly from the station concerned. As the tool setting was not yet validated, the correct dimensions of the parts were not guaranteed either. After producing a part with the milling cutter that had just been changed, the PO put the machine into emptying mode to avoid the production of potentially non-conforming parts. The PO waited for the part to go through the entire transfer and then took it out of the last transfer station. The part was then picked up and moved to the marble bench where the height of the housing was accurately measured. Once the manufacturer confirmed the correct dimensions of the part, he could validate the correct tool setting and start production. As the transfer was emptied, it must be refilled again. This means that 25 stations that were empty must be filled. The emptying and refilling of the transfer alone meant that 48 parts were lost.

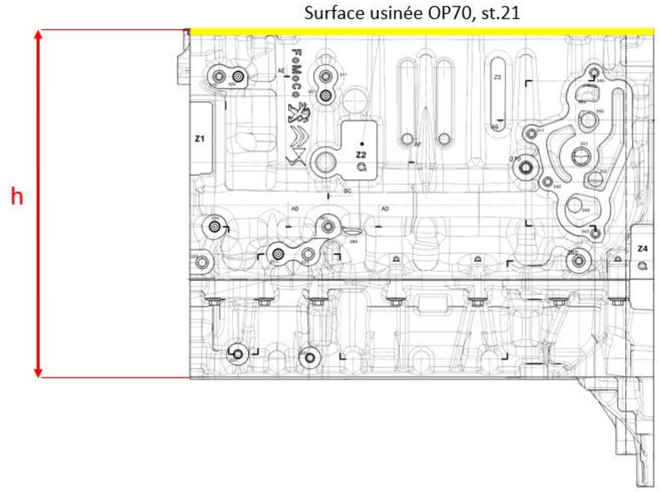


Figure 5.2.2.3 The height that has to be controlled after TC

In addition to this, the PO was forced to make a large number of trips between the station, the main desk and the measuring bench. This further increased the production losses due to the test parts after the TC.

Optimisation objective

The aim of optimising this TC was, first of all, to reduce the "test parts & adjustment" part. Instead of taking the part out of the mean of production, it could be measured directly in the mean of production without having to take it out of the transfer.

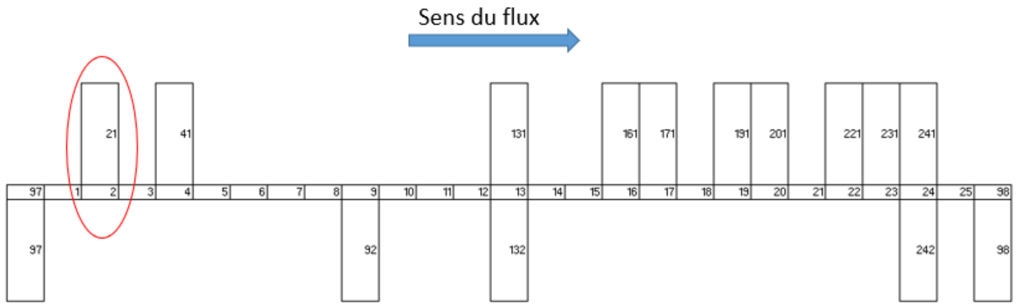
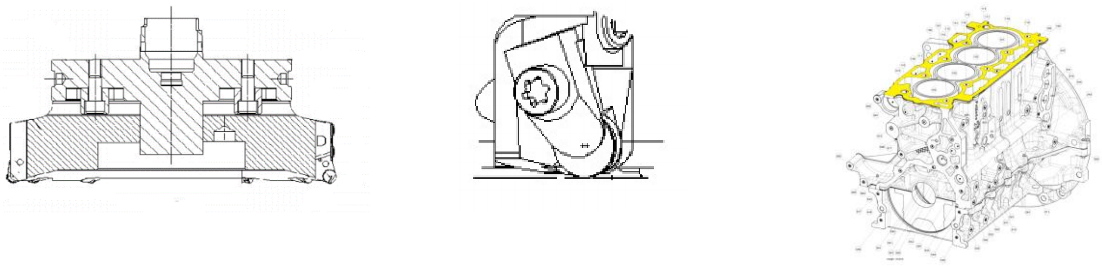


Figure 5.2.2.4 OP70 transfer scheme



a) b) c)

Figure 5.2.2.5 the cutting tools of the OP70 st.21.

a) the face mill, b) a CBN milling insert, c) surfaces machined by this OP.

Process improvement - part measurement directly in the mean of production

The idea was to validate the correct setting of the cutter without the need to remove the part from the mean of production. Even if the height could not be measured directly because of the machine footprint, the correct dimensions could be validated indirectly by using another reference.

The reference used was the centring pin bore which was machined on the OP10 and then validated by the frequency metrology control.

The aim was to measure the distance between the chamfer and the surface of the cylinder head plane (the one machined with st.21 OP70). A reference would be taken just before the milling cutter change with the help of a comparator. After the workpiece with st.21 and its surface had been machined by the new cutter, the same dimension was measured again using the dial indicator. With defined tolerance zones, the PO has the ability to tell if the thickness that has just been removed by face milling corresponds to a properly set milling cutter.

Figure 5.2.2.6 The reference bore,

position of the bore on the cylinder head plane (on the left), the stepped reamer machining the reference hole at OP10 (on the right)

The dial gauge had a half-spherical touch whose diameter has been calculated according to the chamfer angle and hole diameter.

Figure 5.2.2.7 measurement of dimensions by the dial gauge with the special probe,

the dial indicator assembled with the holder (on the left), the spring and the half-spherical probe, the dial indicator mounted on the reference bore (on the right)

Such a modification could in theory considerably reduce or even eliminate the "test parts and adjustment" phase in the TC.

The total time of the TC could then be reduced from 40 min per TC to only 15 minutes by eliminating the emptying, filling of the transfer, and all handling and moving of the part out of the transfer. This time would be replaced by production.

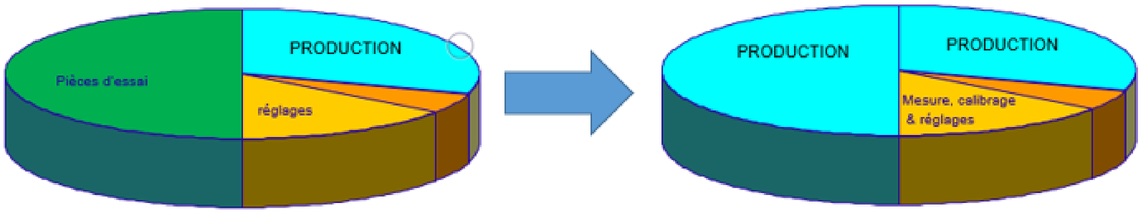


Figure 5.2.2.8

The implementation of a dial gauge measurement would bring a (theoretical) gain of 25 minutes per TC. As there were 3 TC's per day, the overall daily gain would correspond to 75 min. 75 minutes of production is the equivalent of 187 cylinder blocks / day.

5.3 CYCLE TIME

As cycle time was the second most serious cause of no-OEE, it must also be analysed. This took place during TCY meetings. The cycle times of each machine were measured regularly and based on the TCY of the whole production line, the action plan was defined.

The machine with the slowest cycle time in the production line should be identified. This machine sets the tempo for the whole line because the machines are connected in series. The slowest machine then sets the rhythm for the whole line.

The TCY of the slowest machine was equal to the actual TCY of the line. By comparing it with the nominal TCY, it was possible to evaluate the losses caused by the leading machine.

The driving machine was the one with the largest difference between the measured TCY and the target TCY. It was determined as the one with the largest TCY overshoot of the target.

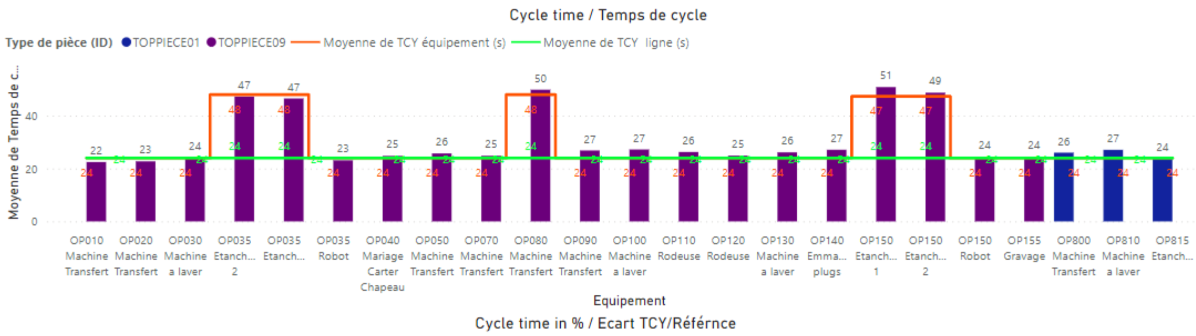


Figure 5.2.2.1 measurement of cycle times for the entire production line

6 OVERALL RESULTS

The work presented in this thesis and the optimisation actions described in it have impacted productivity as well as the character of the causes of the losses.

The following figure compares the no-OEE decomposition that was taken as a reference in February 2021 and the no-OEE decomposition made in July 2021 after the implementation of changes. Both benchmarks were determined as the average over several months in order to obtain statistically reliable data. For each case, the no-OEE decomposition includes 4 categories of losses that were most present at the time.

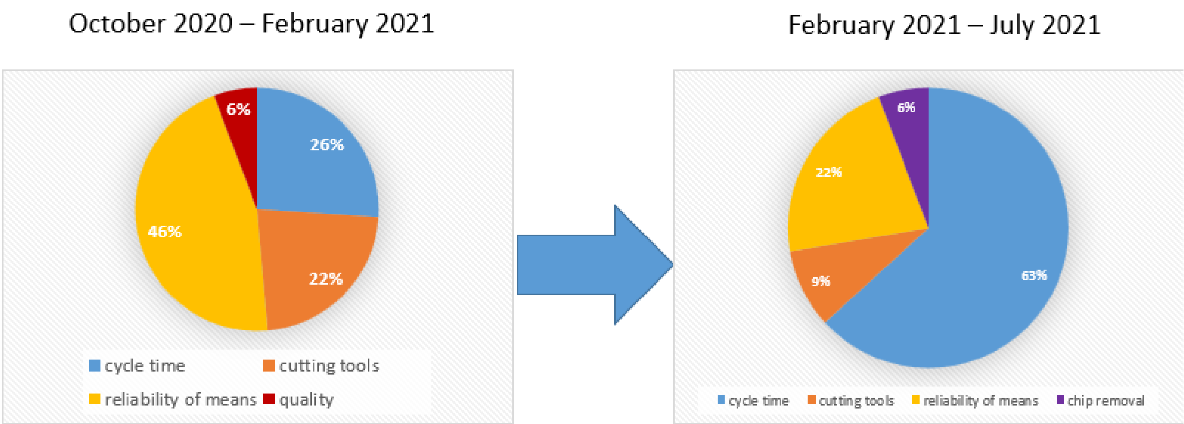


Figure 66.1 - Decompsition of no-OEE before and after internship in comparison.

An evolution between both benchmarks is clearly visible. The categories that appear in the analysis of the no-OEE are almost the same in both cases. Table 12 summarises the evolution of the different categories of the no-OEE in these two periods.

Table 6.1 - The analysis of no-OEE [in %]

	February 2021	July 2021	Changes: decrease or increase
Cycle time	26	63	-142
Reliability of means	45	22	51
Cutting tools	23	9	61
Quality	6	N/A	N/A
Chip removal	N/A	6	N/A
			All values in %

There is a high rate of change for all categories except quality and chip removal where comparable data was not available. The reliability of the means has been improved by more than 50% during the period between May 2021 and July 2021 compared to the baseline data.

The TPM principle of eradicating small recurring breakdowns and thus preventing the occurrence of larger breakdowns has proven to be successful.

The changeover of cutting tools has been improved by more than 60% during the same period. The work around cutting tools was systematic and covered several topics. Two concrete examples are explained further in this thesis as they were the most important improvements.

In the area of cycle time, the cycle time deteriorated by 1.5 times its initial value. The cycle time is now responsible for more than 63% of the losses on the production line. This work only marginally touched on Cycle Time because of the great complexity of the subject. Nevertheless, there were actions carried out on the TCY issue throughout the period between February and July 2021 by the maintenance teams.

It must be noted that the fourth non-OEE category is different for the two periods mentioned above. In the first period (between October 2020 and February 2021) there was quality added as a fourth of major losses. For the second period (between May 2021 and July 2021), chip cleaning losses represented the fourth non-OEE category. The non-OEE loss of quality is closely linked to the reliability of the means, the reliability of the equipment and the domain of cutting tools.

The evolution of the OEE

The evolution of production, whether it is over days, weeks or months, is very fluctuating and dynamic. This is because productivity is a parameter that depends on many factors. In addition to all the families of losses that influence productivity, it also depends on a lot of other factors such as electricity blackouts, cutting fluids, supply, lack of stocks, number of employees, presence of operators, motivation of operators, start-ups of the production line after a shutdowns, changeovers and other.

The evolution of the OEE during the period August 2020 - July 2021 is visualised in Figure Below. The period from October 2020 to December 2020, which corresponds to the calculation of the baseline OEE, is shown in red. The period marked in green represents the last 3 months of the internship at Stellantis (May - July 2021).

The OEE in DV machining production is measured per production crew or per shift. Based on this, the daily, weekly and monthly OEE can be calculated.

In order to offer an overview of results, the monthly OEEs are visualised on the following graph.

The average OEE for the first reference period was 80.78%. This was the average of the monthly OEEs for this period. The average OEE for the period May - July 2021 was 81.46%. This was also calculated as the average of the monthly OEEs during the same period.

This difference between these two benchmarks corresponds to a gain of 0.68% which means an increase in production of 20 pieces per day. The price of a cylinder block being 95€, the increase means a gain of 1900€ per day.

$$0{,}68\%\ OEE = 2990\ parts * 0{,}0068 = 20\ parts$$

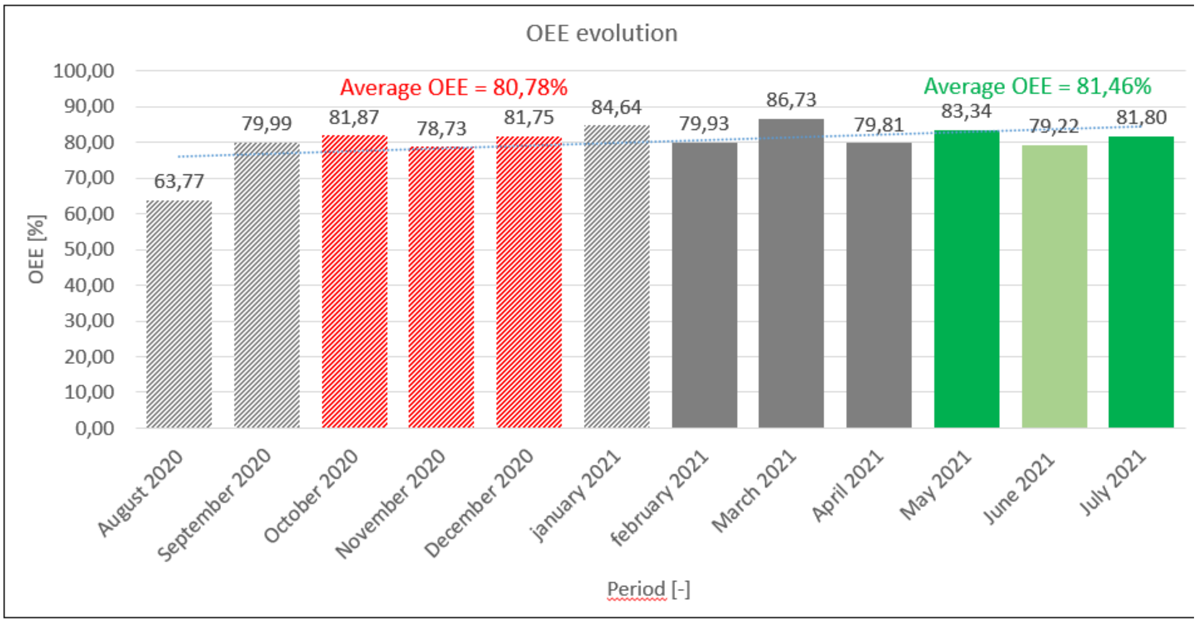


Figure 6.2 - the monthly OEE over the period: August 2020 - July 2021

Despite the increase in OEE and an increasing trend, production over the period January 2021 to July 2021 was affected by major events that negatively impacted productivity. The months of April and June were particularly affected:

- April was affected by a high rate of absenteeism caused by the covid-19 pandemic in France.
- The productivity of June was influenced by a shortage of components in the automotive industry. Terminal assembly plants were experiencing a shortage of computer chips. They could therefore not produce cars. As all factories in Stellantis work in pull flow mode, this crisis stopped the production also in engine factories. The production line was at a standstill for half of every week in June 2021. Production was running at nominal for 3-4 days of the week. The OEE is not calculated on the days that the factory is not producing, nevertheless these long stoppages had an indirect impact on the performance of the production line. This was caused by the following reasons among others: the changeover of production line was more frequent and disruption of machining transfers. To make a changeover, it was first of all

necessary to empty all the buffers and transfer machines. The emptying of the buffers took a lot of time and once emptied, the line stops were not easily absorbed. Each stop had a big impact on productivity. Secondly, the machining transfers have been designed to work continuously. Each stop and emptying of the machine therefore disrupted nominal performance.

Beyond April and June, the automotive industry continued to be affected by the tendency to transition from fossil fuels to alternative energy sources to reduce CO_2 emissions. Although diesel engines still have a significant share of the automotive market, the demand for diesel cars is decreasing more and more each year.

All these factors combined have impacted productivity.

CONCLUSIONS

In this thesis, a complex study of productivity of a machining production line was elaborated. The aim being to optimize the production of the line, the most significant and penalising root causes have been revealed. Solutions were applied in order to optimize the production while spending a reasonable effort and cost.

Productivity was measured in Overall equipment effectiveness (OEE). By its definition, OEE never reaches its maximum potential because in the context of real-life conditions, there are always some factors that disrupt it and cause production losses. Improvements in OEE were made nevertheless.

Firstly, the losses in production were analysed. Secondly, solutions were proposed and applied. Among the methods applied to optimize production, lean manufacturing tools were further deployed. Finally, the impact of the actions carried out on productivity was assessed.

The impact of the actions taken was measured on two main indicators:

- OEE of the production line,
- types of losses.

The first indicator was the overall equipment effectiveness of the production line. The OEE evolved during this project from 80.78% to 81.46% with an increasing long-term trend. This increase is the result of the optimisation described in this thesis. The increase in productivity was 0.68%. This increase in production means a gain of 20 pieces per day which results in a gain of 1900€ per day.

The second indicator was the breakdown of the types of losses. By breaking down the reasons for losses that negatively impacted production, it was possible to conclude that the nature of losses had changed over the project period. The impact of these losses (divided into categories) on productivity has decreased thanks to the implemented changes. Especially the impacts of equipment reliability of the means of production and cutting tools losses were significantly decreased.

The evolution of the two main indicators proved the relevance of the actions carried out on these categories of losses as well as on the overall productivity. Results showed that TPM and SMED were very relevant tools in today's industry and their proper deployment had a very important impact on productivity.

DISCUSSION

Even with very satisfactory results over such a short period of time in a production line that had already been optimized several times, the results are only partial. In reality, improvement of productivity is a complex process that takes place over the long term. Many of the actions were started in the period between February 2021 and July 2021, but at the progress of these actions continued even after the end of the internship. It is therefore more than likely that the gain from these actions will increase further in the. In the months following the end of the internship.

In particular, the production line digitalisation project had great potential to be implemented after the end of the internship, once everyone was fully familiar with. By continuing to deploy the right forms of management, the project has potential to bring further significant results.

The gains from SMED part of the project were only theoretical and partial at the end of the internship. Once all actions are completed, the OEE should increase even more.

The benefit and the main merit of the work stems in the successful implementation of the control tools. That would continue to act in the production optimization, as well as the training of the staff to learn how to use these tools. This should result in further increase of the productivity and efficiency of the DV cylinder block production line in future.

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PAGE OF SYMBOLS AND ABBREVIATIONS

Abbreviation	Unit	Description
OEE	- or %	overall equipment effectiveness
OPR	-	operational ratio
ST	h	shift length
PPT	h	planned production time
TCY	s	takt time
PDCA	-	plan, do, check, act
TPM	-	total productive maintenance
PO	-	plant operator
TCY	-	cycle time
FM	-	flow manager
GM	-	group manager
UM	-	unit manager
EPU	-	effective production unit
PSPS	-	production system pilot specialis
PMP		planned preventive maintenance
OPM		operational productivity meeting
AMPERE		Acceleration Management PERformance Equipment
TC		Tool Change
PPE		Personal Protective Equipment
OP		Operations
GQS		General Quality Station

LIST OF APPENDICES

1) A non-exhaustive list of deployment of the DV5R and DV6 engine on today’s cars.

APENDICES:

1) APPENDICE 1 - A non-exhaustive list of deployment of the DV5R and DV6 engine on today's cars.

Brand	model	DV5R (€6)	DV6 (€5)
DS AUTOMOBILES	DS3	✓	
	DS7	✓	
CITROËN	C3	✓	✓
	C3 aircross	✓	✓
	C4		✓
	C4 Cactus	✓	
	C4 Picasso	✓	
	C- Elysée	✓	✓
	Jumpy	✓	✓
	SpaceTourer	✓	
PEUGEOT	208	✓	✓
	301	✓	✓
	308	✓	✓
	408		✓
	508	✓	
	2008	✓	
	3008	✓	
	5008	✓	
	Expert	✓	✓
	Traveller	✓	
	Partner	✓	✓
OPEL / VAUXHALL	Corsa	✓	
	ZafiraLife	✓	
	Adam	✓	
	Combo	✓	✓
	Crossland X	✓	✓
	Grandland X	✓	
	Vivaro	✓	
	Traveler	✓	
TOYOTA	Proace	✓	
	Proace Verso	✓	
	K9	✓	