TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Mechanical Engineering

Design of universal tool for rear axle adjustment

Master Thesis

Studyprogramme: N2301 Mechanical Engineering

Studybranch: Manufacturing Systems and Processes

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Master Thesis Assignment Form

Design of universal tool for rear axle adjustment

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Study programme: N2301 Mechanical Engineering

Study branch: Manufacturing Systems and Processes

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1.1.1 Rules for Elaboration:

The main aim of this thesis is the design of a universal tool for adjusting the rear axle, which will serve as a basis for production.

1. Research in the field of development and use of available materials and new knowledge in the field of ergonomics.
2. Detailed analysis of the current state of axle and tool design at ŠKODA AUTO.
3. Design of tool design variants.
4. Structural designs of solutions connected with strength analysis.
5. The use of theoretical knowledge in practice.

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Rozsah pracovní zprávy:	60 pages
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[1] BUDYNAS, R. G. and J. K. NISBETT. Shigley's Mechanical Engineering Design (in SI Units). 10th ed. Asia: McGraw-Hill, 2015, 1104 p. ISBN 978-981-4595-28-5.
[2] Corporate standards of Škoda Auto.
[3] CHAFFIN, Don B. a C. NELSON. *Digital human modeling for vehicle and workplace design*. Warrendale: Society of Automotive Engineers, 2001. ISBN 0-7680-0687-2.

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ABSTRACT

The work presented in this thesis is the design of universal tool for adjusting the nut in the rear axle of the cars in the assembly line of Skoda Auto. The main aim of this thesis is to design a universal tool for adjusting a nut in the rear axle which attaches the brake carrier and the suspension carrier with the rear axle through the control arm. The current working conditions are analysed and the new universal tool is designed in such way that it is suitable for all the models of the cars, this is done by combining the design of the existing tools. The final result is presented in the form of CAD model as per the requirements of the company.

KEYWORDS

Universal tool, Rear axle, Torque wrench.

ABSTRAKT

Práce prezentovaná v této práci je návrhem univerzálního nástroje pro seřizování matice v zadní nápravě automobilů na montážní lince Škoda Auto. Hlavním cílem této práce je navrhnout univerzální nástroj pro seřizování matice v zadní nápravě, která spojuje brzdový nosič a nosník zavěšení se zadní nápravou přes ovládací rameno. Současné pracovní podmínky jsou analyzovány a nový univerzální nástroj je navržen tak, aby byl vhodný pro všechny modely automobilů, a to kombinací designu stávajících nástrojů. Konečný výsledek je prezentován ve formě CAD modelu dle požadavků společnosti.

KLÍČOVÁ SLOVA

Univerzální nástroj, Zadní náprava, Momentový klíč.

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1. INTRODUCTION

The Automotive assembly line is one of the advanced and high demanding workstations in the manufacturing industry. Any production process in an industry aims at the maximum efficiency with a minimal wastage, automotive assembly line is no exception to that. Automotive assembly lines have evolved to a greater extent from the past to where we are now and continue to evolve to increase the output and the efficiency. Continuous researches and efforts go into the assembly lines to improve the processes and frequent changes occur to provide room for the improvements. Automotive manufacturers have constantly adapted to the newer technologies and methodologies such as Lean Manufacturing, Automation, etc., to improve the process and achieve greater efficiency in the assembly line. Apart from the technologies and methodologies the other major contributor for better efficiency is the workers and the workstation itself. A well designed workstation increases the efficiency of the process and reduces the wastes and the risk of injuries, which increases the overall efficiency. The factor which influences this efficiency is the Ergonomics of the workplaces. Ergonomics deals with layout of the workstation, position of the job, working posture, flow of the job, placement of tools and equipments etc. And thus the workstations are frequently analysed for its ergonomics and necessary changes are made to improve the layout and other above mentioned factors related to the workstation.

The main aim of this thesis is to design a universal tool for adjusting a nut in the rear axle of the cars in Skoda Auto plant’s assembly line. The new universal tool should be designed in such way that it is suitable for all the models of the cars, this is done by combining the design of the existing tools. The new design is also done to optimise the ergonomics of the tool to make easy the tightening operation for the worker. This new design also reduces the space occupied by the existing tools on both the left and right side.

This thesis work includes the following steps.

- Analysing about the current approach and the existing tools.
- Designing new universal tool.
- Analysing the newly designed universal tool.

2. WORKPLACE ERGONOMICS

Workplace ergonomics is a branch of science which deals with the designing of the workplace, considering the capabilities and limitations of the worker. Poor workplace design can lead to fatigue among the employees; it can also cause frustration and might cause harmful injuries to the workers. Poor workplace design might lead to reduction in the rate of productive workers resulting in lower productivity and poor product quality.[5][6]

Improving the ergonomics of the workplace eliminates the risk factors that leads to musculoskeletal injuries and allows for improved human performance and productivity. By making improvements to the work process, we are removing barriers to maximise the safe work performance by doing which we can provide the workers with a job that is within their body's capabilities and limitations.[7]

An ergonomics improvement process if done correctly can become a key factor to the company's competitiveness in the marketplace and provide a better work experience for the employees.[8]

2.1 RISK FACTORS IN WORKPLACE

Injuries to the workers can be a major risk factor at the workplace. When said workplace injuries everyone thinks of falling objects, cut or broken body part, heavy machinery, etc. However for shop floors like automobile assembly line Repetitive Motion Disorders (RMDs) are the most common injuries for the workers. Repetitive Motion Disorders are a type of Musculoskeletal Disorders (MSD) which occurs due to the repeated set of motions performed by the worker during his course of work.[8]

The major factors contributing to RMDs are:

- High Task Repetition
- Forceful Exertions
- Awkward Postures

2.1.1 HIGH TASK REPETITION

In an automotive assembly line most of the works are repetitive in nature. A work is identified as highly repetitive if its cycle time is less than or equal to 30 seconds. Such high repetitive tasks can result in MSD for the workers.

2.1.2 FORCEFUL EXERTION

In certain tasks high loads of force might be exerted on the human body, which increases the muscle efforts, increasing the fatigue of those muscle groups leading to MSD.

2.1.3 AWKWARD POSTURES

Awkward postures exert excessive unwanted force on the joints, which overloads the muscles around that joint. Joints in the body are efficient when they are worked nearest to the mid-range of its motion. Joints when operated outside the mid-range its motion repeatedly or for sustained time period without any proper recovery time poses high risk of MSD.

2.1.4 AFTERMATHS OF RMDs

The common RMDs occurring in automotive assembly line workers are Tendonitis, Arthritis, Trigger Finger, Carpal Tunnel Syndrome, which are identified by pain, swelling or redness of the affected muscle and the loss of strength and flexibility. Over a period of time, RMDs causes temporary or permanent damage to the muscles, nerves and ligaments. Employers must then deal with reduced worker productivity, increased sick leave, worker compensation claims and increased insurance premiums [3].

2.2 PRINCIPLES OF WORKPLACE ERGONOMICS

Ergonomic principles are the fundamental rules with which a workplace can be ergonomically designed. There are eight such basic rules which are as follows.[2]

2.2.1 MAINTAIN NEUTRAL POSTURE

In neutral postures while sitting or standing the body is aligned and balanced in such a way that only a minimal amount of stress is exerted on the body while performing an operation. In awkward postures the work area is moved towards the extremes of the range of motion, putting excessive stress on the worker’s muscles leading to MSDs, which must be avoided.

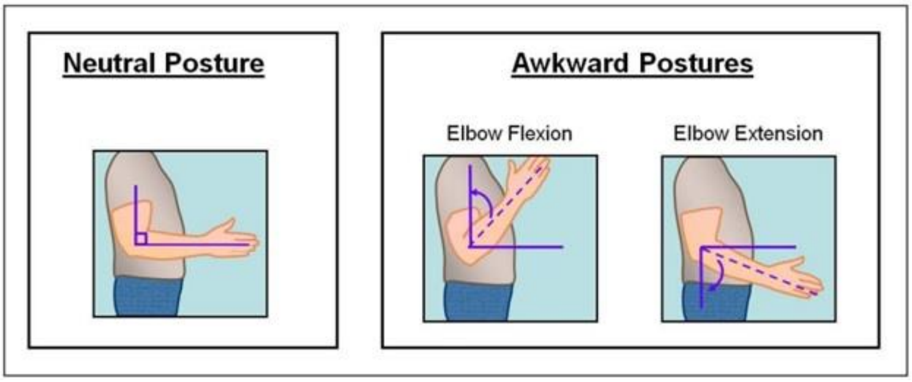

Figure 1: Neutral and Awkward Elbow position.[1]

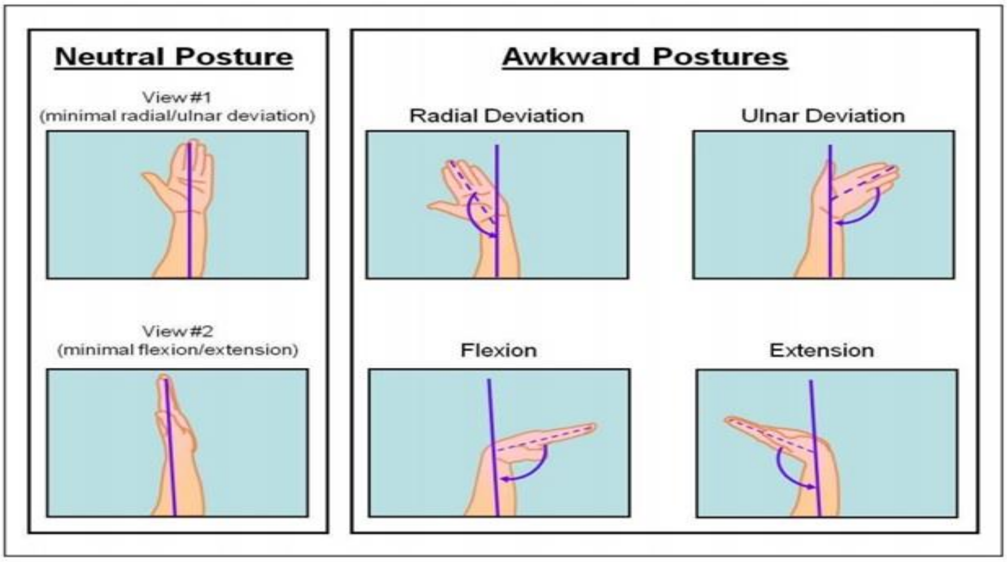

Figure 2: Neutral and Awkward Wrist position.[1]

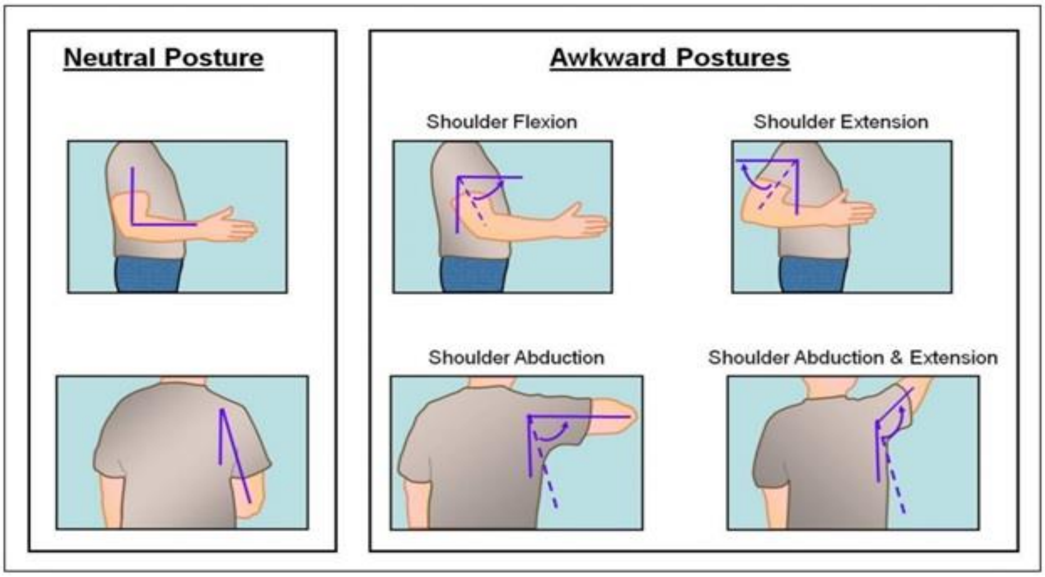

Figure 3: Neutral and Awkward Shoulder position.[1]

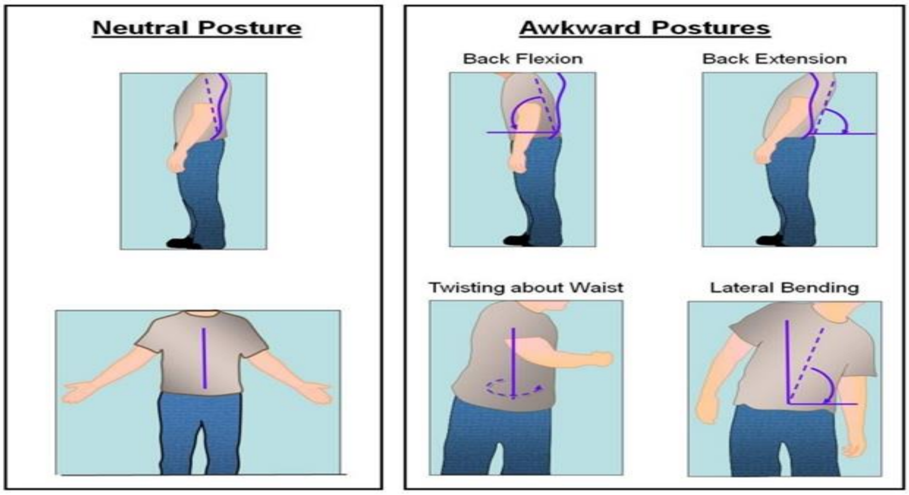

Figure 4: Neutral and Awkward Back position.[1]

2.2.2 WORK IN THE POWER ZONE

This principle is same as maintaining the neutral posture. For lifting objects the power zone is near the body, between mid-chest and mid-thigh height. In this zone the back and arms is able to left the maximum weight least amount of effort. This is also referred as comfort or handshake zone. The concept is that if we are able to handshake with our work we are minimising the excessive reach and maintaining the neutral posture. Working from this comfort zone ensures that we are working with proper reaches and heights, thus reducing the risk factor for the MSD and performing more efficient and pain free work.

Figure 5: Comfort/Power Zone[2]

2.2.3 MOVEMENT AND STRETCHING

The musculoskeletal system is the human body's movement system which is designed to move. Working in a static position for a longer period of time causes fatigue in the body, this fatigue is known as static load. Stretching will reduce these fatigues on the muscles and joints, it improves muscle's coordination, its posture and balance. Stretching improves performance and lowers the risk of injuries, it regulates blood circulation and restores energy.

2.2.4 REDUCE EXCESSIVE FORCE

Excessive force is one of the major ergonomic risk factor. In an automotive assembly line, many works demand high force from the worker for the task to be performed, which requires high muscle effort and thus increasing the fatigue and risk of MSD. The excessive force involved in a work task must be identified and reduced. Eliminating the excessive force will significantly reduce the fatigue and the MSD for the workers. The excessive force can be reduced using mechanical assists, counter balance systems, manipulators, adjustable height lift tables, powered equipment and ergonomic tools, thus reducing the fatigue.

2.2.5 REDUCE EXCESSIVE MOTIONS

Excessive motion is another one of the major ergonomic risk factors. In an automotive assembly line most of the works are repetitive in nature. A work is identified as highly repetitive if its cycle time is less than or equal to 30 seconds. Such high repetitive tasks can result in MSD for the workers. Excessive motion must be eliminated wherever possible, which can be done by performing Time, Motion and work Study. Periodic rotation of job and intermittent stretch breaks reduces the repetitive motion and reduces the fatigue.

2.2.6 MINIMIZE CONTACT STRESS

Contact stress are caused due to consistent contact or rubbing between hard or sharp articles/surfaces and delicate body tissue, for example, delicate tissue of the fingers, palms, thighs and feet. This contact makes restricted weight for a little region of the body, which can restrain blood, nerve function, or movement of ligaments and muscles. Few examples of contact pressures are laying wrists on the sharp edge of a work area or workstation while performing the work, squeezing of tool handles into the palms, particularly when they can't be put down, works that require hand hammering, and sitting without enough space for the knees. Contact stress can be minimized by using proper equipments like wearing gloves while handling sharp objects and having proper workspace setup.

2.2.7 REDUCE EXCESSIVE VIBRATION

Exposure to vibration over a long period of time like contact with vibrating tool or job can cause permanent adverse health effects such as Hand-Arm Vibration Syndrome (HAVS), white finger or Raynaud's syndrome, carpel tunnel syndrome and tendinitis. These syndromes can cause serious circulatory and neural effects in the hand causing numbness, pain and balancing.

2.2.8 PROVIDE ADEQUATE LIGHTING

Poor lighting can be one of the common issues in the workplace that hinders the worker's comfort level and performance. Too extreme lighting or too minimal lighting both makes work difficult. Dark work areas and glare can cause eye debility and headache, poor lighting in the workstation poses higher risk for all types of injuries for the workers. Hence the workstation and nature of work should be assessed properly and adequate lighting must be provided to avoid the risk of any injury.

2.3 BENEFITS OF WORKPLACE ERGONOMICS

2.3.1 COST REDUCTION

When the ergonomics risk factors in a workstation are eliminated, the injuries and musculoskeletal disorders for the workers can be prevented. This significantly reduces the worker's availing sick leave, it also reduces the compensation cost for the injuries and MSDs. The indirect cost may sum up to 20 times the direct cost of an injury.

2.3.2 IMPROVED PRODUCTIVITY

The efficiency increases with the more ergonomically designed workstation like better posture, less force requirement, minimized motions and better heights and reaches, thus improving the productivity of the workstation.

2.3.3 IMPROVED QUALITY

Poorly designed workplace can be physically challenging for the workers during, which causes body fatigues and frustrations thus reduces the productivity of the worker and poor performance leading to product quality issues. Whereas the workplace with better design and improved ergonomics can reverse this scenario.

2.3.4 IMPROVED EMPLOYEE MORALE

With a better ergonomics in the workplace, employees will not experience and fatigue or discomfort during the working hours, which significantly decreases the absenteeism, increases productivity and turnover, improves morale and increases employee involvement.

2.3.5 BETTER SAFETY CULTURE

The combined effect of all the above benefits of the ergonomics signifies a strong safety culture in the workplace. Practicing a better safety culture reduces accidents and injuries in the workplace which will lead to better overall performance of the organisation.[9]

2.4 ERGONOMICS ASSESSMENT

Automotive industry is one the leading industries that implement ergonomic mandate in their work stations. In an automotive manufacturing plant, there are many works that demand proper posture or equipment to handle parts in order to ensure safety. Few of such works are bending down and picking up, twisting, pushing and pulling, turning or bending wrists, hand vibrations, overhead works. These tasks need to be assessed for ergonomics and proper guidelines must be set for performing these tasks.

Applying a logical, proof based method to deal with the ergonomics procedure is significant. The objective is to distinguish ergonomic risk factors, evaluate it, and then make quantifiable upgrades to the working environment, guaranteeing that the tasks performed by the workers are under their limits and abilities. The best way for doing that is to make ergonomics a process of risk evaluation and reduction based on the analysis of the workplace.

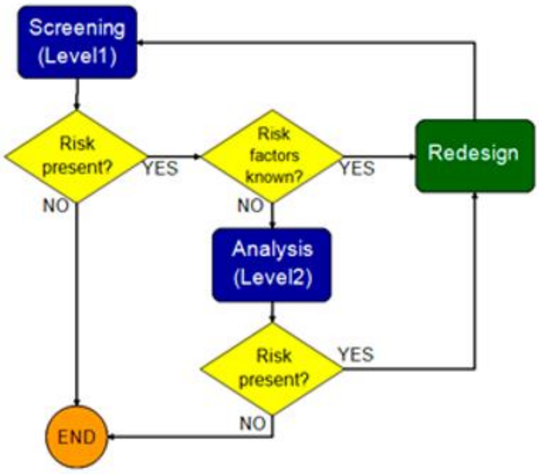

Figure 6: Risk Evaluation Structure[3]

The risk evaluation process can be performed using various ergonomic risk assessment tools like EAWS, OWAS, NIOSH Lifting Equation, REBA, RULA and Snook Tables.[3]

2.4.1 ERGONOMIC ASSESSMENT WORK-SHEET (EAWS)

EAWS is an **ergonomic tool for screening the risk due to biomechanical overload,** developed to provide an overall risk evaluation that includes every biomechanical risk to which an operator may be exposed during a working task. EAWS is used in first level risk screening for an overall risk evaluation, where the risk is due to any biomechanical load. In this process scoring is given in traffic signal scheme with which the intensity of risk is analysed and required improvements are done.

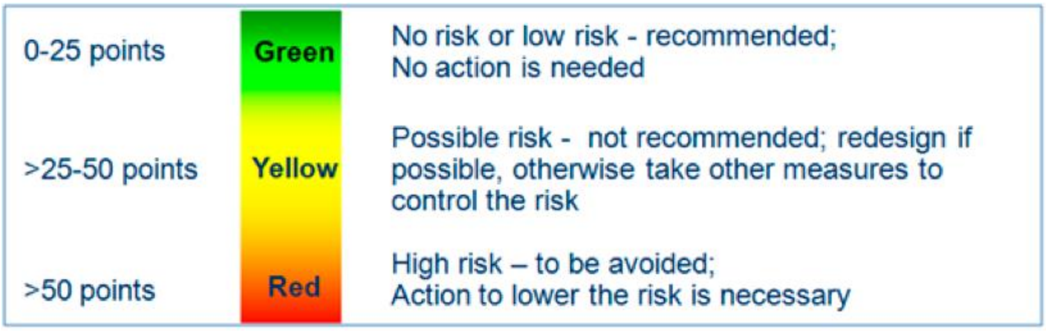

Figure 7: Scoring Classification[3]

2.4.2 OVAKO WORKING POSTURE ANALYZING SYSTEM (OWAS)

This method allows the analyst to record posture, load and force used according to categories. The method was designed for medium and heavy assembly tasks. In this method the body posture is observed and a four digit code to represent the positions of the back, the arms, the legs and the force of exertion is observed. The procedure takes only a few seconds and may be used in conjunction with random schedule of observations to reflect the magnitude of risk.

2.4.3 NIOSH LIFTING EQUATION

The manual material handling risks are analysed using the NIOSH Lifting Equation, in which the risks associated with lifting and lowering tasks in the workplace are assessed. Various factors such as the Recommended Weight Limit (RWL), which is the maximum acceptable weight (load) that the healthy employees would be able to lift over the course of an eight hour shift without increasing the risk of MSDs. And also the Lifting Index (LI) is determined to give an overall estimate of the degree of physical stress and MSD risk related with the manual lifting work which is being analysed.

2.4.4 RAPID ENTIRE BODY ASSESSMENT (REBA)

In this method the entire body postural MSD and ergonomic risk factors related with works are evaluated using a systematic process. A form is used to assess the body pose, required force, type of movement or action, repetition, and coupling. A score is set for the body portions like wrists, lower arms, elbows, shoulders, neck, trunk, back, legs and knees. The data are collected to compile the risk factor variables and a single score representing the MSD risk level is generated.

2.4.5 RAPID UPPER LIMB ASSESSMENT (RULA)

This ergonomic risk analysis tool evaluates the biomechanical and postural load on the neck, trunk and upper extremities. A form is used to assess the body posture, force and repetition required for performing the tasks in the workstation. Based on the assessments, scores are noted for each body portion, for the arm and wrist in section A, and for the neck and trunk in section B. The data are collected to compile the risk factor variables and a single score representing the MSD risk level is generated.

2.4.6 SNOOK TABLES

The Liberty Mutual Manual Material Handling Tables, also known as Snook Tables provide design goals for various lifting, lowering, pushing, pulling, and carrying tasks. The weight/force values are provided by the tables for the tasks that are acceptable to an established percentage of the population. This is achieved by collating the data for individual manual handling works against the appropriate table.

2.5 ERGONOMICS CONTROL MEASURES

After analysing all the ergonomics risk factors and identifying the required ergonomic improvement it's time to determine the most suitable engineering and administrative control methods for implementing the suggested improvements. This process is a team work where all the data are collected employees, process engineers and managers, ergonomics team members to find a solution to the problem.[9]

ENGINEERING CONTROLS

Engineering control methods eliminate the ergonomic risk factors by modifying the workplace and the operations ensuring the range of motion is within the comfort zone, thereby reducing the vulnerability of the muscles and joints of the workers.

ADMINISTRATIVE CONTROLS

Administrative control methods deal with the processes and procedures that will reduce the risk of injuries. Work practice controls, job rotation and counteractive stretch breaks are few administrative controls.

2.5.1 CONTROL METHODS FOR HIGH TASK REPETITION

- ***Engineering Controls:*** Eliminating excessive force requirements and awkward posture will reduce the fatigue for workers and are able to perform high repetition tasks without any risk of MSDs

- ***Work Practice Controls:*** By implementing safe operation procedures for completing the tasks helps to reduce risk of MSDs. And proper training on work techniques must be given to the workers and should be encouraged to accept their responsibilities for preventing the MSD.

- ***Job Rotation:*** Severity of MSD risk factors can be reduced by job task enlargement which reduces the duration and frequency of the task. Workers can be switched between workstations and tasks to avoid performing a single task for a prolonged period of time, thereby reducing fatigue that can lead to MSD.

- ***Counteractive Stretch Breaks:*** Provide periodic rest or stretch breaks to increase the blood circulation needed for the muscle recovery.

2.5.2 CONTROL METHODS FOR FORCEFUL EXERTIONS

- ***Engineering Controls:*** Eliminating the excessive force will significantly reduce the fatigue and the MSD for the workers. The excessive force can be reduced using mechanical assists, counter balance systems, manipulators, adjustable height lift tables, powered equipment and ergonomic tools, thus reducing the fatigue

- ***Work Practice Controls:*** Lifting and carrying tasks can be reduced by using carts and dollies. Sliding the objects instead of carrying or lifting, and eliminates the fatigue which can lead to MSD.

- ***Proper Body Mechanics:*** Lifting and carrying tasks can be reduced by using carts and dollies. Sliding the objects instead of carrying or lifting, and eliminates the fatigue which can lead to MSD.

2.5.3 CONTROL METHODS FOR AWKWARD POSTURES

- ***Engineering Controls:*** Eliminate the sustained awkward postures by modifying the workplace and the operations ensuring the range of motion is within the comfort zone, thereby reducing the vulnerability of the muscles and joints of the workers.

- ***Work Practice Controls:*** Workplace and tasks must be designed in such a way that eliminates awkward postures. And proper training on work techniques must be given to the workers and should be encouraged to accept their responsibilities for using their body properly and avoid awkward postures.

- ***Job Rotation:*** Repeated and sustained awkward postures which lead to MSD can be reduced by job rotation and job task enlargement.

- ***Counteractive Stretch Breaks:*** Provide periodic rest or stretch breaks to counteract any repeated or sustained awkward postures and increase the blood circulation needed for the muscle recovery.

3. MATERIALS FOR MAKING THE WRENCH

This study is to analyse the possibilities of using various materials and compare their properties for making the Torque Wrench.

3.1 CARBON STEEL (AISI 1065)

Steel alloys with carbon as major element in its composition is known as carbon steel. Along with Carbon elements such as copper, molybdenum, aluminium, chromium and nickel are also present in these steels. AISI 1065 carbon steel is a high-carbon steel, which has high tensile strength and heat treatable.[10]

3.1.1 CHEMICAL COMPOSITION

ELEMENT	CONTENT (%)
Iron, Fe	98.31 – 98.8
Manganese, Mn	0.60 – 0.90
Carbon , C	0.60 – 0.70
Sulphur, S	0.05
Phosphorous, P	0.04

Table 1: Carbon Steel Composition

3.1.2 MECHANICAL PROPERTIES

Tensile strength, ultimate	635 MPa	92100 psi
Tensile strength, yield	490 MPa	71100 psi
Modulus of elasticity	200 GPa	29007 ksi
Bulk modulus	140 GPa	20300 ksi
Shear modulus	80 GPa	11600 ksi
Poissons ratio	0.27-0.30	0.27-0.30
Elongation at break (in 50 mm)	10%	10%
Hardness, Brinell	187	187
Hardness, Rockwell B	90	90

Table 2: Carbon Steel Properties

3.2 CHROME VANADIUM STEEL (AISI 6150)

Chrome – Vanadium steel is a steel alloy containing Chromium, Vanadium, Manganese, Carbon, Silicon and traces of Phosphorous and Sulphur. Chromium and Vanadium in the alloy makes the steel more hardenable. This alloy can also be used as High-Speed steel. Chromium increases resistance for abrasion, corrosion and oxidation. Carbon and Chromium combined increases the elasticity of the steel.[11]

3.2.1 CHEMICAL COMPOSITION

ELEMENT	CONTENT (%)
Iron, Fe	96.7 – 97.7
Chromium, Cr	0.80 – 1.10
Manganese, Mn	0.70 – 0.90
Carbon , C	0.48 – 0.53
Silicon, Si	0.15 – 0.35
Vanadium, V	0.15 – 0.30
Sulphur, S	0 – 0.04
Phosphorous, P	0 – 0.035

Table 3: Chrome-Vanadium Steel Compostion

3.2.2 MECHANICAL PROPERTIES

Tensile strength, ultimate	940 MPa	$140x10^3$ psi
Tensile strength, yield	620 MPa	$89x10^3$ psi
Modulus of elasticity	190 GPa	$27x10^6$ psi
Bulk modulus	160 GPa	$23.2x10^6$ psi
Shear modulus	73 GPa	$11x10^6$ psi
Poisson’s ratio	0.29	0.29
Elongation at break (in 50 mm)	22%	22%
Hardness, Brinell	270	270
Hardness, Rockwell B	99	99

Table 4: Chrome-Vanadium Steel Properties

3.3 CHROME MOLYBDENUM STEEL (AISI 4140)

In this steel alloy the key elements are Chromium and Molybdenum. Chrome – Moly alloy finds its application in high temperature and pressure working conditions in various industries such as Oil and Gas, Construction, Energy and Automotive industries. This alloy has high corrosion resistance and tensile strength.[12]

3.3.1 CHEMICAL COMPOSITION

ELEMENT	CONTENT (%)
Iron, Fe	96.785 – 97.77
Chromium, Cr	0.80 – 1.10
Manganese, Mn	0.70 – 0.90
Carbon , C	0.38 – 0.43
Silicon, Si	0.15 – 0.30
Molybdenum, Mo	0.15 – 0.25
Sulphur, S	≤ 0.04
Phosphorous, P	≤0.035

Table 5: Chrome-Moly Steel Composition

3.3.2 MECHANICAL PROPERTIES

Tensile strength, ultimate	655 MPa	$95x10^3$ psi
Tensile strength, yield	415 MPa	$60.2x10^3$ psi
Modulus of elasticity	205 GPa	$29.7x10^6$ psi
Bulk modulus	140 GPa	$20.3x10^6$ psi
Shear modulus	80 GPa	$11.6x10^6$ psi
Poisson’s ratio	0.29	0.29
Elongation at break (in 50 mm)	25.7%	25.7%
Hardness, Brinell	197	197
Hardness, Rockwell B	92	92

Table 6: Chrome-Moly Steel Properties

3.4 S2 TOOL STEEL

S2 steel is one among the group of ‘S’ steels based on the AISI classification which are shock resistance tool steels. The group includes S1, S2, S5, S6 and S7 steels. High hardness is achieved in these types of tools, by varying the composition. Addition id silicon to the alloy enhances the tempering resistance of the steel.[13]

3.3.1 CHEMICAL COMPOSITION

ELEMENT	CONTENT (%)
Iron, Fe	97.0
Vanadium, V	≤0.5
Manganese, Mn	0.4
Carbon , C	0.4 – 0.55
Silicon, Si	1.05
Molybdenum, Mo	0.4
Sulphur, S	≤ 0.03
Phosphorous, P	≤0.03

Table 7: S2 Steel Composition

3.3.2 MECHANICAL PROPERTIES

Tensile strength, ultimate	2150 MPa	312×10^3 psi
Tensile strength, yield	2000 MPa	290×10^3 psi
Modulus of elasticity	205 GPa	29.7×10^6 psi
Bulk modulus (typical for steel)	160 GPa	23.2×10^6 psi
Shear modulus (typical for steel)	80 GPa	11.6×10^6 psi
Poisson’s ratio (typical for steel)	0.27 – 0.30	0.27 – 0.30
Elongation at break (in 50 mm)	7%	7%
Hardness, Rockwell C	55	55

Table 8: S2 Steel Properties

3.5 COMPARISION OF VARIOUS MATERIALS

3.5.1 CARBON STEEL (AISI 1065)

- Based on the Carbon content the steel can be classified as low carbon steel, medium carbon steel and high carbon steel.
- The higher the carbon content, the greater the hardness and the lower the toughness.
- Due to high strength and hardness high carbon steel is used to manufacture hand tools.
- As the toughness is less and hence screw drivers cannot be manufactured as they will break easily, but it is used to manufacture some general purpose hand tool, such as wrenches.

3.5.2 CHROMIUM-VANADIUM STEEL (AISI 6150)

- Chromium vanadium steel is alloy tool steel with chromium (Cr) and vanadium (V) alloy elements.
- Having better strength and toughness than carbon steel, it is a great material for high quality tools.
- Chrome vanadium steel is generally used to manufacture wrenches, screwdrivers, manual sleeves.

3.5.3 CHROME MOLYBDENUM STEEL (AISI 4140)

- It is tool steel with chromium (Cr), molybdenum (Mo), iron (Fe) and carbon (C) alloy elements.
- Its performance is better than chromium vanadium steel due to its excellent impact resistance, strength and toughness.
- Top grade screwdrivers and small hex wrenches are manufactured using Chrome – Moly steel alloy.
- But material is more expensive than others.

3.5.4 S2 TOOL STEEL

- It is an alloy tool steel with carbon (C), silicon (Si), manganese (Mn) ,chromium (Cr), molybdenum (MO) and vanadium (V).
- Excellent impact resistance and excellent strength and toughness are the advantages of S2 tool steel.
- Usually high strength screwdrivers and hex wrenches are made using S2 tool steel.
- And the performance is better than chrome vanadium steel.
- For actual material selection, CR-V is more widely used than S2 because the import factor.[14]

4. EXISITING SITUATION

The nut in the rear axle of the car needs to be tightened only with specified predetermined torque. But at Skoda Auto in the production line while assembling the axle in the axle sub-assembly station the specified torque is not set, this is because the specific torque cannot be set before having the full load of the car being applied on the axle.

So after completing the entire assembly of the car, the actual load of the car is on the axle and now the nut can be adjusted with the specific predetermined torque. This is done at the wheel alignment inspection station. This is done using a tool called torque wrench. In Skoda Auto's assembly line they use two different types of Torque Wrench tool to suit the various models of the car and one common tool to hold the bolt on the other side.

Images of the workstation are not provided by Skoda Auto as it is confidential.

4.1 CAR MODELS

Skoda Auto has a large variety of cars in production, among which the models being manufactured in the Mlada Boleslav plant are Karoq, Octavia, Kamiq, Scala and Fabia. The project in which I was assigned to work on the car models Karoq, Octavia and the New Octavia, which are being produced in the line M13.

4.1.1 KAROQ (SK – 326)

Skoda Karoq is a SUV type of car with front mounted engine. Based on the drive system the car is classified into two variants Front wheel drive and all wheel drive. Cars with all wheel drive system have a differential gear box on the real axle, which makes the rear axle bit complex setup.

Figure 8: Skoda Karoq[4]

4.1.2 OCTAVIA (SK – 37)

Skoda Octavia is a sedan type of car with front mounted engine. Based on the drive system the car is classified into two variants front wheel drive and all wheel drive. SK – 37 is the 3rd generation Octavia.

Figure 9: Skoda Octavia[4]

4.1.3 NEW OCTAVIA (SK – 38)

Skoda Octavia is a sedan type of car with front mounted engine. The Octavia comes with front wheel drive system and also gets an all wheel drive system for the sport variant Octavia RS. SK – 38 is the 4th generation Octavia which will be available to customers from mid 2020.

Figure 10: New Octavia[4]

4.2 REAR AXLE

There are two rear axle types based on the type of drive system which the car runs on, which are front wheel drive and rear wheel drive. The rear axle of a car with front wheel drive system is called dead axle as there is no power transmission in that axle. Whereas in a car with the all wheel drive system both the axles are drive axle.

4.2.1 FRONT WHEEL DRIVE (FWD)

In a front engine, front wheel drive car the rotational force from the engine is transmitted to front wheel. In this type of cars the rear axle remains as dead axle with less complex setup. All the three cars Karoq, Octavia and the New Octavia with front wheel drive system has almost similar design of the rear axle as all these cars share similar platform.

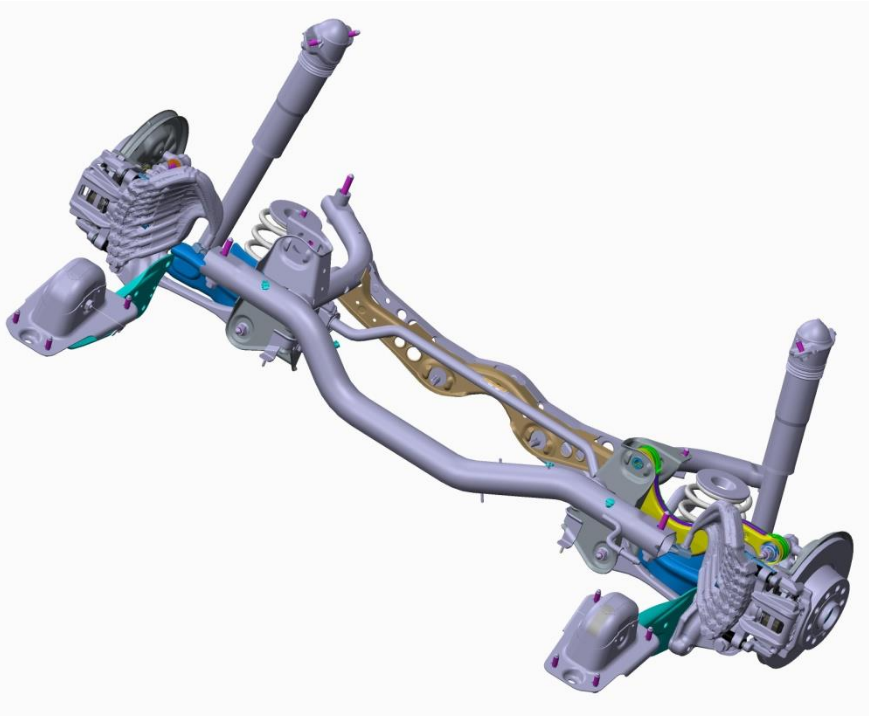

Figure 11: Rear Axle (FWD) [source: own]

4.2.2 ALL WHEEL DRIVE (4x4)

In a car with all wheel drive system the rotational force from the engine is transmitted to all the four wheels of the car. The design of the rear axle for an all wheel drive car varies from front wheel drive car in order to accommodate extra components like differential gear box, drive shaft, etc, and to withstand more dynamic forces as it is one of the drive axles. All the three cars Karoq, Octavia and the New Octavia has one variant with all wheel drive system.

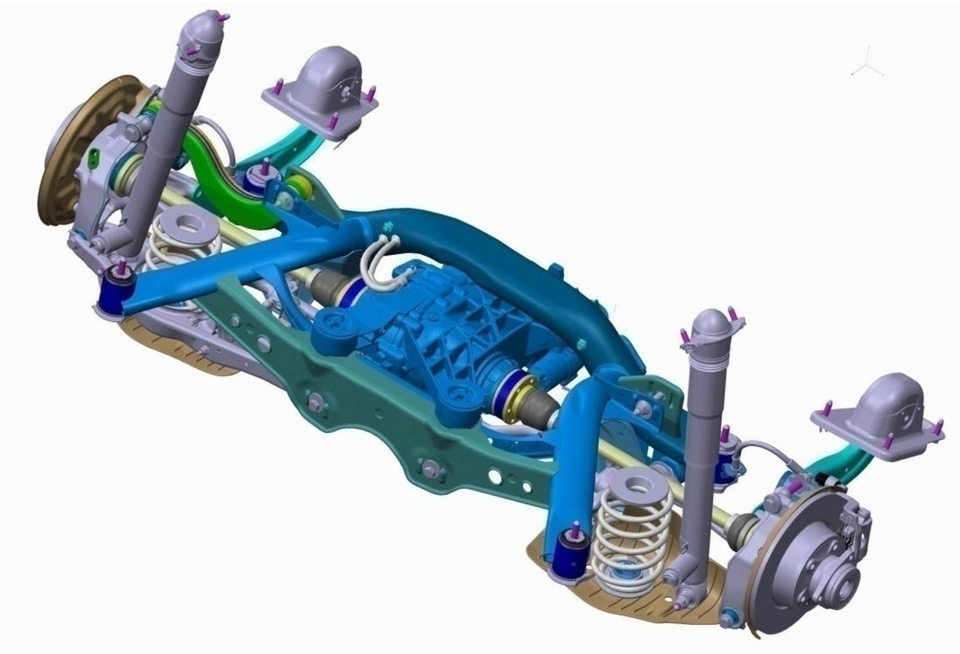

Figure 12: Rear Axle (4x4) [source: own]

Figure 13: All Wheel Drivetrain[4]

4.2.3 NUT

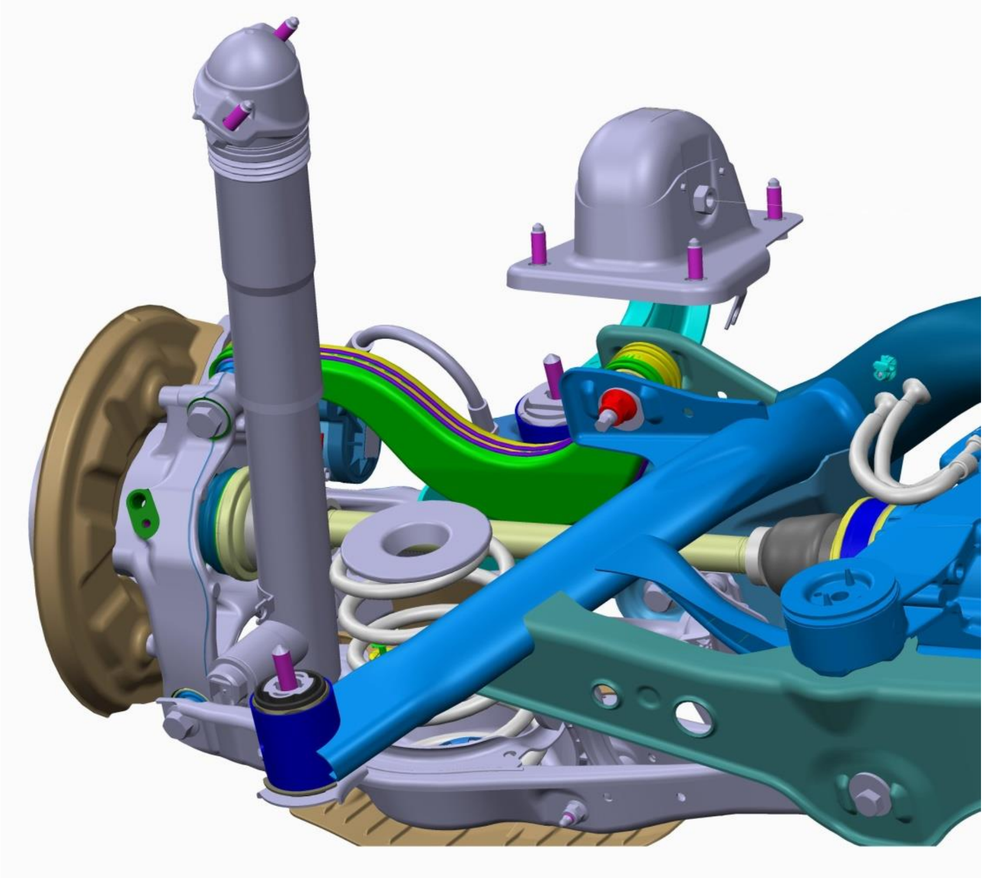

Figure 14: Nut [source: own]

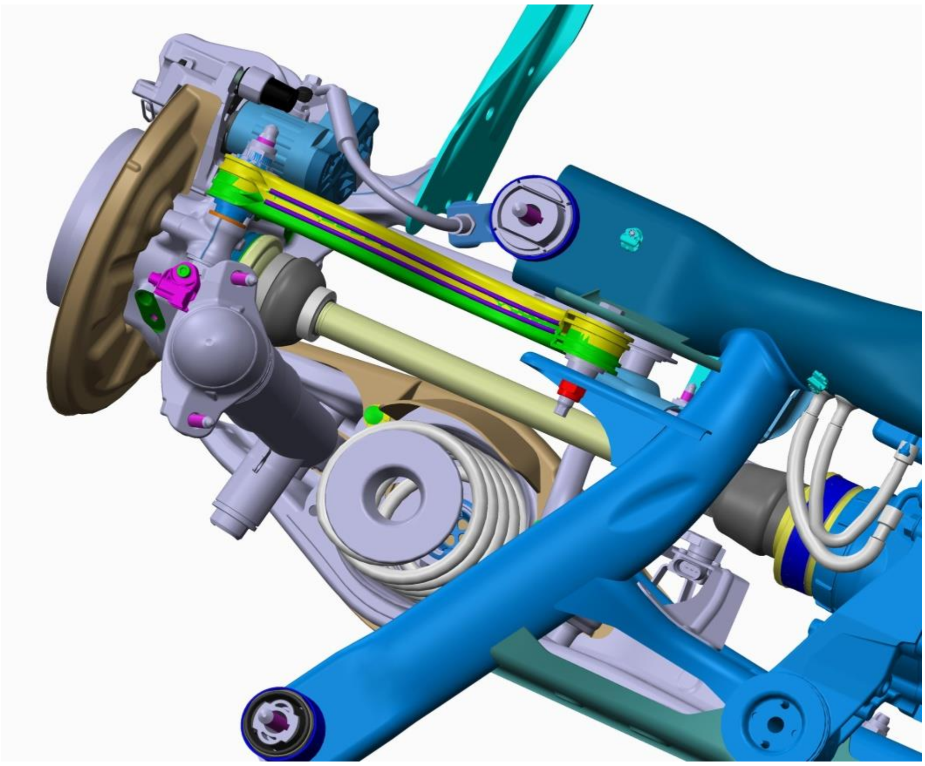

Figure 15: Nut (Top View) [source: own]

The nut which is highlighted in red colour is the nut being adjusted in the wheel alignment inspection station. Purpose of this nut is to attach the brake and suspension carrier with the axle of the car. The brake and suspension carrier is attached with the axle through the control rod which is held with the axle by the above mentioned nut.

4.3 TORQUE WRENCH

The tool used to adjust the nut in the rear axle if the car is a Torque Wrench. Purpose of the torque wrench is to tighten the nut with accurately specified torque. Tightening of the fasteners with proper tension helps in avoiding the damage from over tightening or under tightening. This enhances the safety and performance of the product.[15]

4.3.1 TYPES OF TORQUE WRENCHES

	**ELECTRONIC TORQUE WRENCHES** ▪ Also known as digital, they don't feature any moving parts and instead work from an electric sensor. ▪ They sense how much twisting force is applied and tells the user via a digital display. ▪ These tools include small chips which contain a memory stick to save readings, which can then be accessed on a computer.
	**BEAM** ▪ These products are generally inexpensive and easy to use. They feature a scale, and once the right level of torque has been reached it stops at the right number. ▪ The main beam features a handle on it which is used to employ force. When in use, the beam stays in place and the scale shows the level of torque. ▪ These tools can be used for tightening or loosening.
	**CLICK** ▪ A click torque wrench gives an audible sound when the correct torque setting has been reached. ▪ This type features a spring-loaded lever which is adjusted by twisting the handle to the right setting. When the required torque level is achieved, the lever breaks which creates a clicking noise. ▪ Most click types are ratcheting and may be used for tightening or loosening.

Table 9: Types of Torque Wrenches

	**HYDRAULIC TORQUE WRENCHES** ▪ This type is often used in industrial settings. They're designed to reach the required level of torque through the use of hydraulics
	**MICROMETER TORQUE WRENCHES** ▪ These scales are often used in the manufacturing and transportation of cargo. ▪ Knowing the weight of a load is vital when transporting large amounts by train, plane, or ship because the weight may change the distribution of the freight. ▪ If it's not monitored properly, this could endanger the crew and the rest of the cargo being transported.
	**DIAL TORQUE WRENCHES** ▪ Dial torque wrenches are widely considered as one of the most accurate to use. ▪ They can be wider than other types, so can be harder to use in small spaces. ▪ As well as regular use in the automotive industry, these tools are used in the aerospace and defence industries.

Table 10: Types of Torque Wrenches

4.3.2 TOOLS USED IN SKODA AUTO

For adjusting the nut in the rear axle of the car two different torque wrenches are used, which are of different shapes. The two tools are tool 2536 and tool 2605. These torque wrenches are click type with mechanical keys and electronic signal and the model used here is CWR 120 and CWR 200.

Tool 2536 is used to adjust the nut in the rear axle of the all wheel drive cars, which includes Karoq (SK_326), Octavia (SK_37) and New Octavia (SK_38). Tool 2605 is used to adjust the nut in the rear axle of the front wheel drive cars, which are the same Karoq (SK_326), Octavia (SK_37) and New Octavia (SK_38) but FWD model. Tool 2476 is a normal spanner used to hold the bolt which is on the other side. This tool is used only for the all wheel drive axle.

Figure 16: Torque Wrenches [source: own]

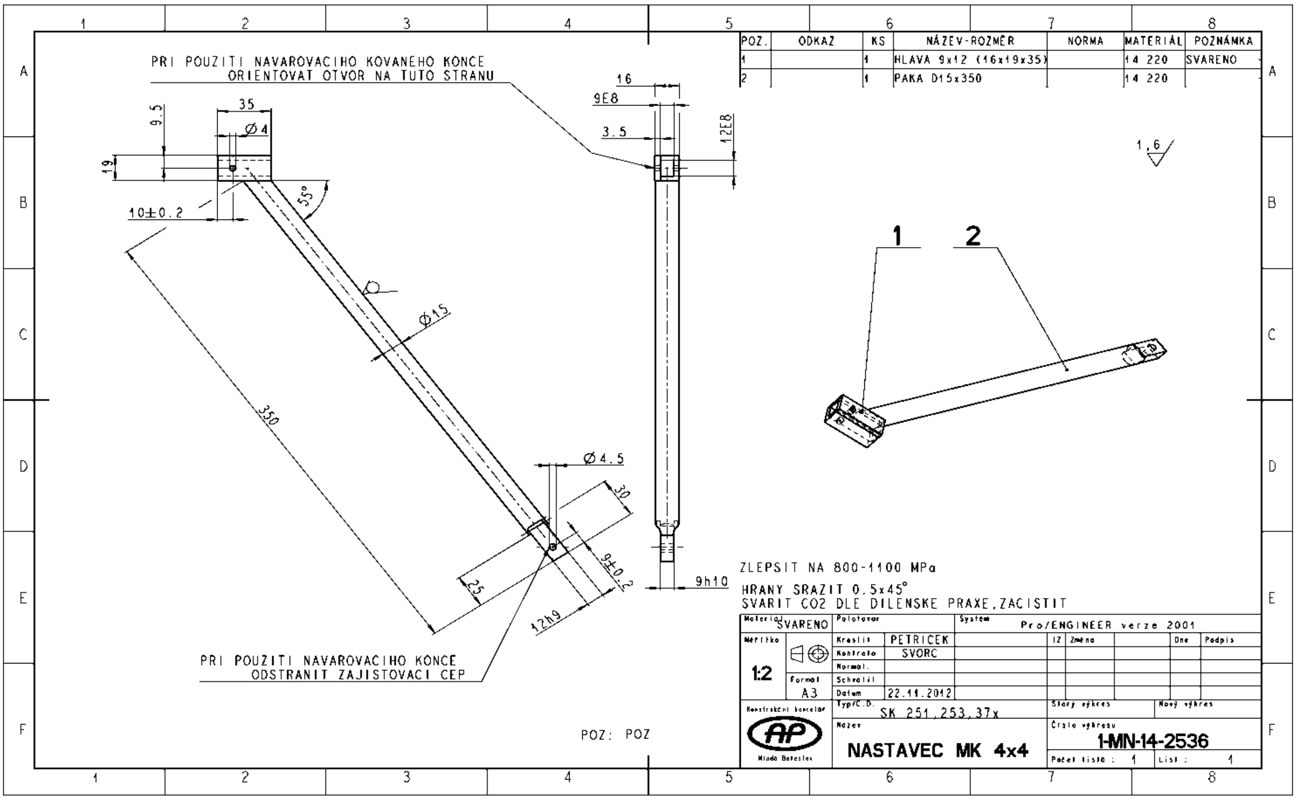

Figure 17: Tool 2536

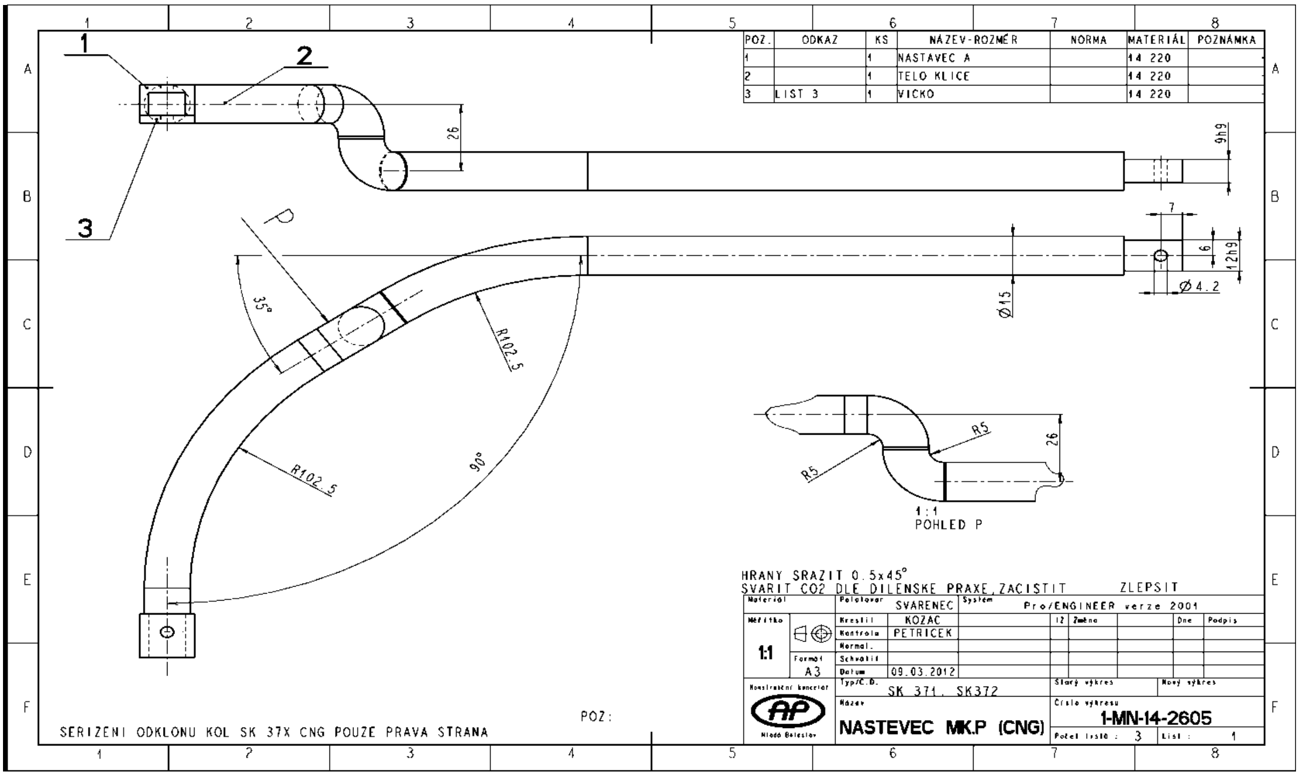

Figure 18: Tool 2605

4.4 CURRENT APPROACH

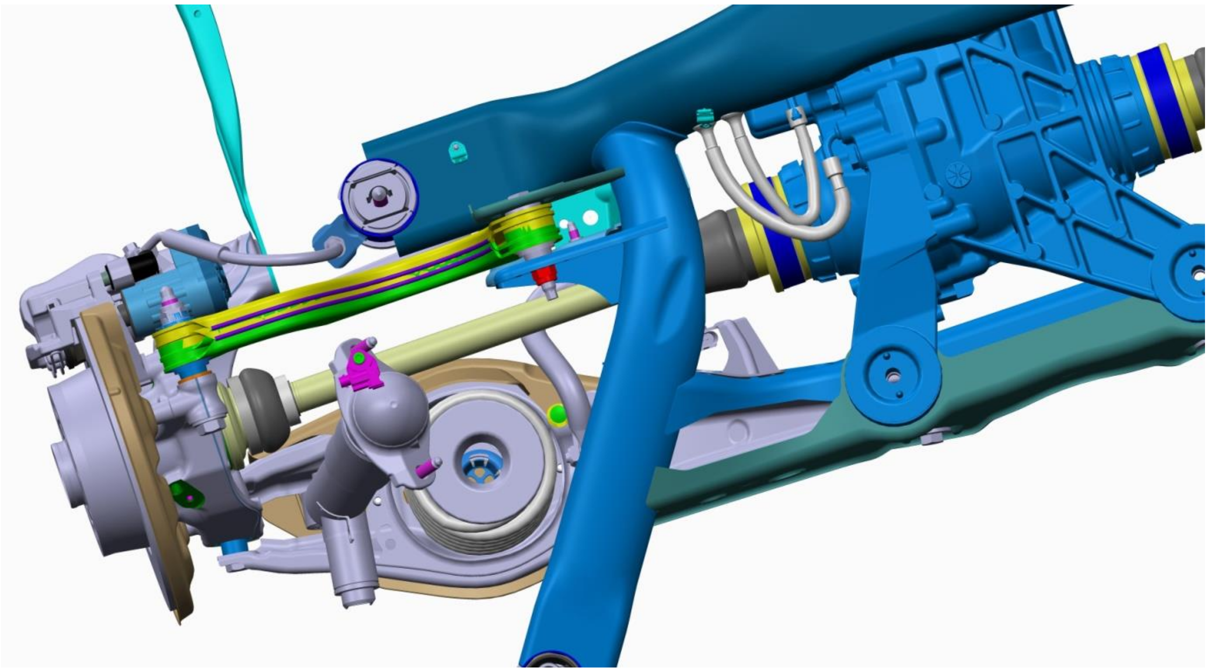

Figure 19: Rear Axle 4x4 (Top View) [source: own]

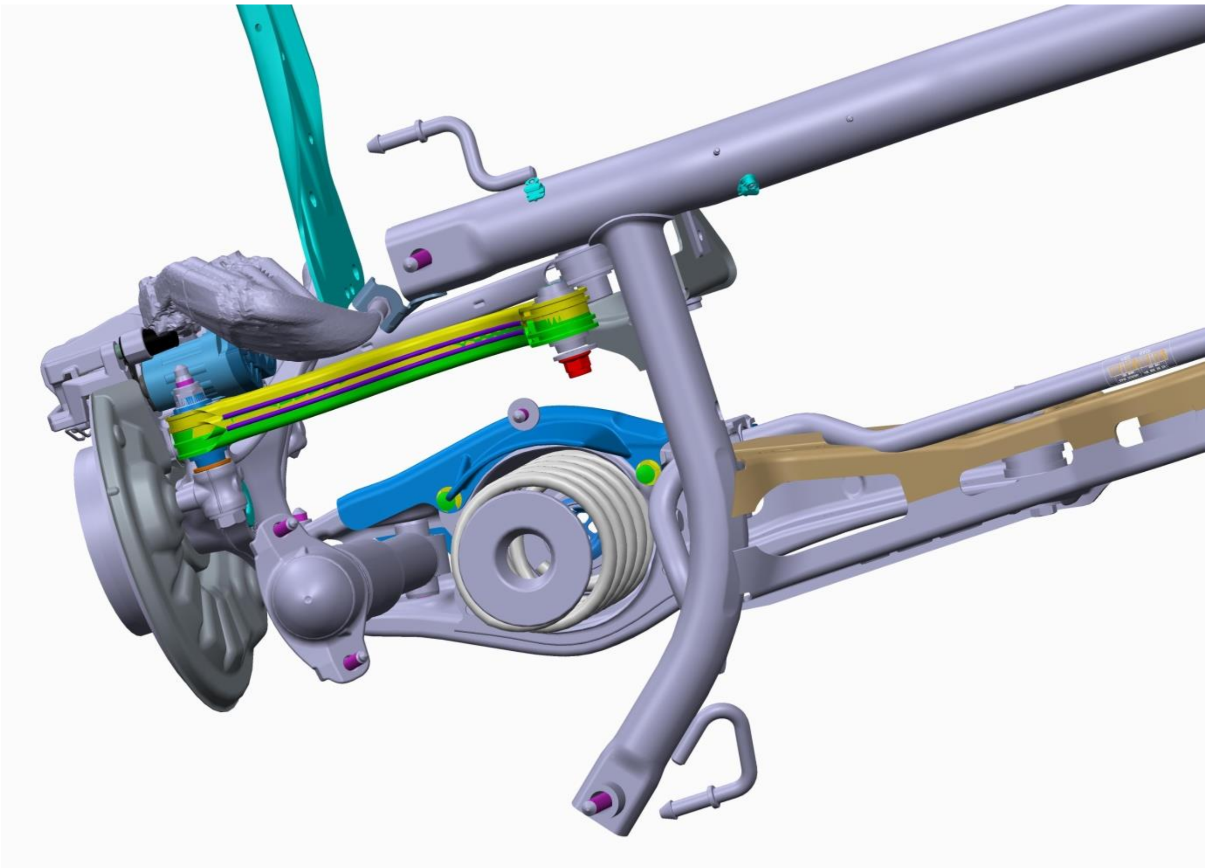

Figure 20: Rear Axle FWD (Top View) [source: own]

The nut which is highlighted in red is to be tightened with predetermined torque. To perform this operation the nut is approached by the torque wrench from the gap at the bottom of the rear axle. To be able to approach the nut from the bottom, the torque wrench needs to be in a specific shape.

This shape varies based on whether the rear axle is drive axle or dead axle. The rear axle which is drive axle has more components which minimises the work space and the path to approach the nut. Whereas the rear axle which is dead axle has very few components thus more workspace, demanding less complex shape of the torque wrench.

Here the current problem can be recognised as the usage of two different tools for the adjusting the nut in the rear axle which is either a drive axle or a dead axle. The required solution is to design one universal tool to adjust the nut in both the type of rear axles.

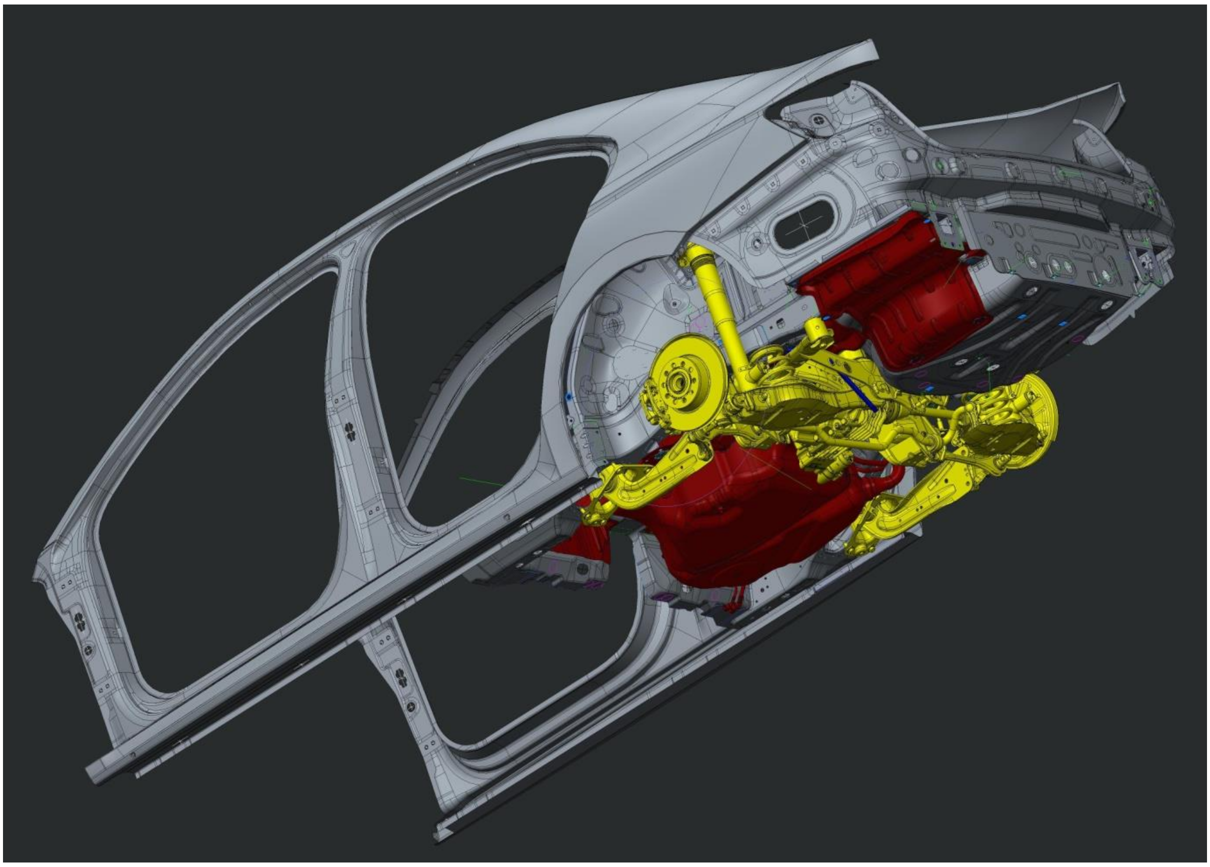

Figure 21: Outer Body (4x4) [source: own]

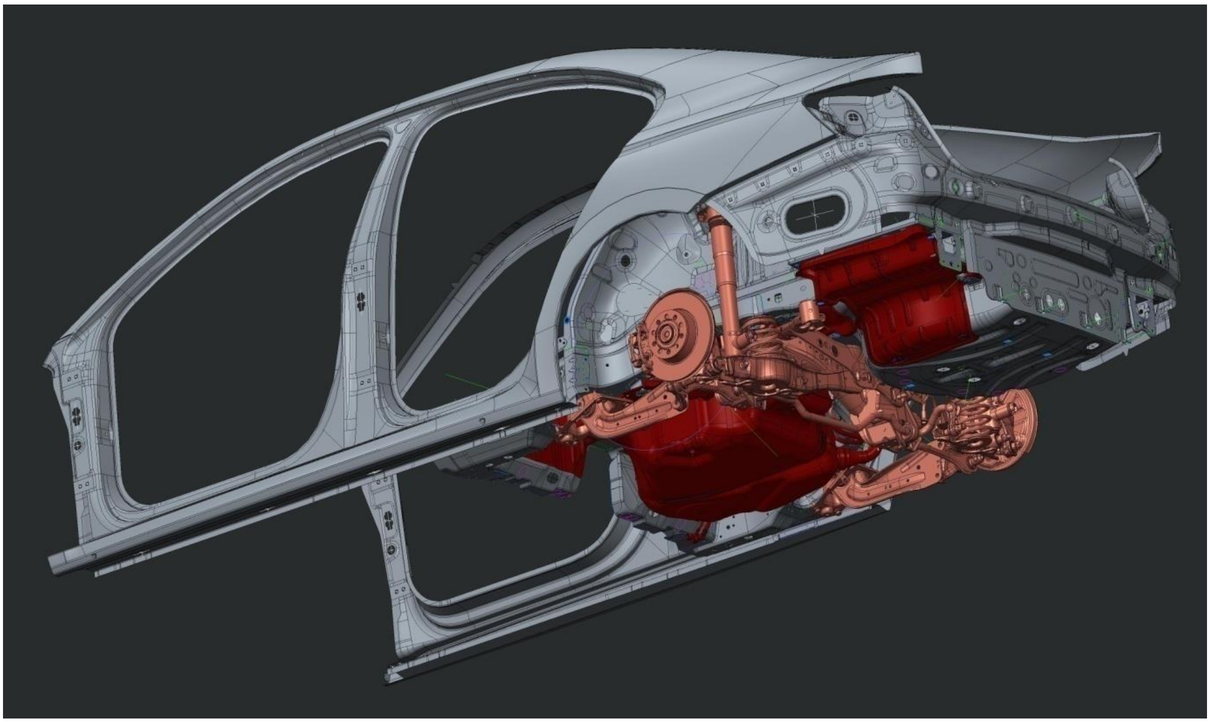

Figure 22: Outer Body (FWD) [source: own]

5. SOLUTION

5.1 NEW TOOL

Here the goal is to design a new universal tool which would replace the existing tools by being able to work with both the type of axles. This is achieved by combining the design of the two already existing tools into on common tool.

5.1.1 METHODOLOGY

STEP 1: For existing working conditions the workspace and the path of the tool for both the axles are determined. This is done by analysing the CAD model of the rear axle assembly of the different models of the cars.

STEP 2: After determining the workspace for reaching the nuts in both the axles surfacing of the workspace is done for each axle. This helps finding the boundary conditions, within which the new tool can be designed.

STEP 3: Once the surfacing of the workspace for both the axle is done, the workspace for both the axles can be extracted out separately, which is then combined to obtain the common workspace. This common workspace can be considered as the boundary conditions for designing the new universal tool.

STEP 4: New sketch is created in the newly obtained workspace not exceeding the boundary. This sketch acts as a centre line around which it can be swept to obtain the 3D profile of the new tool. This gives us a new universal tool which can be worked with both the axles.

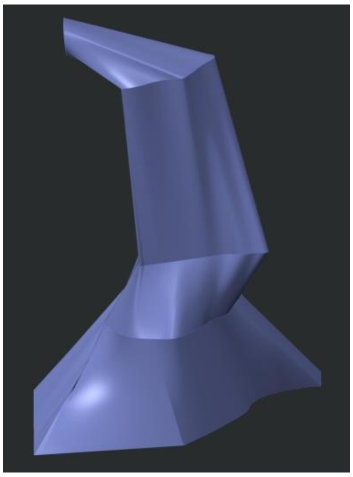

Figure 23: New Workspace [source: own]

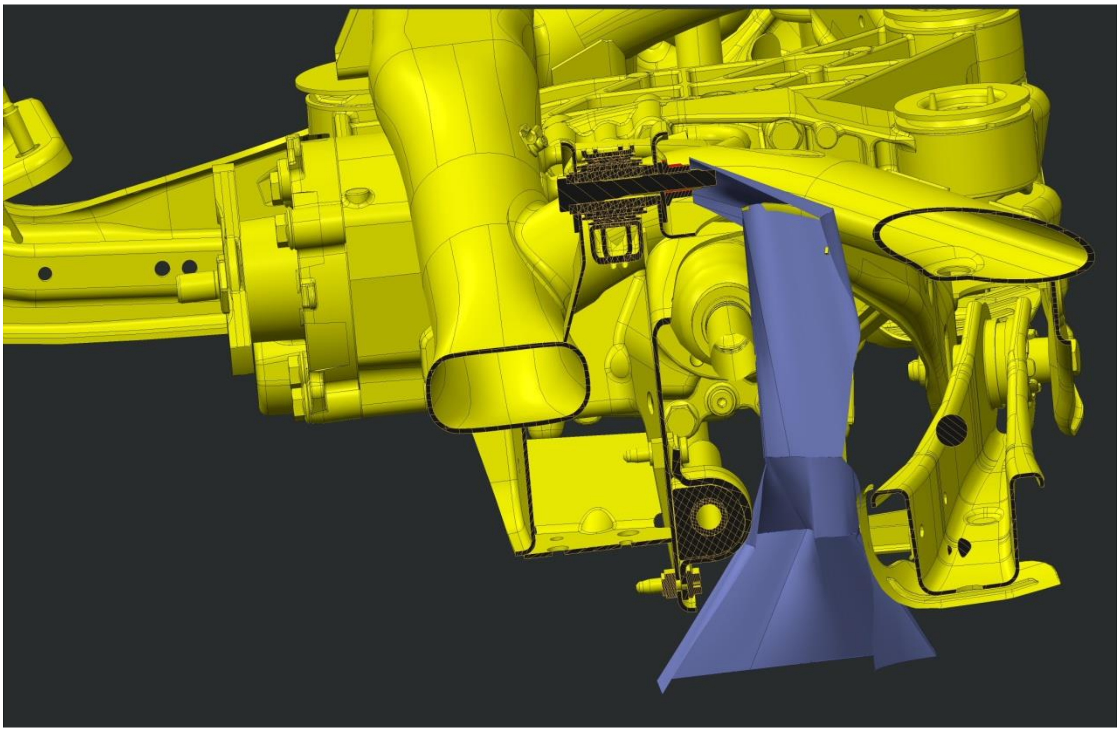

Figure 24: Workspace Section View [source: own]

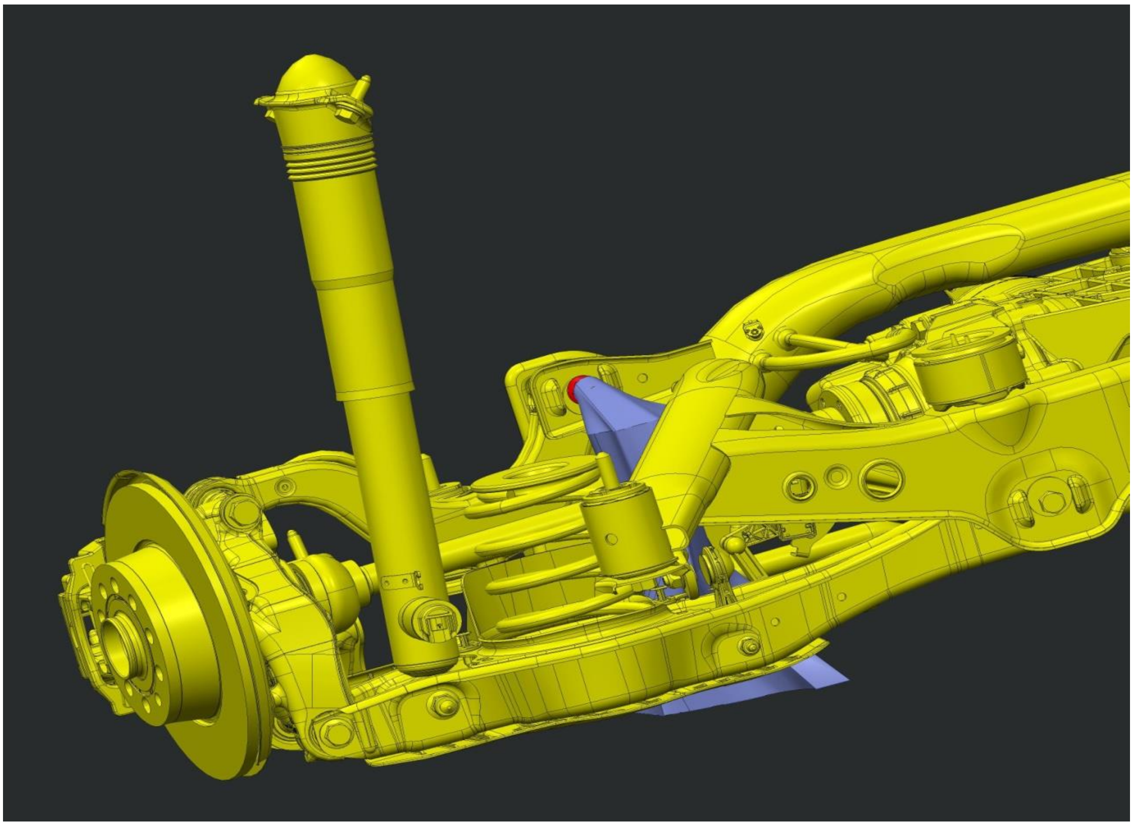

Figure 25: Workspace in Axle [source: own]

5.1.2 3D DESIGN

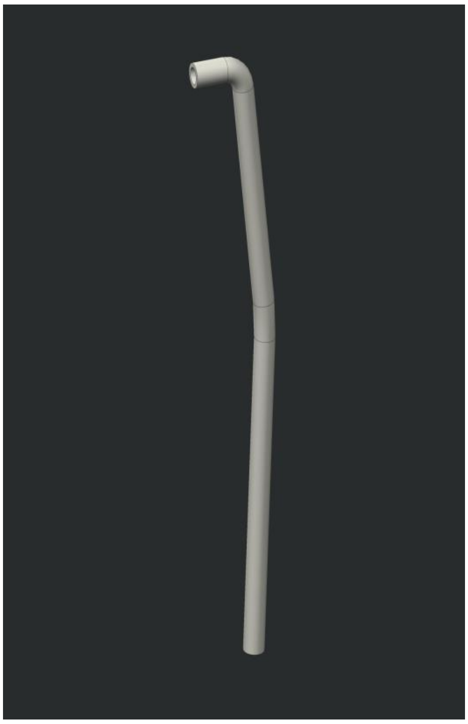

Figure 26: New Tool [source: own]

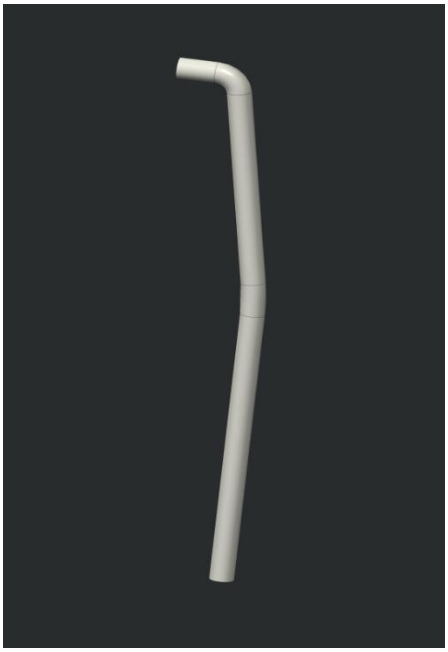

Figure 27: New Tool [source: own]

On following the above mentioned steps, I finally arrived at the solution which is a new universal tool for adjusting the nut in both type of rear axles in all the cars in M13 assembly line. This new tool is designed in such a way that it reaches the nut from the bottom without hitting the components around.

The simple design ensures easy accessibility of the nuts in the rear axle. The body is designed in cylindrical shape which helps proper weight distribution thereby increasing the ease of use. The body is designed hollow to reduce the weight but the walls are thick to avoid any failure of the tool while working.

The new tool has two bends one is in the middle of the body which is to ensure the maneuverability of the tool in its path around the components in the rear axle and other bend is at the top which is to help the tool reach the nut for adjusting it. This new tool can now replace the existing two tools.

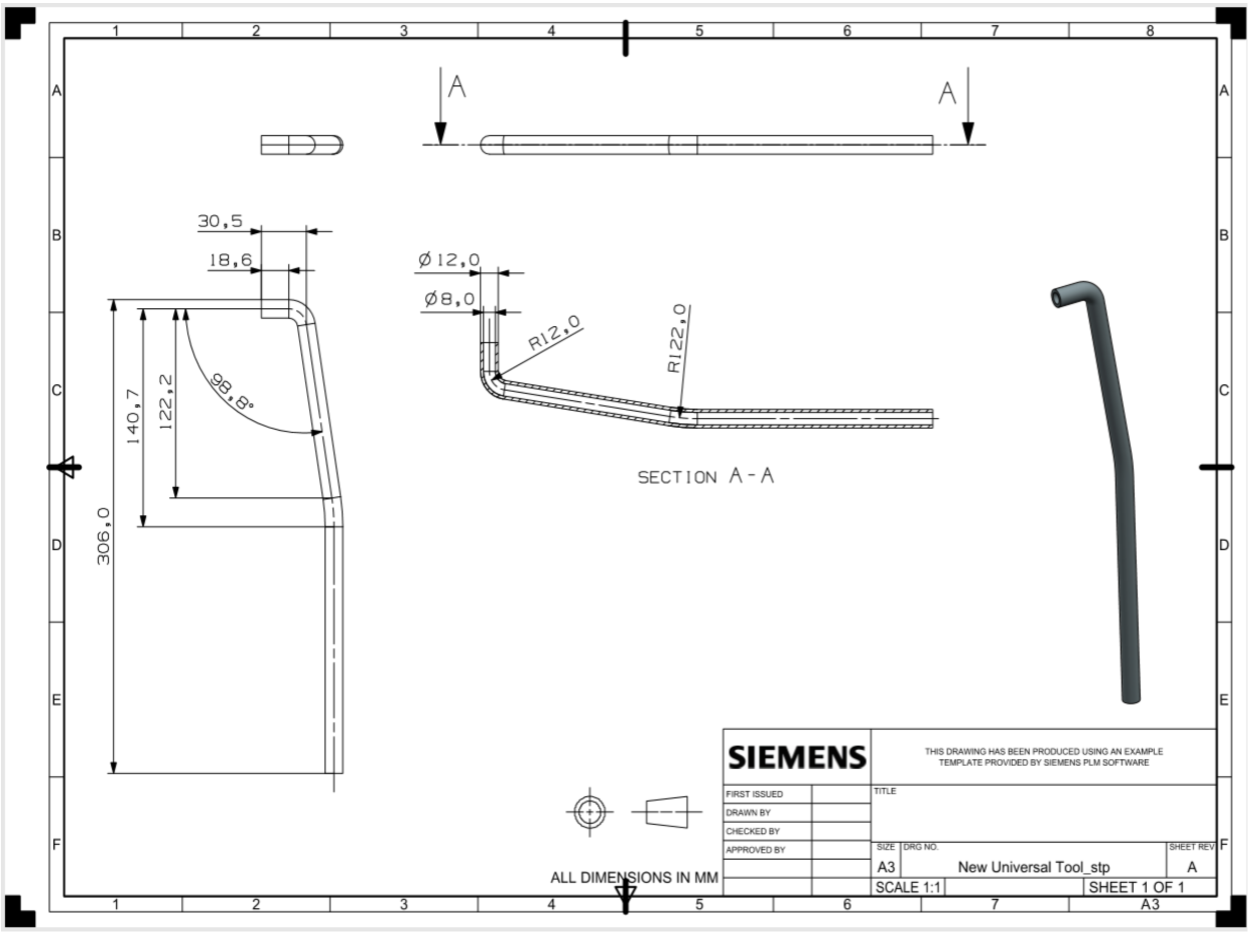

Figure 28: New Tool Production Drawing [source: own]

5.2 MATERIAL FOR TOOL DESIGN

Possibilities of using various materials for making the tool has been discussed in the 3rd chapter, inferring the data from it we can conclude the material to be used for making the new tool.

High Carbon steel is widely used for making tools due to its high hardness, but having less toughness it can easily snap under impact; hence carbon steel is not recommended for making torque wrench.

S2 tool steel being shock resistance tool is used in applications where there is frequent impact on the tool, e.g., Chisel. This high level shock resistance characteristic is not required for a torque wrench which is being used in an automotive industry. And S2 tool steel is expensive; hence S2 tool steel will be overkill for torque wrenches used in automotive industry.

Two major properties to be considered for the tool material are Ultimate Tensile Strength and Hardness. Comparing these two properties for the other two materials Chromium – Vanadium steel and Chrome – Molybdenum steel, Chromium – Vanadium steel has higher tensile strength and hardness hence it can be used to make the high performance tools such as Torque Wrenches for automotive industry.

As our tool is used to adjust the nut in the rear axle of the car high strength is needed and so it is recommended to use Chromium – Vanadium steel for making the Torque Wrench.

5.3 NEW APPROACH

This chapter shows the approach and path of the new universal tool to reach the nut in both the axles.

5.3.1 ALL WHEEL DRIVE AXLE

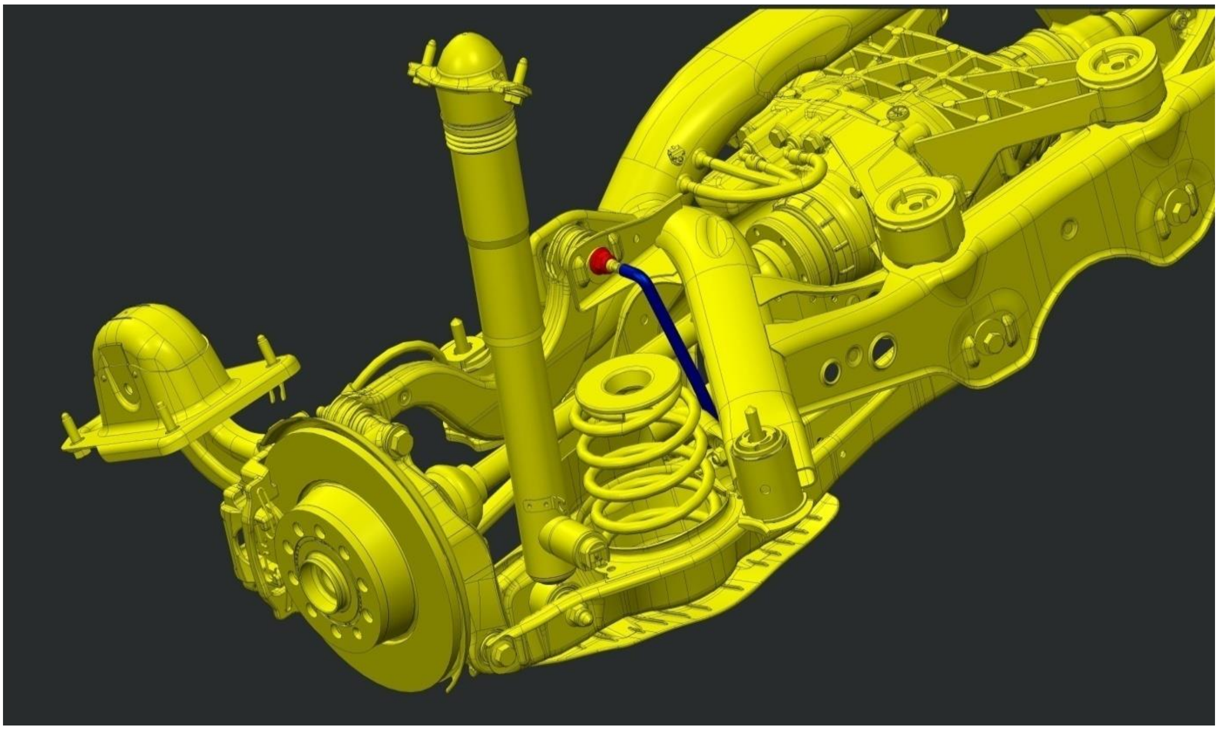

Figure 29: New Tool Position (4x4) [source: own]

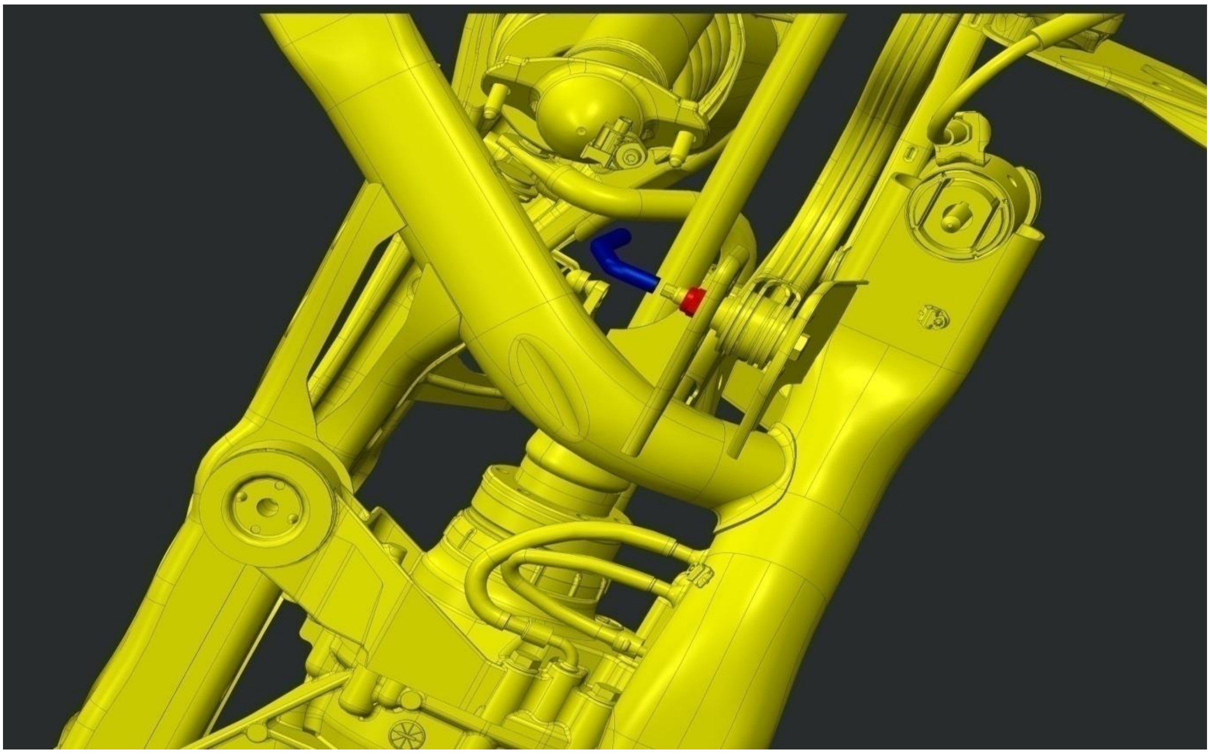

Figure 30: New Tool Position (4x4) [source: own]

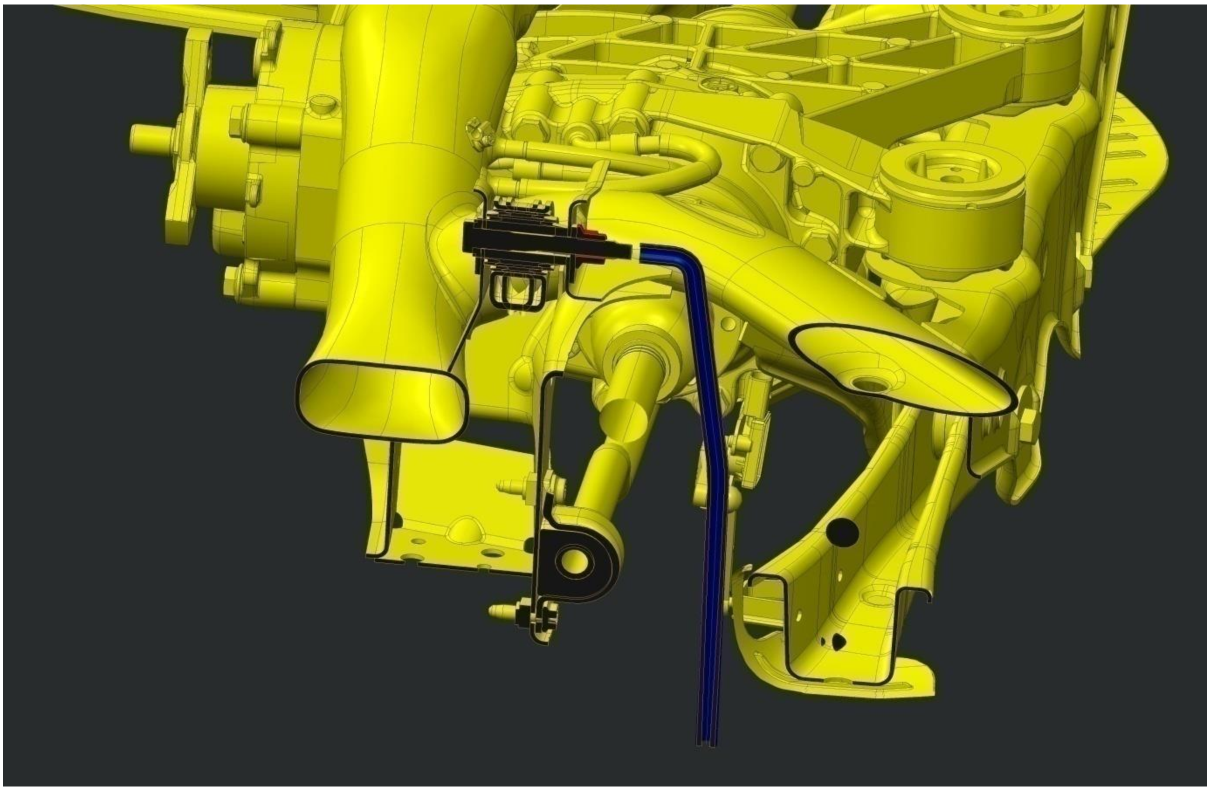

Figure 31: New Tool (Section View) [source: own]

5.3.2 FRONT WHEEL DRIVE AXLE

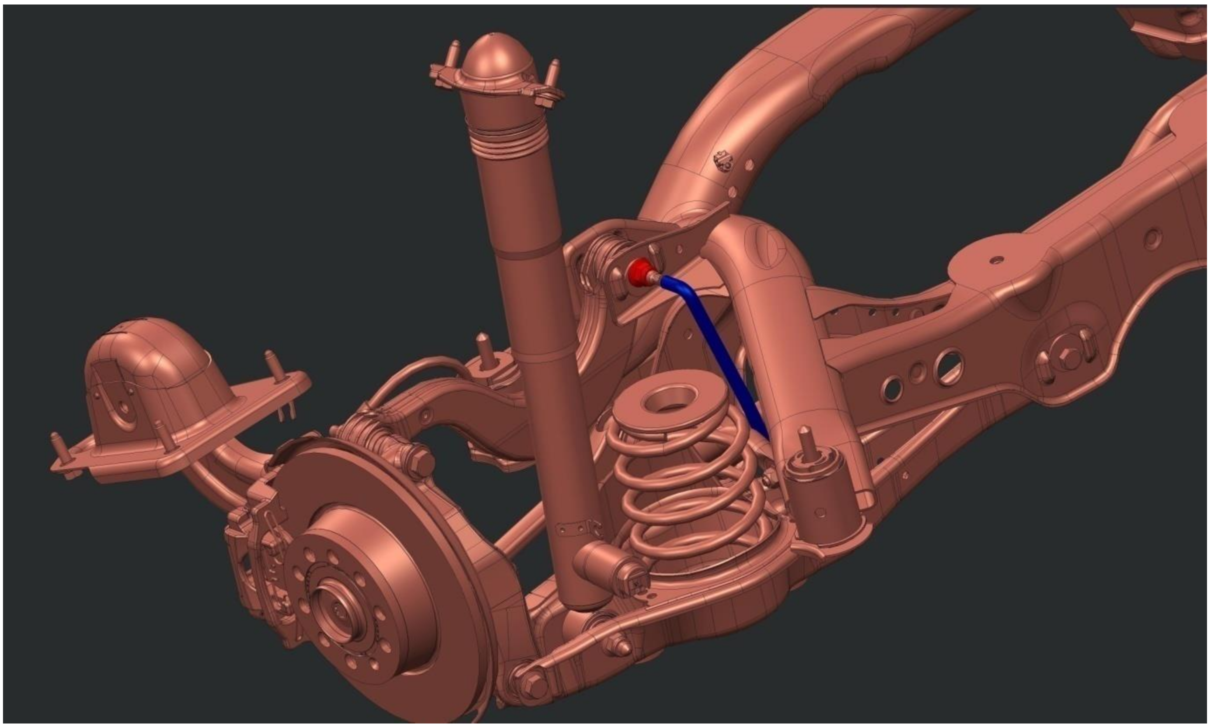

Figure 32: New Tool Position (FWD) [source: own]

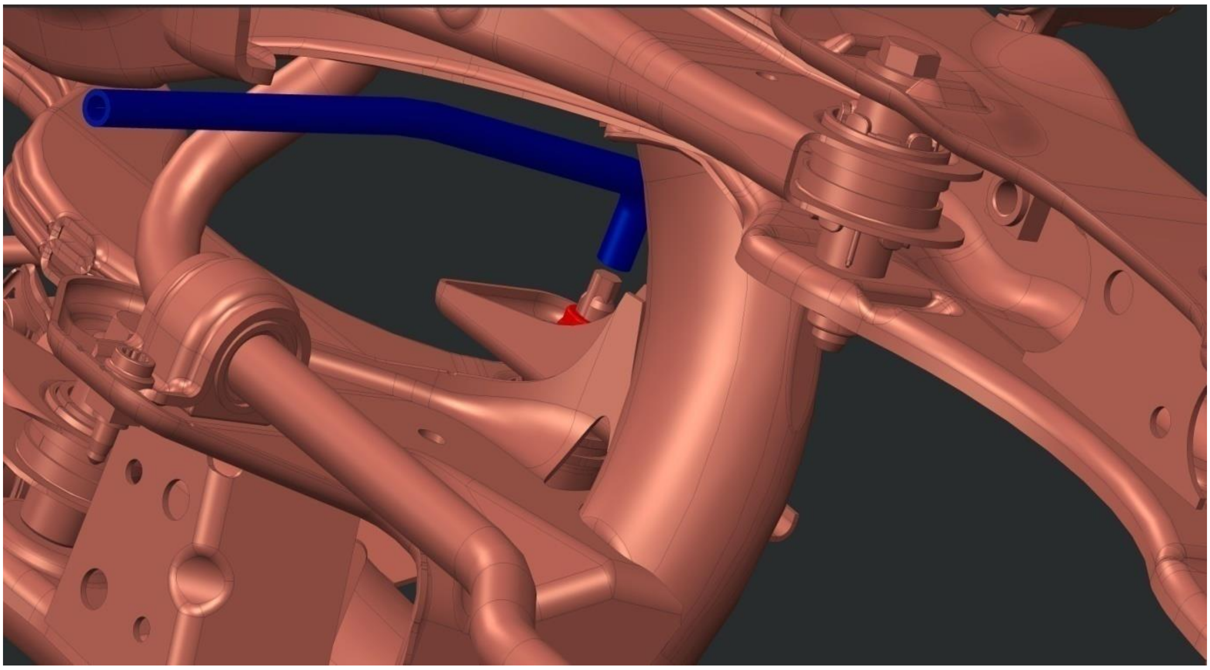

Figure 33: New Tool Position (FWD) [source: own]

6. CONCLUSION

The aim of this thesis is to design a new universal tool for adjusting the nut in the rear axle of the cars in Skoda Auto's M13 assembly line. This work has been divided into two parts, theoretical part (Chapter 2 & 3) and design part (Chapter 4 & 5) respectively.

In theoretical part the workplace ergonomics has been defined and described and the possibilities of using various materials for making the torque wrench has been studied.

In design part the current approach for adjusting the nut in the rear axle and the tools are analysed. And data such as CAD model of axles, CAD model of the tools are gathered and analysed. Then the new universal tool is designed by the method of extracting the different workspaces and combining them to obtain the boundary conditions for the design.

This newly designed universal tool can now be used in Skoda Auto's M13 assembly line to adjust the nut in the rear axle of all the car models. This new tool having simple design improves the ergonomics of tightening the nut for the worker. The new universal tool can now replace the existing two tools thus reducing the occupied space and improves the movement of the worker in the workstation.

Structural analysis of the new tool was not done because the client i.e. Skoda Auto wanted only the 3D design but not the analysis data.

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