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Desing of mobile jack for lifting clay model of cars

Diplomová práce

Studijní program: N2301 – Mechanical Engineering
Studijní obor: 2302T010 – Machines and Equipment Design

Autor práce: **Venkatesh S**
Vedoucí práce: Ing. Petr Zelený, Ph.D.

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Faculty of Mechanical Engineering

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Master thesis

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Study branch:	2302T010 – Machines and Equipment Design
Author:	**Venkatesh S**
Supervisor:	Ing. Petr Zelený, Ph.D.

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DIPLOMA THESIS ASSIGNMENT

(PROJECT, ART WORK, ART PERFORMANCE)

First name and surname:	**Venkatesh S**
Study program:	**N2301 Mechanical Engineering**
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Assigning department:	**Department of Manufacturing Systems and Automation**

Rules for elaboration:

This work is to design a jack for lifting actual scale clay model of production cars. The jack must also be able to move on the factory floor as and whenever needed by the manufacturer. The design of the lifting device must have a capacity to lift models of about 5 tons in mass and also up to a height of 1 meter. The clay model of car is built of various materials assembled on a Steel frame with Four Jacking Points all in the same plane in a rectangular arrangement. The length and width between the Jacking points might differ from different models of car, so the design of the Jack should be able to accommodate as many types of models as much possible.

1) Literature review about preexisting equipments.
2) Define parameters for own design.
3) Desing possible solutions two concepts or more.
4) Necessary calculations.
5) Selection one design.
6) Create 3D CAD model.
7) Create production drawings.

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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] MAREK, J. et al. Design of CNC Machine Tools. Praha: MM publishing, 2015, 730 p. ISBN 978-80-260-8637-6.

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Head of Department

Liberec, dated: 15 November 2017

DECLARATION

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Abstract:

This work is to design a jack for lifting full scale clay model of production cars for the company Svott s.r.o. The jack must also be able to move on the factory floor as and whenever needed by the manufacturer. The design of the lifting device must have a capacity to lift models of about 5 tons in mass and also up to a height of 1 meter. The clay model of car is built of various materials assembled on a Steel frame with Four Jacking Points all in the same plane in a rectangular arrangement. The length and width between the Jacking points might differ from different models of car, so the design of the Jack should be able to accommodate as many types of models as much possible. The whole design is carried out in Catia V5 student.

Keywords:

Jack, Clay model, Lift, Load Capacity, Height, Steel Frame, Jacking Points, Design Models

Abstrakt:

Tato práce se zabývá návrhem zvedacího zařízení pro zvedání hliněného modelu automobilu v plném měřítku pro firmu Svott s.r.o. Zařízení musí být schopné se pohybovat po výrobní hale dle potřeby výrobce modelu. Konstrukce zvedacího zařízení musí mít schopnost uzvednout modely o hmotnosti přibližně 5 tun a také do výšky 1 metr. Hliněný model automobilu je vyroben z různých materiálů umístěných na ocelovém rámu se čtyřmi zdvižnými body, které jsou v jedné rovině v obdélníkovém uspořádání. Délka a šířka mezi body zdvihu se mohou lišit dle různých modelů automobilů, takže konstrukce zvedacího zařízení by měla být schopna přizpůsobit se co nejvíce typům modelů. Celý návrh byl proveden v sw Catia V5.

Klíčová slova:

zvedák, hliněný model, nosnost, ocelové rámy, body zdvihu, konstrukční modely

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List of Symbols

C_y	-	Reaction force at Point C
D_y	-	Reaction force at Point D
w	-	Weight of Load above Jack
w_{legs}	-	Weight of Scissor member legs
α	-	Angle of scissor member with base
β	-	Angle of Hydraulic cylinder with base
P	-	Hydraulic Cylinder Force
P_x	-	Horizontal component of Hydraulic force
P_y	-	Vertical component of Hydraulic force
F	-	Force acting on the scissor pivot
F_x	-	Horizontal component of Force F
F_y	-	Vertical component of Force F
a	-	Length between cylinder and scissor pivot
L	-	Length of scissor member
L_x	-	Horizontal component of length L
L_y	-	Vertical component of length L

1. Introduction

Ever since the designing of cars was seen as a work of art, the clay modelling has been a part of it. The people wanted to visualize the car even before it is manufactured. It was then realized the importance of hand modelling which revolutionized the automotive designing forever. The leap has taken us forward for the past 70 years from clay modelling to virtual reality. Although the modern designing methods are much faster and are more cost effective, still some of the automotive giants tend to use the clay for critical visualization. [1]

A perfect line for an aesthetic design comes from tireless re-shaping of line which is very difficult to do in a virtual software than a hand model. A designer breathes when he is near to the real model and can have an essence of it in Three-Dimension. [2]

A car clay model design starts with designer sketches. Then a rough skeleton of the design is made on a steel frame of adjustable length and width onto which the clay is laid in the form of cylinders. Then a programmed CNC is used to run onto the clay to form a rough surfaced car clay model. After a day or two, some professional clay sculptors do the detailed work for smooth and aesthetic looking model [3]. This clay model is final and scanned for further design process using computer software.

Fig 1 Automotive Clay model [4]

2. Aim of the Thesis

The main aim of this thesis is to design a mobile jack lifter device for automotive clay models for the company Svott s.r.o. The design must be optimal as well as economical for use. The jack must be able lift the clay model up to a height of 1 meter and be able to withstand 5 tons in capacity of mass of the clay model. The design is made very carefully considering all the safety factors so as to avoid any instability of the equipment.

Also, the jack must be able to move on the factory floor as and whenever needed. The floor conditions are assumed to be moderately rough so as to select the proper mobility mechanism or components.

The jack must be compatible with the frame structure given by the company and must be within the limits of the workspace of the factory. The whole design process is to be completed within the stipulated time period without compensating the effectiveness of the model.

3. Svott Design and Prototyping

The Company Svott s.r.o. is mainly specialized on providing services for car-design development and more. They have been working for world-leading automotive companies since 2007 with whom they collaborate on projects on car exterior and interior from A-class surfacing and visualization to the production of full size design-model prototypes.

The company uses high-end SW applications like ICEM SURF, AUTODESK ALIAS, CATIA V5 and rapid-prototyping technologies as 3D-printing or milling models from soft materials (clay, Polystyrene, PUR, etc.) up to 6m x 3m x 2m for the processes. [5]

Fig 2 Rapid Prototyping in the Company Svott s.r.o.

The Company mainly focuses on the below following areas of work:

- Design & styling
- A-class surfacing
- Visualization
- Reverse engineering
- 3d printing
- Clay modeling
- Prototyping

4. Description of Lifting Jack

4.1. What is a jack?

A jack is a device which is used to lift heavy masses up to certain height for many further usages. It is also used for special purposes in areas of high force applications. A vehicle jack uses the power of hydraulics to lift up part of a car allowing the user access to change a tire or perform repairs or maintenance. Jacks come in a variety of types and weight ratings. Choosing the right kind of jack for the work being performed is key, not only for the safety of the mechanic, but the vehicle as well.

4.2. Types of Jack

4.2.1. Floor Jack

A floor jack is the most common type of jack used for maintenance and repairs. They are easy to move around and position in the exact spot that needs to be lifted. A floor jack consists of a low to the ground unit with four wheels and a long handle that the user pumps to operate the hydraulic lift portion of the jack. The jack saddle is a round disk that makes contact with the vehicle.

Fig 3 Floor Jack

The low profile of the base unit allows it to be easily maneuvered. The handle must be turned clockwise which closes the valve before pumping the handle to raise the jack. The handle is turned counter clockwise to open the valve and lower the jack saddle. [6]

Floor jacks are the workhorses of the jack community and they are extremely helpful when performing work that requires the mechanic to get underneath the vehicle. [7]

4.2.2. Scissor Jack

A scissor jack is the type of jack that most people have in the trunk of their car. It uses a screw mechanism to produce the lifting power. The main advantage of this type of jack is its small size and portability.

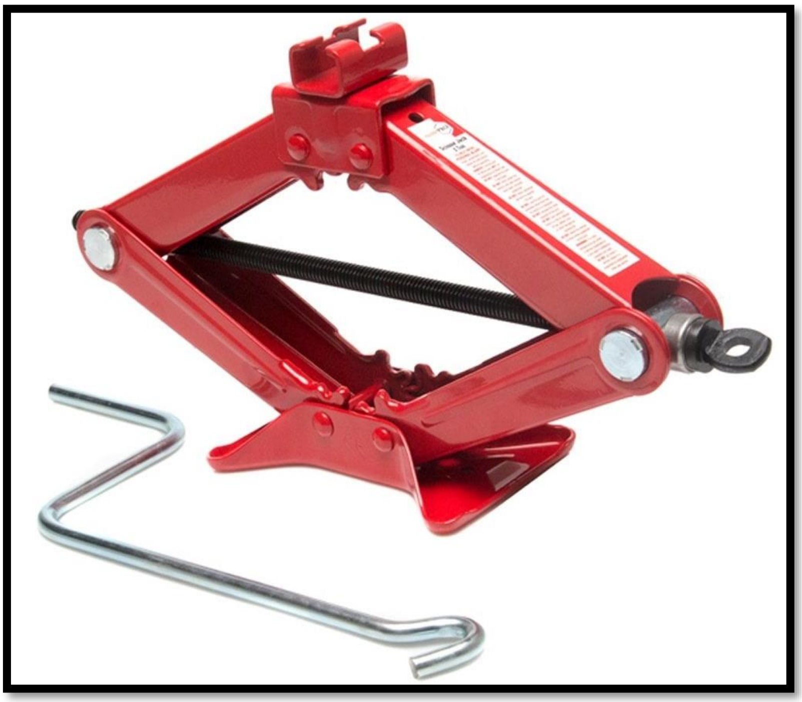

Fig 4 Scissor Jack

The jack is placed underneath the spot to be lifted and the screw is turned using a handle to raise or lower the vehicle. In many cases the handle will be the tire iron that is included with the car.

In most cases the jack that is included with the vehicle is designed to fit the specific lifting spots on the car. If a replacement is needed, verify that it will fit the car and has a lifting capacity that is appropriate for the vehicle. [8]

4.2.3. Bottle Jack

This bottle shaped jack uses either hydraulic or pneumatic pressure to lift heavy vehicles and other large equipment. These jacks have a high lifting capacity and must be used on a hard and level surface. A lever is inserted and pumped to lift the vehicle.

Fig 5 Bottle Jack

While bottle jacks are high capacity and are quite portable, they lack the mobility of a floor jack and are not stable enough to be used on the side of a road, making them less than ideal for changing a tire.

As with all jacks, check the lifting capacity of a bottle jack against the weight of the vehicle before using it. [9]

4.2.4. Hi-Lift Jack

This is a specialty jack that is used with lifted or off-road vehicles. These jacks are mainly used in off road situations or where rugged terrain limits the use of other types of jacks. The lifting mechanism is basically a cast steel socket which drops over the top of the rack which contains two hardened steel lifting pegs. These ‘pegs’ are chamfered on their no-load tops and are pushed into the holes in the rack by two light springs.

To the bottom of the lifting mechanism is the ‘toe’ which carries the weight of the load. On the opposite side of the top is pivoted the operating handle. The “Hi-Lift” has a two-piece handle and the “Jackall” is all in one. In either case, just above the handles’ pivot point is a further pivot to which a short link is attached to its lower runner that carries one of the two ‘pegs’. The upper runner which is the main body of the mechanism carries the top ‘peg’.

Fig 6 Hi-Lift Jack

Hi-lift jacks are often high capacity, rated up to 7,000 pounds and can lift a vehicle up to five feet. They are usually 3 to 5 feet long and can weigh up to 30 pounds making them unsuitable for carrying around in a typical car. [10]

4.2.5. Scissor Platform Lift

A scissor lift is a type of platform that can usually only move vertically. The mechanism to achieve this is the use of linked, folding supports in a crisscross "X" pattern, known as a pantograph (or scissor mechanism). The upward motion is achieved by the application of pressure to the outside of the lowest set of supports, elongating the crossing pattern, and propelling the work platform vertically. The platform may also have an extending "bridge" to allow closer access to the work area, because of the inherent limits of vertical-only movement.

The contraction of the scissor action can be hydraulic, pneumatic or mechanical (via a leadscrew or rack and pinion system). Depending on the power system employed on the lift, it may require no power to enter "descent" mode, but rather a simple release of hydraulic or pneumatic pressure. This is the main reason that these methods of powering the lifts are preferred, as it allows a fail-safe option of returning the platform to the ground by release of a manual valve. [11]

Fig 7 Scissor Platform Lift

4.3. Comparision of Jack types

Table 1 Jack Types Comparison

Features	*Floor Jack*	*Bottle Jack*	*Scissor Jack*	*Hi-Lift Jack*	*Scissor Platform*
Lifting-Type	Hydraulic	Hydraulic	Mechanical	Mechanical	Hydraulic/ Pneumatic
Load Capacity	4 Tons	50 Tons	2.5 Tons	3 Tons	2 Tons
Lifting Height	0.5m	0.45m	0.6m	1.5m	12m
Portability	Medium	Good	Very Good	Medium	Not Good
Human Effort	Very less	Very Less	Medium	Less	Less
Lifting Time	Fast	Average	Average	Too Slow	Slow

Each of the Jack has its own type of pros and cons. The best lifting device to be selected depends on the type of applications. Below given is a graphical representation of the comparison between different types of jacks.

They are scored on a scale of 1-10 where 10 means a better feature as compared to other jacks.

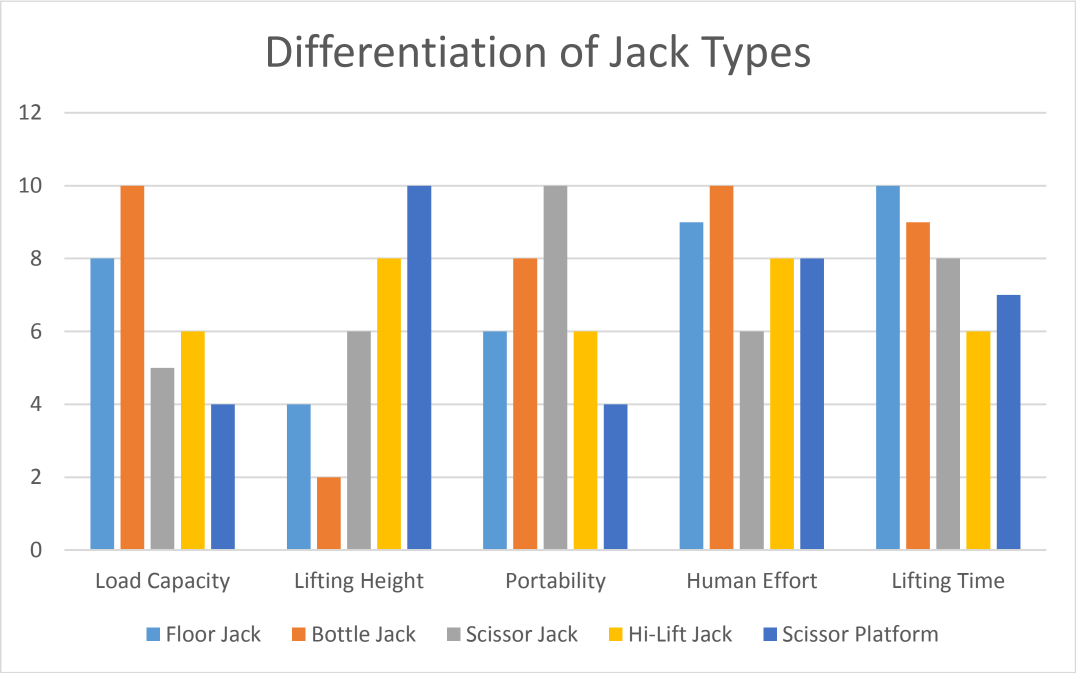

Fig 8 Differentiation Graph for Jack Types

From the above chart, it is clear that the lifting height is a big advantage for the scissor platform. Moreover, the load capacity is highest for the bottle jack which is no wonder because of the high-pressure fluid in the hydraulic system which enables to lift heavy loads.

In this thesis, we are going to combine both these features together to make a sustainable design to achieve the perfect combination of lifting height and load capacity.

5. Description of Design Requirements

5.1. Requirements of Jack Design

Based on the different models of cars modeled by the company Svott, some parameters were analyzed and fixed for designing of the jack. These data were concluded by the company itself according to their needs. Hence, the proposed design requirements of jack are:

Table 2 Design requirements of Jack

Design Parameter	**Required Value**
Longitudinal Distance between two jack points	1400 mm
Transversal Distance between two jack points	950 mm
Maximum Overall Height	1000 mm
Minimum Headroom	150 mm
Minimum Load Capacity	5 tons

5.2. Components of Clay Model

The automotive clay model for which the jack is designed consists of various elements. The whole clay model can be divided into four portions:

- Structural Frame
- Shape skeleton
- Wax Clay
- Other accessories (Ex. Wheels, paint)

In this Thesis work, our main focus will be on Structural Frame to which our jack will be attached for lifting.

5.2.1. Structural Frame

The structural frame is the part which holds all the other sub-components together in place. Also, it provides strength to the clay model. The approximate mass of the frame is 750 kilograms. The company Svott s.r.o. is using an adjustable frame as shown in Fig. 3.1 below.

This type of Frame is generally referred to as ladder frame which is generally used in heavy vehicles like trucks. The ladder frame is one of the simplest and oldest of all designs. It consists of two symmetrical beams, rails, or channels running the length of the vehicle, and several transverse cross-members connecting them.

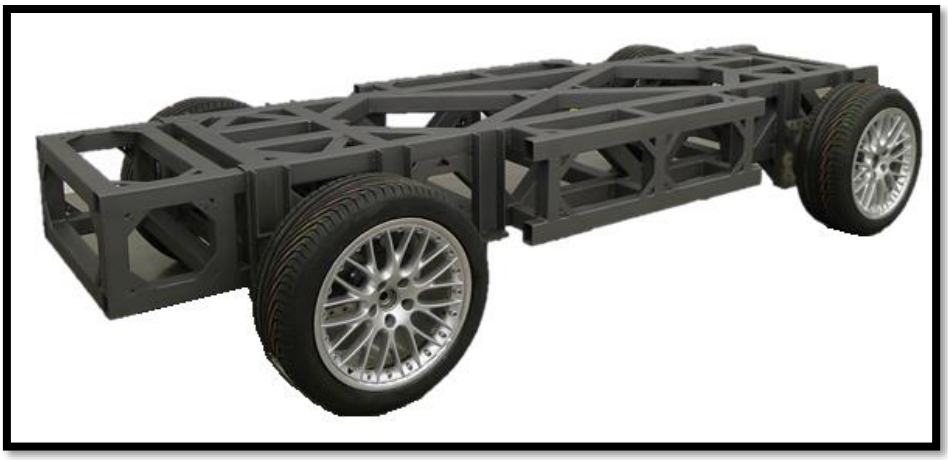

Fig 9 Clay model Frame in Svott Company

The maximum length and width of the frame are 3550 (+420 mm adjustable) and 918 mm respectively as shown in Fig 3.2.

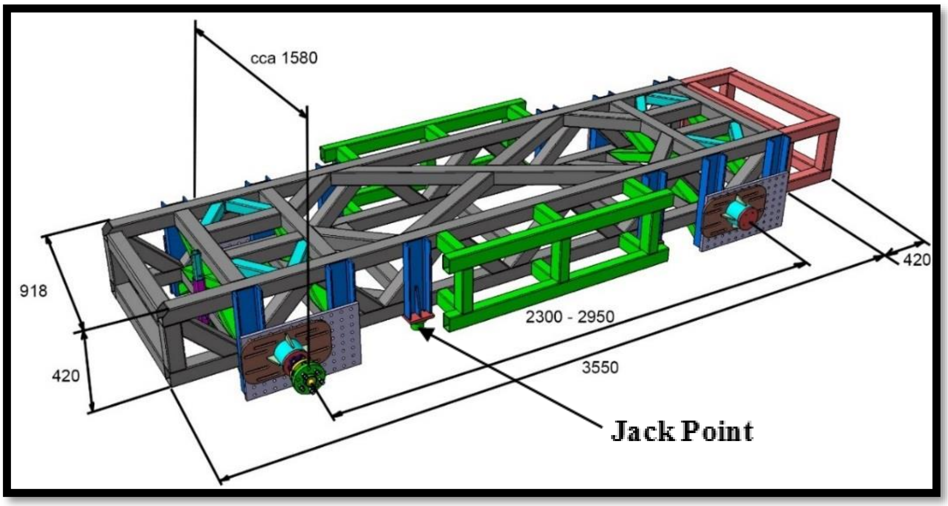

Fig 10 Structural Frame Design model with Dimensions

This frame consists of four jack points. The given longitudinal and transversal length between the jack points varies for different frames. So, to accommodate all, the design of the jack may be made in such a way that it may vary its own length and width.

But due to the time constrain, this jack will be designed only for one type of frame having a standard width and length between Jacking points as shown in the below fig 8 & 9 clearly.

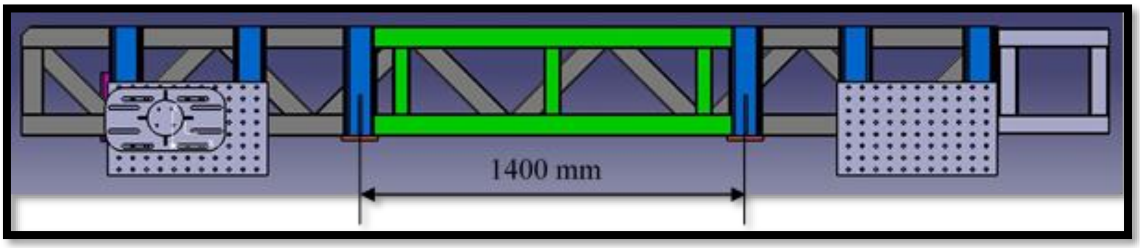

Fig 11 Longitudinal distance between the Jack Points

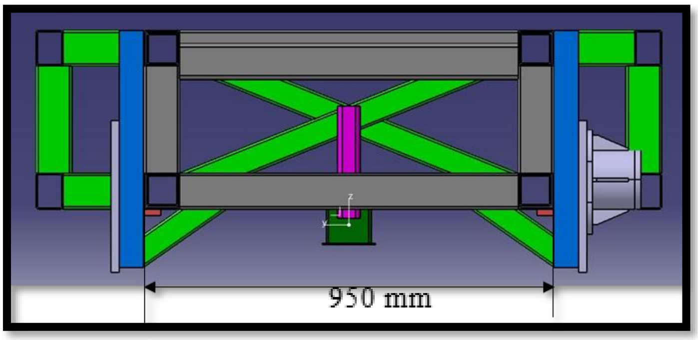

Fig 12 Transversal distance between the Jack Points

5.2.2. Shape Skeleton

The shape skeleton is made up of Chipboard and Foam sits on top of frame and defines the basic layout of the clay which will be laid onto it. The Approximate mass of Chipboard and Foam are:

- Mass of Chip board : 120 – 180 Kilograms
- Mass of Foam : 50 – 80 Kilograms

The Foam is then machined using CNC to get a rough design shape after which the clay is laid. The arrangement of the frame, chipboard and the foam together look as shown in Fig 10.

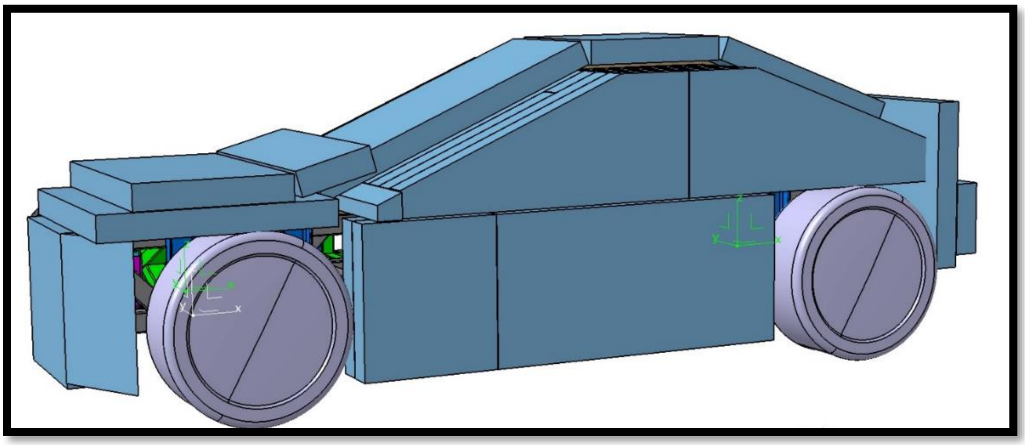

Fig 13 Arrangement of the frame, chipboard and the foam together

The hand modeler applies the clay to 12 to 18 inches of foam cut into the rough shape of a vehicle, which is itself attached to an armature of lightweight steel with adjustable fittings. Those fittings are placed to reflect the briefing the designers are working from, so that the model is built with hard constraints showing overall wheelbase, powertrain, and people packaging. The model would weigh probably ten tons if it were all made of clay. A cut section view of the Foam and Chipboard is shown below in Fig 3.6.

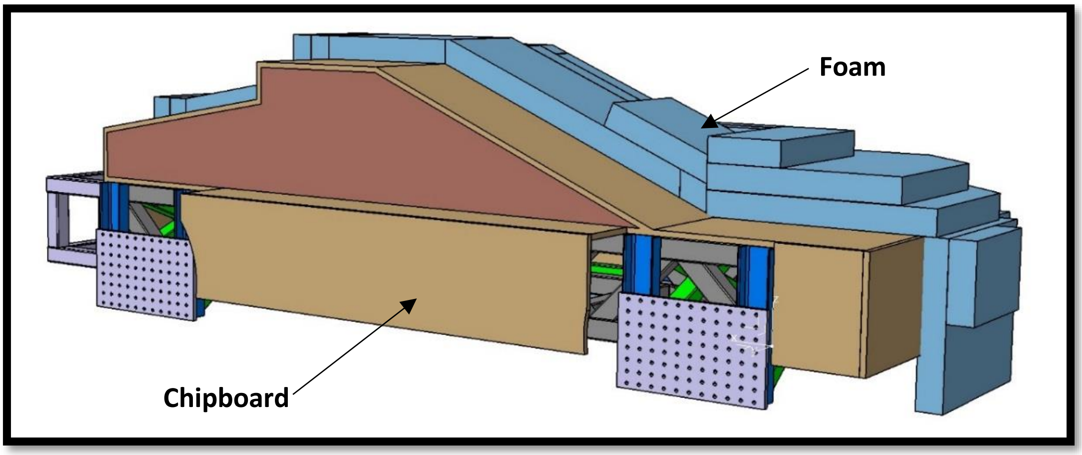

Fig 14 Cut section view of the Foam and Chipboard

5.2.3. Wax Clay

The first thing to know about this marvelous medium is that it isn't actually clay. Clay is different waxes with some filler in it. There are half a dozen companies that make plasticine clay suitable for full-scale design modelling (a few car companies make their own blends), and they deliver their product to design shops on flatbed trucks by the pallet-load. But, in the company Svott, they buy readily available Mars Clay which is specifically used for car clay modelling.

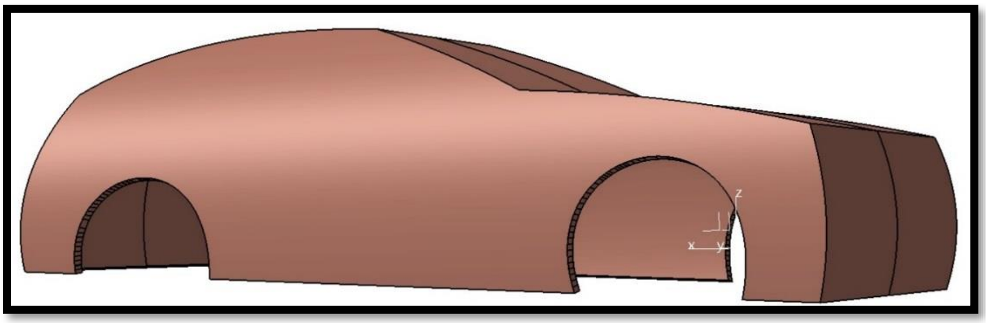

Fig 15 Final Clay Layer on the Foam

In a typical year, Svott goes through about 100 tons of the stuff, formed into hard, extruded cylinders about 3-4 inches in diameter. When a designer is ready to build, a lump of it is heated to about 66°C (150°F) and applied onto the foam.

5.2.4. Other Accessories

As the design reaches its aesthetic perfection according to the hand modelers, items like headlights and turn signals get added to clay to turn it into a hard model. The entire model is then coated with a stretchable modelling film (known, Kleenex-like, by the original trade name DI-NOC) that mimics the look and feel of a painted surface. A symmetrically half completed design model is shown below in Fig. 13.

Fig 16 One-side coated clay model [12]

The design remains flexible, though, with clay being smoothed on or scraped off until the final design is approved by corporate executives milling around in the factory floor itself. Once that happens, a model (still nonfunctional, but very expensive) of fiberglass or resin, perfect inside and out, is created for people to see at press events and car shows. A perfectly looking final clay model is ready for presentation with headlamps, wheels, etc.

6. Possible Design Solutions

There are many possible solutions for the design of jack. These ideas were constituted as a result of extensive research over various books and patents. In some cases, only a part of the system was taken which assembled together gave a possible solution. Hence, based on market trends and requirements of the company, there are the feasible solutions for the jack:

- Electrically driven Hi-lift system
- Pneumatic bag assisted platform-type
- Hydraulic piston assisted platform-type

Each of the above given possible solutions were researched and analyzed thoroughly to conclude the most feasible solution. Some of the considerations taken while narrowing down the final design included the following:

- The safety factor of the design was given the highest priority
- The jack must be economical enough to be commercially available
- The maintenance must be minimum to give the user an enhanced experience and concentrate more on the subject of work
- The overall efficiency of the equipment related to power, load capacity etc.
- The flexibility of the machine to change over different frames if required.
- Time taken for lifting and retraction of the jack

6.1. Electrically driven Hi-lift system

It is a type of portable electrically driven automobile jack lift. In automobile lifts of the type having a vertically movable load lifting carriage, there are numerous ways to drive the carriage upwardly and downwardly. One of the simplest and most effective ways of driving a load lifting carriage is by electric motive power.

Oftentimes it is desired to use a pair of portable jacks to lift both ends of an automobile. By using a pair of portable jacks, it may be possible to raise an entire automobile in much the same manner as the larger, stationary automotive lifts. To perform work on the underside of an automobile, it is necessary to lift an automobile to a considerable height. For this purpose, jacks having a high lift are required.

High lift jacks employing screw shafts tend to become heavy and bulky. There are several reasons for this. The screw usually must be quite large in diameter in order to tolerate the weight of the load to be lifted. Since the screw shaft itself must be large, the support for the base of the screw shaft usually must be comparatively heavy. [13]

Some of the features of mobile column lifter WERTHER LTW

- 4-8 columns with total capacity 22 - 44 tons
- Electromechanical system with Nylatron GSM nuts
- Automatic lubrication of nuts
- Control panel on the main pole and on each column. Up / Down / Stop
- Option to control each row of columns separately or all at once
- Electronic synchronization of all columns
- Maximum distance between columns 12 m
- Stroke 1750 mm, column height 2484 mm
- Each column with 2 motors

Fig 17 Electrically driven Hi-lift system

One method of controlling the extent of vertical travel of the carriage and also of controlling a safety lock mechanism is to provide a plurality of limit switches which are engaged during the travel of the carriage. The switches are used to shut off the source of motive power. Provision of a plurality of switches, however, is not desirable due to the complexity of the circuit arrangement and the cost of providing several switches in the path of the carriage.

Furthermore, if the electric power system should require repair, all of the switches would have to be removed along with the remainder of the power unit. This would be expensive and difficult, if not impossible, since the Switches and their circuit connections are desirably enclosed within a portion of the jack frame.

However, electrically operated jacks have not been widely accepted. One reason for this is that the control of the jack may be quite complicated and require expensive structure. Necessarily, means must be provided to limit the vertical travel of the carriage since it would be destructive of the jack if the carriage were permitted to move too far upwardly or downwardly. Also, it is desirable to provide a safety lock mechanism to lock the carriage in its upper position to insure against accidental downward travel of the carriage beam and the load carried thereby. [14]

6.2. Pneumatic bag assisted platform-type

Kolb Portable Lifts let you place your full-scale clay models wherever you want to work on them.

Some of the features of Kolb Portable Lifts are:

- Moving on integrated air pads
- Easy to handle and flexible
- Floating on nothing else but air, heavy models will be gliding through the studio pushed by a single person
- The lifting function provides a comfortable working position for the modelers on all parts of the model.

Kolb Portable Lift is available with lifting capacities of 2.8 tons and 3.2 tons.

Fig 18 Kolb Portable Lift

Design specifications of 3.2-ton Kolb portable lift:

- Max. Lifting capacity: 3.2 t
- Lifting time (empty): approx. 25 secs
- Lowering time (empty): approx. 35 secs
- Max. Lifting height of platform: approx. 825 mm
- Min. Headroom: 150 mm
- Max. Overall height: 950 mm
- Base body width: approx. 1,100 mm
- Base body length: approx. 2,000 mm
- Weight: approx. 480 kg
- Quantity of air cushions: 4
- Pneumatic connection to supply system: 8 bar (min. 6 bar) [15]

Pneumatic systems use pressurized gas to power machines and tools. There are many disadvantages and advantages of pneumatic systems. The pros and cons of a pneumatic system:

Pros:

- Source availability: Pneumatic systems require air to operate successfully. As a result of air being extremely abundant, and free, it is easy to restock the system.
- Safety: As a result of pneumatic systems running on air, safety hazards are significantly reduced. There are limited occurrences of fires because air is non-flammable, and leakages in the system do not negatively affect the outside environment
- Cost effectiveness: The initial cost of manufacturing a pneumatic device is minimal as a result of the low-cost design materials. Plastics, zinc, and aluminum are all relatively affordable materials that are commonly found in pneumatic designs.
- Cleanliness- As a result of the system being powered solely by air, the pneumatic device typically requires limited cleaning. Pressurized air constantly pushes out dirt or debris that get stuck in the system. If there is a blockage, the simplicity of the design also helps. Due to the limited amounts of tubes, the system can be easily disassembled and cleaned.
- Maintenance- In order for the system to properly operate it must be lubricated with oil consistently but they have less plumbing than hydraulic systems.

Cons:

- Control and Speed- Air is a compressible gas, which makes control and speed in a pneumatic system more difficult, in comparison to electric or hydraulic systems. When specific speeds are needed, additional devices have to be attached to the pneumatic system in order to procure the desired result.
- Maintenance- Pneumatic systems are less durable that hydraulic counterparts. Due to moisture accumulation the system can freeze up.
- Safety: Pipes that feed the system air have the ability to move on uncontrollably on their own, which could cause serious injuries to those nearby

- Environment suitability: Devices are known to fail over long periods of time due to the dampening of inside edges in the tubes. Additionally, systems cannot operate underwater and are sensitive to changing temperatures and vibrations
- Loudness: Pneumatic systems are the loudest type of designs that power machines. Actuators that run the system are the source of the noise and are sometimes placed in a separate room to limit sound pollution.
- Toxins and chemicals: Sometimes, pneumatic systems use hazardous chemicals in their design. This can result in accidental launches of chemicals into the air, which can be harmful to the surrounding environment. [16]

6.3. Hydraulic piston assisted platform-type

A lifting device, for vehicles, has two support platforms. Scissor mechanisms connect these platforms, to bases, and are actuated by hydraulic piston and cylinder assemblies. A combiner and divider valve supplies fluid to the two hydraulic cylinders. A single cross brace can be provided between the two support platforms. This ensures the two platforms operate uniformly, even for an uneven load distribution, while giving a clear working space.

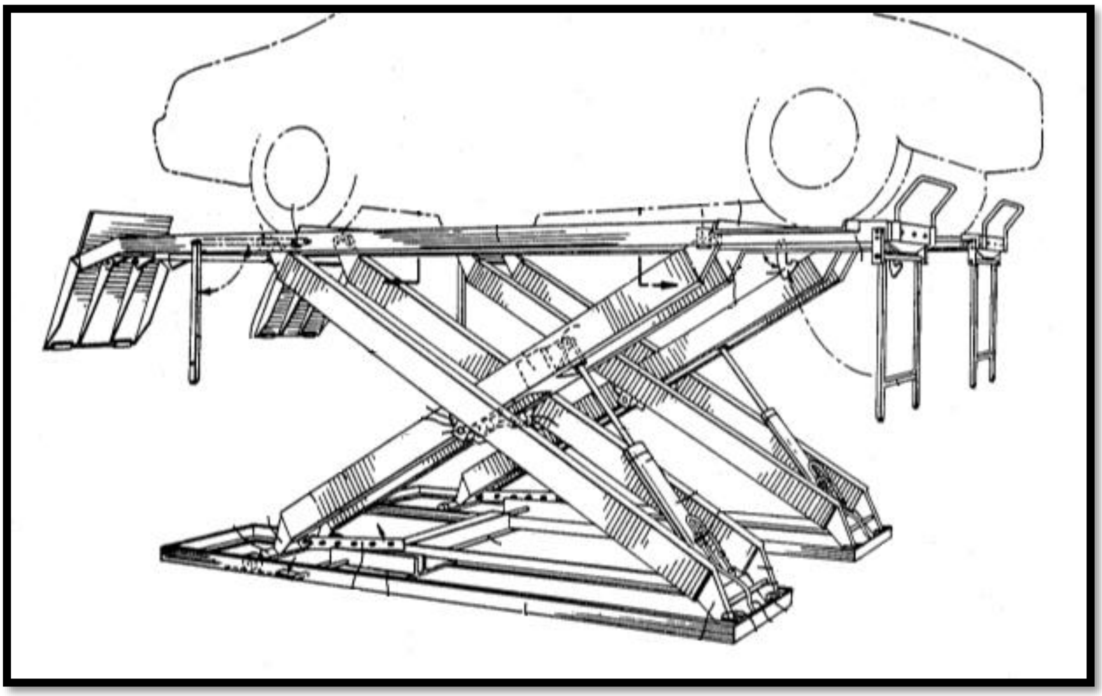

Fig 19 Hydraulic piston assisted platform-type Jack [17]

The concept of a scissors lift with hydraulic power comes from Pascal’s law applied in car jacks and hydraulic rams which states that “The pressure exerted any-where in a conformed incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure ratio remains the same”. [18]

Since the emergence in the light of different cultural achievements, the individual tries to maximize their use to facilitate the work. Only a century ago, the society did not have the opportunity even to dream about what is already openly available at present. The rough labor is replaced by technology, for example lifting mechanisms.

A scissor lift elevator is a vertical transportation cab which is raised and lowered from underneath, somewhat like a traditional hydraulic elevator, except that instead of a hydraulic cylinder the extendable mechanism is a folding lattice of crisscrossed beams similar to a pantograph. The entire mechanism extends upward when pressure is applied to the lowest members. [19]

Generally, these devices can be split into two categories. In one category, a vehicle is lifted by its wheel, whilst in a second category, the vehicle is supported by its chassis or bodywork, with its wheels hanging freely.

6.3.1. Lifting by alignment rack

The first category of lifting devices is necessary for carrying out alignment work. Alignment involves adjusting the steering mechanism of a vehicle, to ensure that the wheels are properly aligned. It cannot be carried out with the wheels hanging freely. It has to be carried out with the suspension loaded to its usual working position. To this end, so-called alignment racks are provided. These include rotatable turn plates on which the front or steering wheels of the vehicle are located. Then, without moving the vehicle, the steering wheels can be readily turned, to adjust the alignment etc.

Usually, the vehicle is lifted by the alignment rack, to give free access to the steering mechanism underneath the vehicle. However, such alignment racks are unsuited for many other types of work. If parts of the suspension mechanism need to be replaced, or if the brakes of the vehicle require work, then it is necessary to support the vehicle, with the wheels and suspension hanging freely. Such work cannot be carried out on conventional alignment racks.

6.3.2. Lifting by vehicle chassis / frame

The second category of lifting are used for carrying out a variety of maintenance work on vehicles. Many current designs include two or four posts above the ground. In these posts, a variety of somewhat complex mechanisms including, for example, hydraulic cylinders and chains are provided. The mechanism is connected to a platform for lifting a vehicle. In use, a vehicle is positioned above the platform. The platform includes movable supports, which are located beneath the support points of the chassis of the vehicle etc. Then, the mechanisms in the posts can be used to lift the platform and vehicle up. This then lifts the vehicle, with the wheels hanging freely, so one can readily work on the brake system, etc.

However, such a lifting device has a number of disadvantages. It does not enable alignment work to be carried out, as the steering wheels are hanging freely. Also, whilst such a lifting mechanism provides free access underneath a vehicle, the provision of posts requires a lot of space. The mechanisms included often require a lot of maintenance.

Hydraulic systems use pressurized fluid to accomplish work with only a small amount of force. This works on the basis of Pascal's law, which states that an increase of pressure in any part of a confined fluid causes an equal increase of pressure throughout the container. If you apply a force to one part of a hydraulic system, it travels through the hydraulic fluid to the rest of the system.

Advantages of Hydraulic system

- Large load capacity with almost high accuracy and precision.
- Smooth movement.
- Automatic lubricating provision to reduce to wear.
- Division and distribution of hydraulic force are easily performed.
- Limiting and balancing of hydraulic forces are easily performed.

Disadvantages of Hydraulic system

- A hydraulic element needs to be machined to a high degree of precision.
- Leakage of hydraulic oil poses a problem to hydraulic operators.
- Special treatment is needed to protect them from rust, corrosion, dirt etc.,
- Hydraulic oil may pose problems if it disintegrates due to aging and chemical deterioration.
- Hydraulic oils are messy and almost highly flammable. [20]

7. Selection of Final concept and Prerequisites

On analyzing the market trends and similar design concepts, the Hydraulic Assisted Platform Elevator solution was most appropriate for meeting the given requirements. This conceptual model is a combination of many pre-invented equipment and currently available ones with some modifications required to match the company's demands. Some of the key characteristics of this feasible solution are:

- Optimal time for lifting and retracting of the clay model
- Safety lock for preventing any accidents
- Smooth movement on the factory floor while model is on the jack
- Different lifting heights available for different positions as required by the hand modeler
- Flexibility in customization of the jack equipment in future for long use
- Long life and lesser maintenance

7.1. Components of Hydraulic Assisted Platform Elevator

The main parts of our final design will include:

- A flat Lifting platform
- Two pair of scissor members
- Two Hydraulic cylinders
- Hydraulic control unit with motors for pressurization
- Safety lock system
- Wheels for movement on floor
- Jack stand pillars

7.2. Brief description of the Design

The scissors lift has a table surface where the weight can be placed. The rising of a platform is carried out due to work of a hydraulic cylinder. The management of the elevator is carried out by the control panel which has four buttons: the main switch, lowering, rise, and blocking.

The jack assembly comprises of first and second scissor units, resting on a base member, a support platform and a pair of levers which are pivotally interconnected adjacent their mid-points, one of which levers is pivotally connected at one end to the base member, and the other of which levers is pivotally attached at one end to the respective support platform, with the other ends of the levers being arranged for rotational and translational movement relative to the respective base member and support platform.

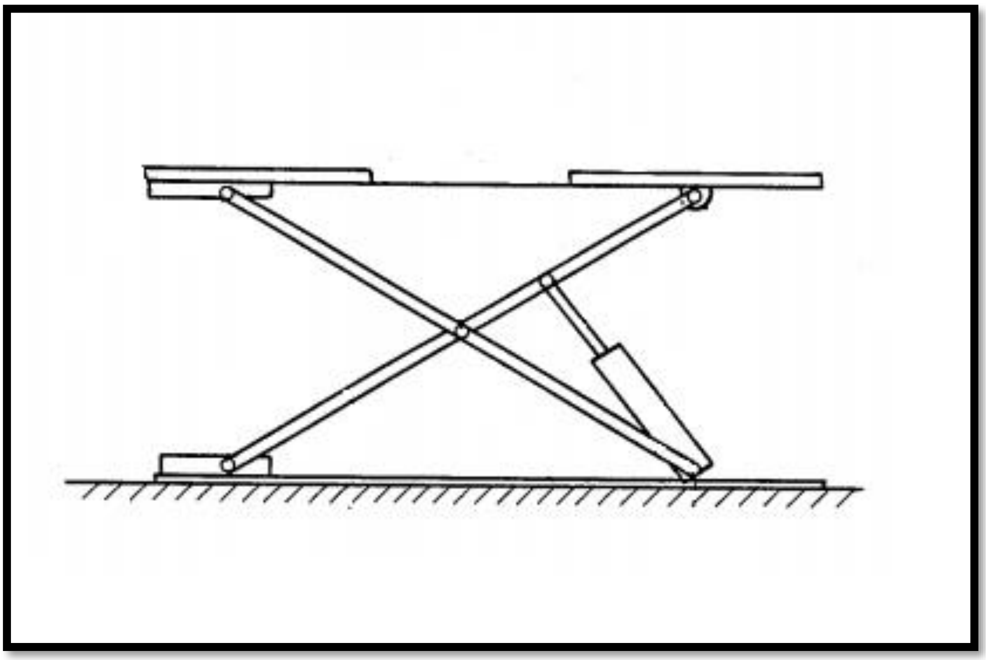

Fig 20 Side view of the scissor hydraulic platform jack [21]

For each scissor unit, a respective hydraulic piston and cylinder assembly pivotally are attached to the levers of the respective scissor unit. The above description is roughly shown in the above Fig 20.

For operating the scissors of the lifting platform according to a known arrangement, two pumps have been provided which are driven by a motor and each of which supplies a hydraulic cylinder with pressure medium which is assigned to one scissors of the lifting platform. In order to monitor the synchronization of the two pair of scissors, a cable is attached at the one pair of scissors movably by way of a spring and is coupled to the other pair of scissors. By way of a cam attached to a cable, it will be possible to operate a switch as soon as one of the two pairs of scissors leads or follows the other.

A rough 3-Dimensional model was created to visualize the size and to understand the assembly in more depth as shown in Fig 21. The 3D cad only contains structural members pertaining to approximate dimensions based on the given requirements as of now which will be optimized according to the strength and other factors.

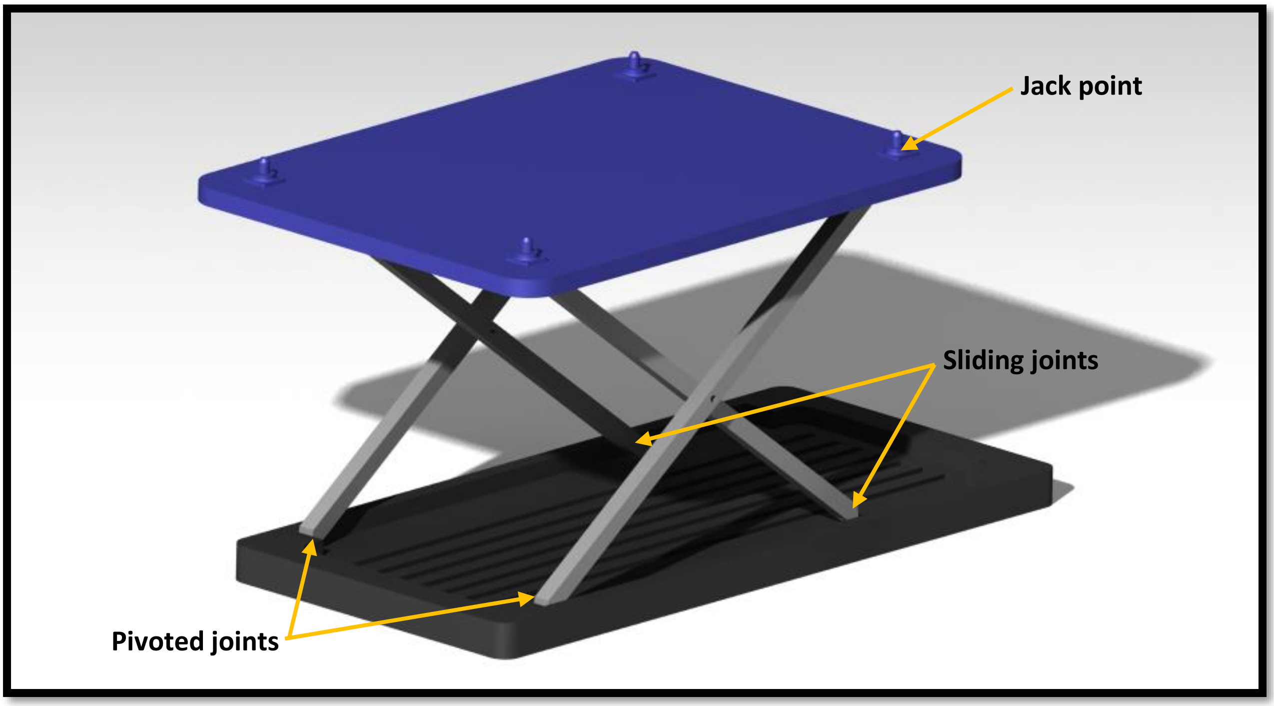

Fig 21 Basic CAD model of scissor hydraulic platform jack

It requires little space, and in particular minimizes the installation work required. There is no need to dig a pit. The device is simply located on the floor of a workshop, together with a unit for delivering hydraulic fluid at the required pressure.

It has an advantage of being relatively easy to assemble. As each cylinder is connected directly to the fluid source, air will automatically be bled from the system, after a few cycles. There is no need to carefully bleed the hydraulic circuit. This enables the device to be assembled by personnel who may not be skilled in hydraulics.

7.3. Material Selection

Depending on a component and tasks that this component performs the selection of a certain material is selected. Different parts of the mechanism take different load and stress because they carry out different functions. It is important to use an individual approach to select a material for every part. It impacts on a total efficiency and benefit received from each detail and best properties which can give different materials. Thus, it is necessary to allocate the main parts of a design and to explain features of each of them separately.

The main interest is made by the legs of the lift, the greatest part of loading is shared between them and they are a basic element of the assembly. It means that the material of which they are made has to be capable of maintaining this load. This part is subjected to a normal force which might cause buckling and shear force which cause bending, which possibly cause bending deformation or even braking of the part. An appropriate material for these purposes is structural steel, more precisely the AISI 1080 steel.

Table 3 AISI 1080 Material Properties

Properties	**Value / Percentage**
Carbon, C	0.75 - 0.88
Density	7.7-8.03 g/cm3
Elastic modulus	190-210 GPa
Poisson's ratio	0.27-0.30
Yield Strength	350-400 MPa
Tensile Strength	600-650 MPa

The second basic element of a design is the cylinder. From the technical point of view, it acts as a bar with pinned ends. It is subjected to direct compressive force which leads to bending and buckling load in the rod. Also, there exists the internal pressure of the fluid, which causes circumferential and longitudinal stresses all around the wall thickness. Thereby the cylinder must have such properties as strength, toughness, ductility and hardness.

There are also such components as top plates and base plates. The top plates take the load caused by a weight of lifting goods. The main needed property here is strength and the selected material is mild steel. The base plates are subjected to the weight of the load and scissors mechanism itself cylinder and legs, hence, hardness and stiffness are required. An appropriate material is mild steel. [22]

8. Calculations for Hydraulic System

The calculations of forces, stresses, and reactions of the structure play the most important role in the design because on the result of these calculations and its correctness depends stability, safety and successful work of the whole mechanism. The lifting table is a dynamic mechanism, but the speed of acting is relatively low, so this fact can be neglected and this system can be concerned as static. Then only two positions are needed to be considered, they are the initial position when the lift is lowered and just lying on the floor, and the highest position, when the mechanism lifted a weight on the highest possible distance. In these two positions, the highest reactions and internal forces are observed. In all the other positions the results will be between the two mentioned above.

8.1. Force acting on the cylinder

8.1.1. Lowest Position

While calculation, it is important to understand the behavior of the structure. For this, the simplified picture is used to focus on the main acting forces. Here is the free body diagram of the jack in the lowest position given below in Fig 22. [23]

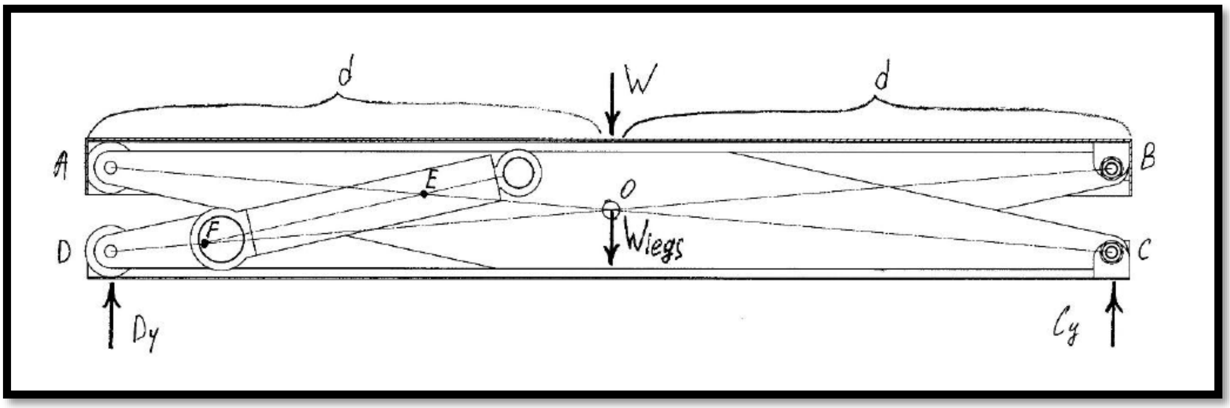

Fig 22 Jack Lowest Position

As it can be seen on Figure 22, A and D are roller supports and B and C are pin supports, point O is also a pin joint between two legs of the lift. Force W is applied as the weight of the load and it is acting in the middle of the table, dimension “d” shows it. Also, in the other plane which is not shown, the weight is supposed to be as well in the middle. When the force acting on the middle or shared over the table, it is transmitted equally to A and B supports. The "W_{legs}" is the load caused by a weight of the legs, it is also acting in the middle, but only in the initial position. Also, the total incoming forces must be equal to the total out coming, which means that whatever is happening inside the system the sum of reactions D_y and C_y would be equal to the weight. Then vertical reactions of D and C are half of the weight of the main load plus the weight of legs.

$$C_y = D_y = \frac{w + w_{legs}}{2} \qquad \text{… (8.1.1)}$$

EF from Figure 22 is the hydraulic cylinder and here it is acting like a truss. It is subjected a compression force, that means the cylinder acts with a certain force to the points E and F. On Figure 23 it can be seen how this force P is decomposed into a Y and X components according to the axes. And as a result:

$$\sin\beta = \frac{P_y}{P} \;\rightarrow\; P_y = P\sin\beta \qquad \text{… (8.1.2)}$$

$$\cos\beta = \frac{P_x}{P} \;\rightarrow\; P_x = P\cos\beta \qquad \text{… (8.1.3)}$$

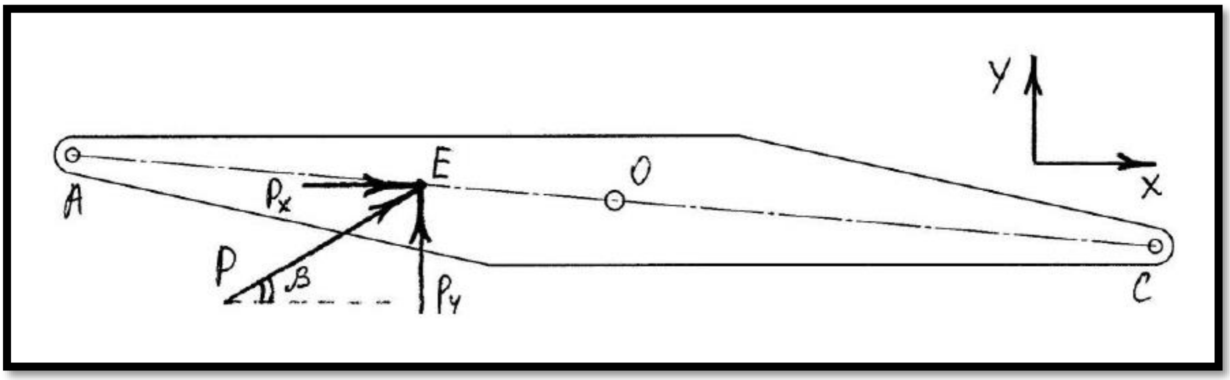

Fig 23 Force components at point E

Then the free body diagram is drawn for each leg separately on Figure 24. F_y and F_x are the components of F force acting on the pin, it is better to decom-pose it right now because its value and direction are not known yet.

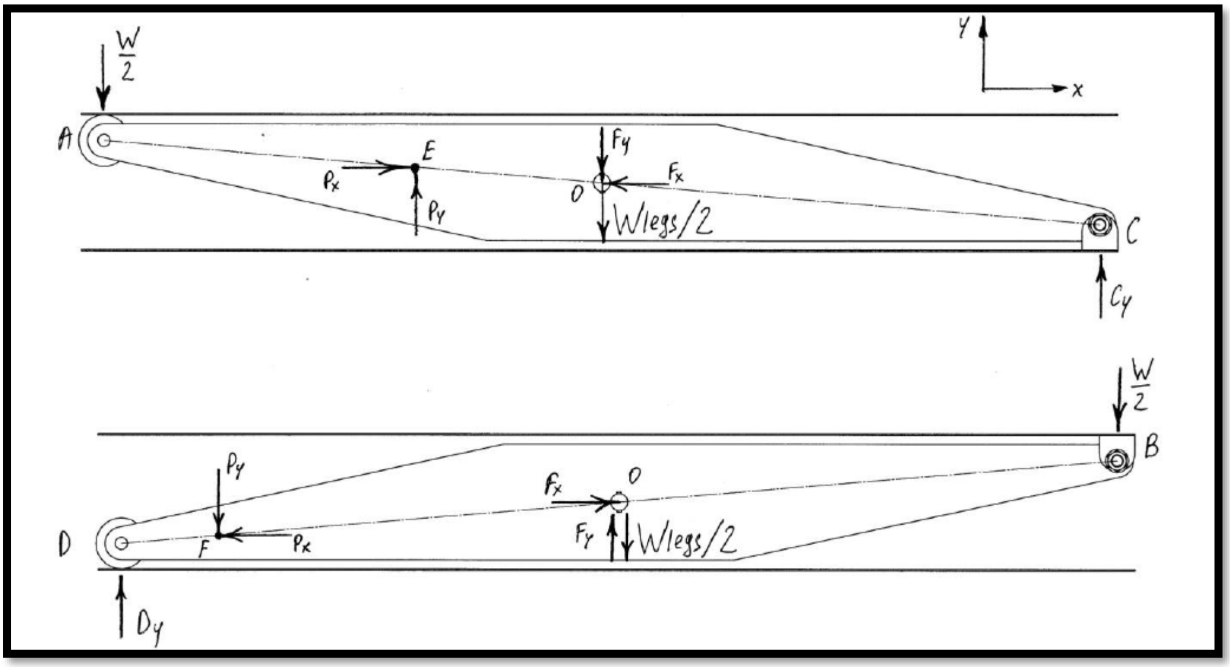

Fig 24 Free body diagram for each of leg separately

Also, it is needed to get the projections of the dimensions of the leg which will be called "L", the dimension between E and O is called "a". The analogous result may be used for projection of CE, the dimension of which is $\left(\frac{L}{2} + a\right)$ as shown on Figure 25.

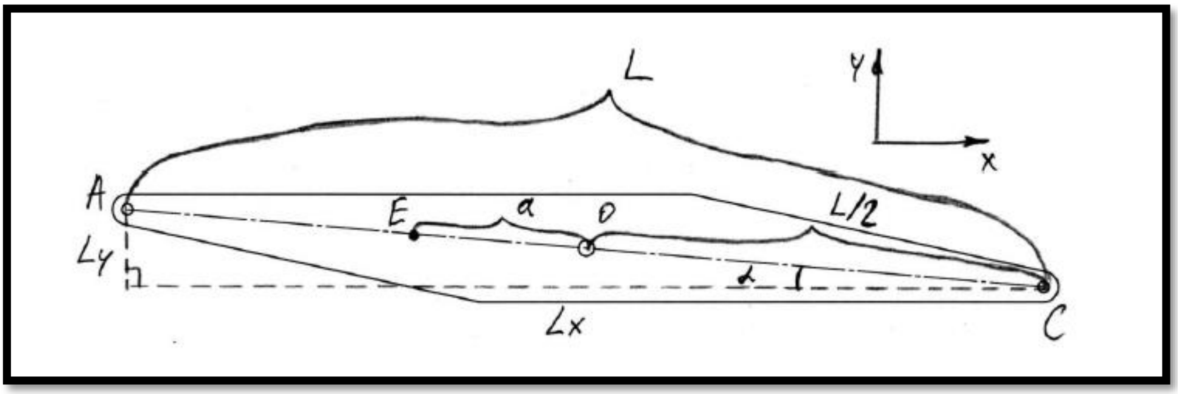

Fig 25 Projections of the leg

$$\cos\alpha = \frac{L_x}{L} \;\rightarrow\; L_x = L\cos\alpha$$

$$\sin\alpha = \frac{L_y}{L} \;\rightarrow\; L_y = L\sin\alpha$$

Then, using the diagram on Figure 25 it is needed to consider a balance of forces in Y and X directions and also the balance of moments created by the action of forces. It is done only for AC, but there will be an identical result on DB because the dimensions are the same.

$$\sum F_{ox} = 0 \;\rightarrow\; P_x - F_x = 0 = P_x = F_x$$

$$F_x = P\cos\beta \qquad \ldots (8.1.4)$$

$$\sum F_y = 0 \;\rightarrow\; -\frac{w}{2} + P_y - F_y - \frac{w_{legs}}{2} + C_y = 0$$

$$Hence, \qquad -\frac{w}{2} + P_y - F_y - \frac{w_{legs}}{2} + \frac{w + w_{legs}}{2} = 0 \;\rightarrow\; P_y = F_y$$

$$F_y = P\sin\beta \qquad \ldots (8.1.5)$$

Now, Taking moment about Point C (Counter-Clockwise positive Direction)

$$\sum M_C = 0$$

$$\frac{W_{legs}}{2}\left(\frac{L}{2}\right)\cos\alpha + \frac{w}{2}\left(\frac{L}{2}\right)\cos\alpha - P\sin\beta\left(\frac{L}{2} + a\right)\cos\alpha + F_y\left(\frac{L}{2}\right)\cos\alpha - P\cos\beta\left(\frac{L}{2} + a\right)\sin\alpha + F_x\left(\frac{L}{2}\right)\sin\alpha = 0$$

$$\frac{W_{legs}}{2}\left(\frac{L}{2}\right)\cos\alpha + \frac{w}{2}\left(\frac{L}{2}\right)\cos\alpha - P\sin\beta\left(\frac{L}{2} + a\right)\cos\alpha + P\sin\beta\left(\frac{L}{2}\right)\cos\alpha - P\cos\beta\left(\frac{L}{2} + a\right)\sin\alpha + P\cos\beta\left(\frac{L}{2}\right)\sin\alpha = 0$$

$$\frac{W_{legs}}{2}\left(\frac{L}{2}\right)\cos\alpha + \frac{w}{2}\left(\frac{L}{2}\right)\cos\alpha + P\left[-\sin\beta\left(\frac{L}{2} + a\right)\cos\alpha + \sin\beta\left(\frac{L}{2}\right)\cos\alpha - \cos\beta\left(\frac{L}{2} + a\right)\sin\alpha + \cos\beta\left(\frac{L}{2}\right)\sin\alpha\right] = 0$$

$$\frac{W_{legs}}{2}\left(\frac{L}{2}\right)\cos\alpha + \frac{w}{2}\left(\frac{L}{2}\right)\cos\alpha + P\left[\sin\beta\cos\alpha\left\{-\left(\frac{L}{2} + a\right) + \left(\frac{L}{2}\right)\right\} + \cos\beta\sin\alpha\left\{-\left(\frac{L}{2} + a\right) + \left(\frac{L}{2}\right)\right\}\right] = 0$$

$$\frac{W_{legs}}{2}\left(\frac{L}{2}\right)\cos\alpha + \frac{w}{2}\left(\frac{L}{2}\right)\cos\alpha + P[-a \times \{\sin\beta\cos\alpha + \cos\beta\sin\alpha\}] = 0$$

According to geometrical rules:

$$\sin\beta\cos\alpha + \cos\beta\sin\alpha = \sin(\alpha+\beta) \qquad [24] \qquad \dots (8.1.6)$$

Hence,

$$\boldsymbol{P} = \frac{\boldsymbol{a}\,.\mathbf{cos}\,\boldsymbol{\alpha}\left(\frac{w+w_{legs}}{4}\right)}{\boldsymbol{L}\,.\mathbf{sin}(\boldsymbol{\alpha}+\boldsymbol{\beta})} \qquad \dots (8.1.7)$$

In this thesis, there was the following order of actions: first, based on the existing examples and approximate representation what has to be the lifting device, rough 3D model was drawn, which can be seen on Figure 26, to get the needed measurements of different members with which calculations can be done. Then in case if the model does not correspond to the necessary result it can be changed in an appropriate way.

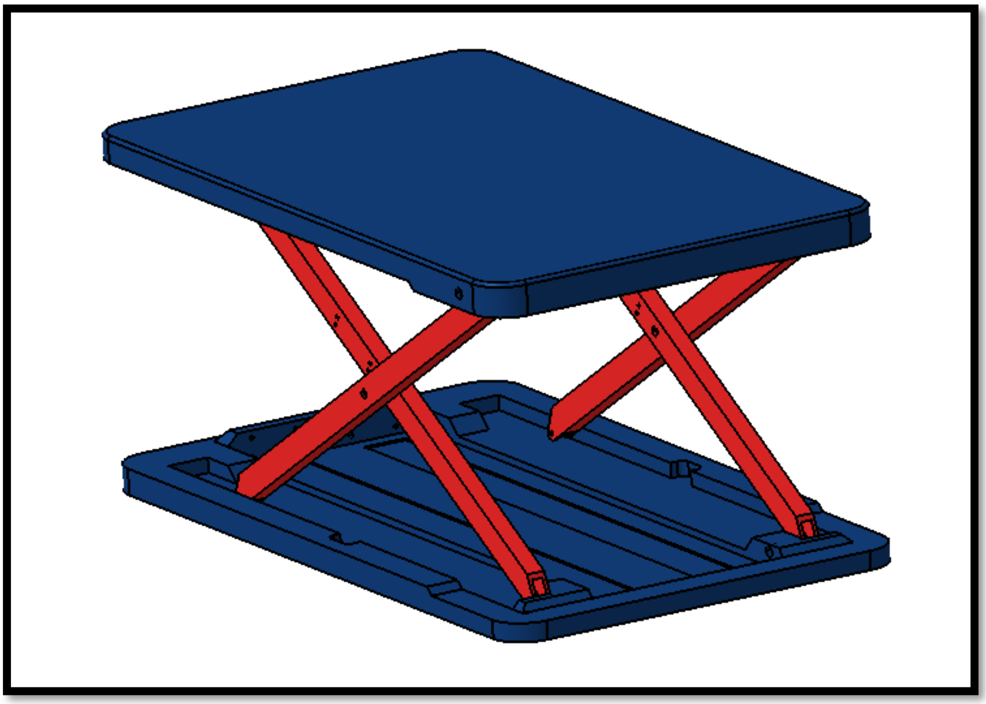

Fig 26 3-Dimensional view of the lifting device

Having the 3D, the needed dimensions for further calculations can be obtained, which can be seen on Figure 27.

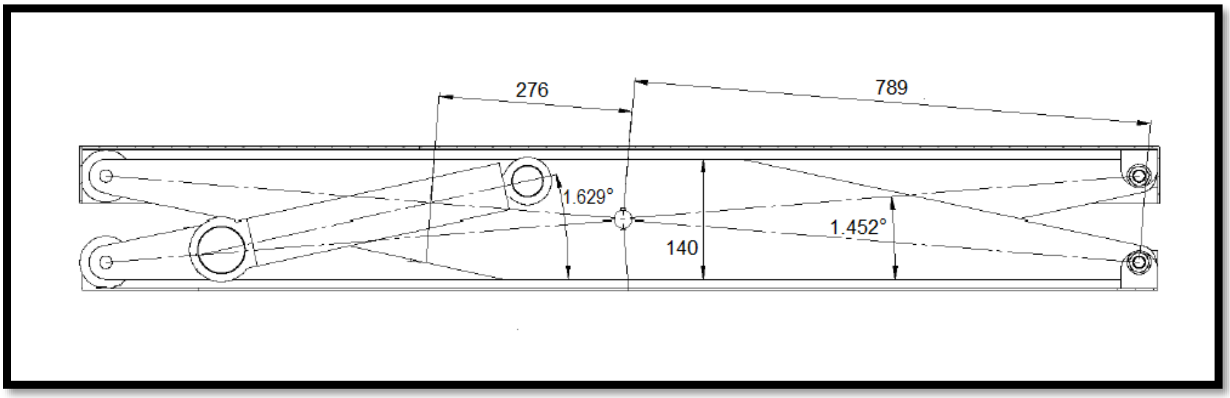

Fig 27 Dimensions in the lowest position

According to the design these are the following measurements:

- $L = 1578\,mm = 1578 \times 10^{-3} m$
- $a = 276\,mm = 276 \times 10^{-3} m$
- Mass of the load is 4500 kg.
- Mass of the legs is 51 kg.
- $\alpha = 1.452°$
- $\beta = 1.629°$

So,

$$P = \frac{a \,.\cos\alpha \left(\frac{w + w_{legs}}{4}\right)}{L\,.\sin(\alpha + \beta)}$$

$$= \frac{276 \times 10^{-3} \times \cos(1.452)\left(\frac{4500 + 51}{4}\right)}{1578 \times 10^{-3} \times \sin(1.452 + 1.629)} \times 9.81 \times 10^{-3}\,kN$$

$$\boldsymbol{P = 36.31\,kN}$$

8.1.2. Highest Position

On Figure 28 the free body diagram for the highest position of the lift is shown:

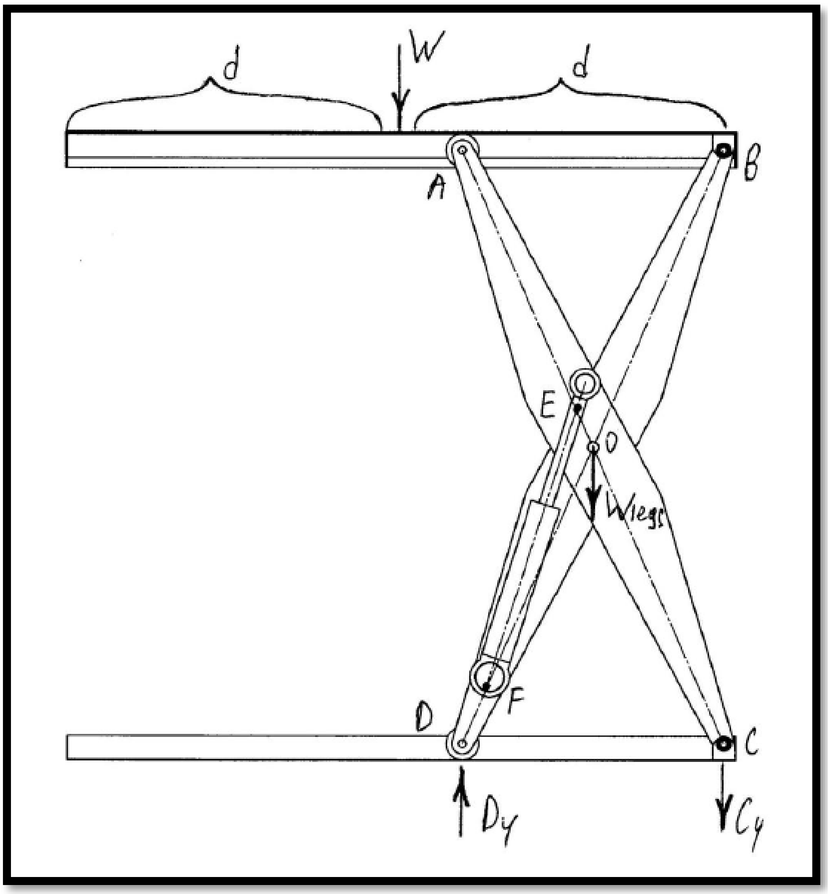

Fig 28 Jack at Highest Position

$d = 700\,mm$

$AB = 1336mm$

$$\sum M_C = 0 \rightarrow w.d + w_{legs}\left(\frac{AB}{2}\right) - D_y.AB = 0 \rightarrow D_y = \frac{w.d + w_{legs}\left(\frac{AB}{2}\right)}{AB} = 0.52w + 0.5w_{legs}$$

… (8.2.1)

$$\sum F_{oy} = 0 \rightarrow D_y - C_y - w_{legs} - w = 0 \rightarrow C_y = 0.52w + 0.5w_{legs} - w_{legs} - w \rightarrow$$

$$C_y = -0.48w - 0.5w_{legs}$$ … (8.2.2)

According to the behavior of the legs: $C_y = -B_y$ and $D_y = -A_y$ for the free body diagrams of the legs in the highest position which is shown on Figure 29. Calculations are done only for AC, but there will be an identical result on DB because dimensions are the same.

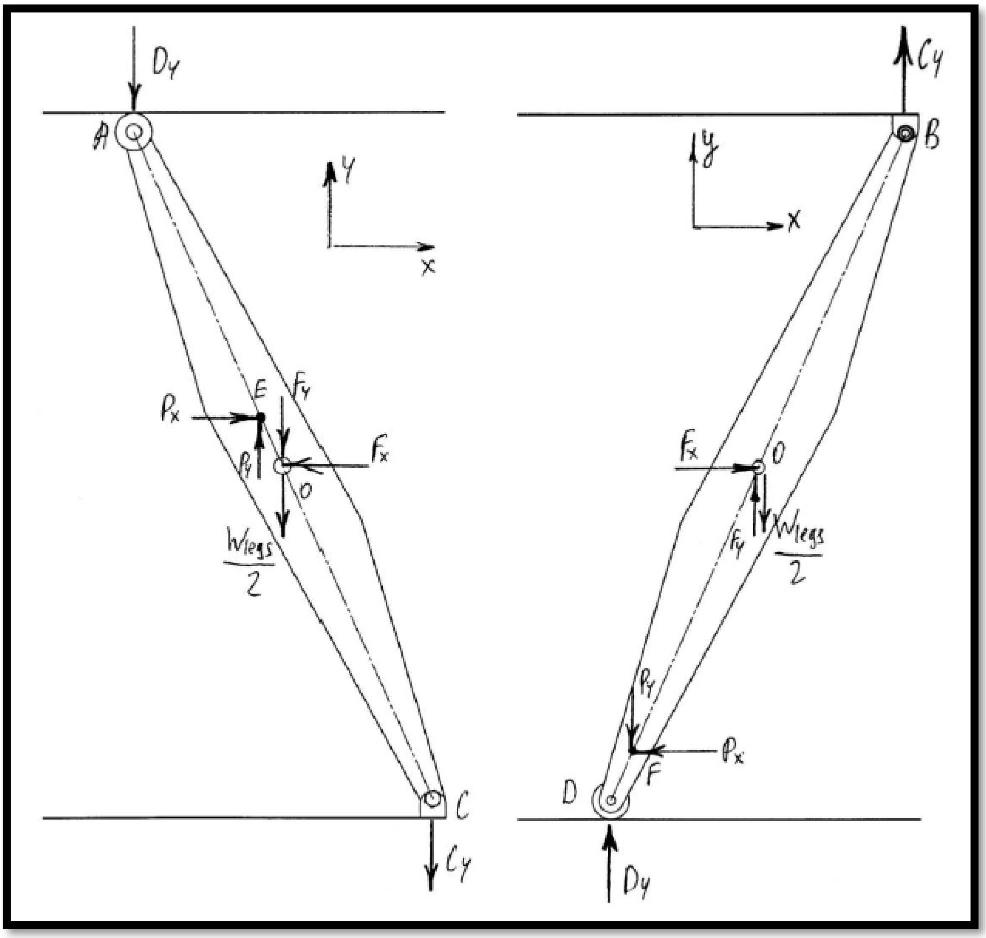

Fig 29 Free body diagram of legs in highest position

$$\sum F_{ox} = 0 \;\rightarrow\; P_x - F_x = 0 \;\rightarrow\; P_x = F_x$$

$$F_x = P\cos\beta \qquad \dots (8.2.3)$$

$$\sum F_{oy} = 0 \;\rightarrow\; -D_y + P_y - F_y - \frac{w_{legs}}{2} - C_y = 0$$

$$\rightarrow F_y = P_y - D_y - \frac{w_{legs}}{2} - C_y$$

$$= P_y - 0.52w - 0.5w_{legs} - \frac{w_{legs}}{2} + 0.48w + 0.5w_{legs}$$

$$= P_y - 0.04w - 0.5w_{legs}$$

$$F_y = P\sin\beta - 0.04w - 0.5w_{legs} \qquad \dots (8.2.4)$$

Now, Taking moment about Point C (Counter-Clockwise positive Direction)

$$\sum M_C = 0$$

Hence,

$$\frac{W_{legs}}{2}\left(\frac{L}{2}\right)\cos\alpha + D_y L\cos\alpha - P\sin\beta\left(\frac{L}{2}+a\right)\cos\alpha + F_y\left(\frac{L}{2}\right)\cos\alpha - P\cos\beta\left(\frac{L}{2}+a\right)\sin\alpha + F_x\left(\frac{L}{2}\right)\sin\alpha = 0$$

$$\frac{W_{legs}}{2}\left(\frac{L}{2}\right)\cos\alpha + 0.52wL\cos\alpha + 0.5w_{legs}L\cos\alpha - P\sin\beta\left(\frac{L}{2}+a\right)\cos\alpha + P\sin\beta\left(\frac{L}{2}\right)\cos\alpha - 0.04w\left(\frac{L}{2}\right)\cos\alpha - 0.5w_{legs}\left(\frac{L}{2}\right)\cos\alpha - P\cos\beta\left(\frac{L}{2}+a\right)\sin\alpha + P\cos\beta\left(\frac{L}{2}\right)\sin\alpha = 0$$

$$0.5w_{legs}\,L\cos\alpha + 0.5w\,L\cos\alpha + P\left[-\sin\beta\left(\frac{L}{2}\right)\cos\alpha - \sin\beta\,.\,a.\cos\alpha + \sin\beta\left(\frac{L}{2}\right)\cos\alpha - \cos\beta\left(\frac{L}{2}\right)\sin\alpha - \cos\beta\,.\,a.\sin\alpha + \cos\beta\left(\frac{L}{2}\right)\sin\alpha\right] = 0$$

$$0.5w_{legs}\,L\cos\alpha + 0.5w\,L\cos\alpha + P\,(-\sin\beta\,.\,a.\cos\alpha - \cos\beta\,.\,a.\sin\alpha) = 0$$

$$0.5w_{legs}\,L\cos\alpha + 0.5w\,L\cos\alpha - P.a\,(\sin\beta\cos\alpha + \cos\beta\sin\alpha) = 0$$

$$0.5\,L\cos\alpha\,(w_{legs} + w) - P.a\,(\sin\beta\cos\alpha + \cos\beta\sin\alpha) = 0$$

According to geometrical rules:

$$\sin\beta\cos\alpha + \cos\beta\sin\alpha = \sin(\alpha+\beta) \qquad \ldots (8.2.5)$$

Hence,

$$\boldsymbol{P} = \frac{\boldsymbol{a\,.\cos\alpha\left(\frac{w}{2}+\frac{w_{legs}}{2}\right)}}{\boldsymbol{L\,.\sin(\alpha+\beta)}} \qquad \ldots (8.2.6)$$

The above Formula can be used for calculating the force in the cylinder in any position where reactions C_y and D_y are not the same, it means that any position except initial lowest position, because in that position dimension between DC is the same dimension as '$2.d$'.

The required dimensions for further calculations can be seen on Figure 30.

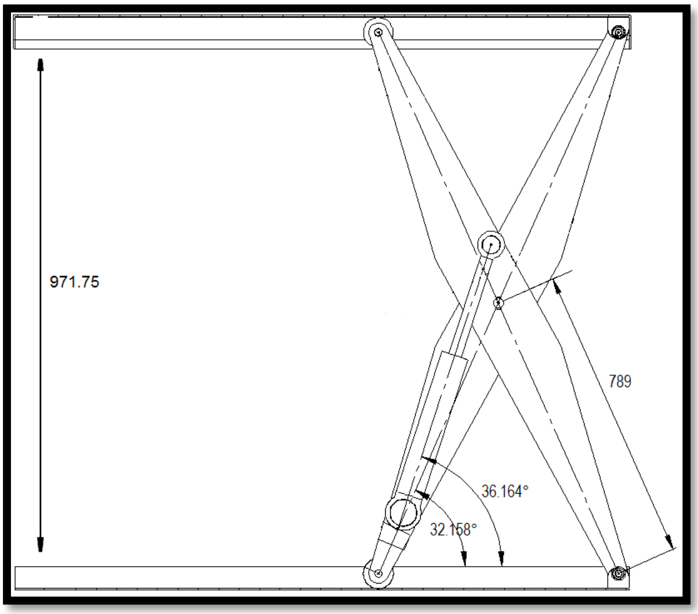

Fig 30 Dimensions in the highest position

According to the design there are the following measurements:

- $L = 1578\,mm = 1578 \times 10^{-3} m$
- $a = 276\,mm = 276 \times 10^{-3} m$
- Mass of the load is 4500 kg.
- Mass of the legs is 51 kg.
- $\alpha = 32.158°$
- $\beta = 36.164°$

So,

$$P = \frac{a \,.\cos\alpha \left(\frac{w}{2} + \frac{w_{legs}}{2}\right)}{L \,.\sin(\alpha + \beta)}$$

$$= \frac{276 \times 10^{-3} \times \cos(32.158)\left(\frac{4500}{2} + \frac{51}{2}\right)}{1578 \times 10^{-3} \times \sin(32.158 + 36.164)} \times 9.81 \times 10^{-3}\ kN$$

$$\boldsymbol{P = 3.07\ kN}$$

8.1.3. Variation of Force in cylinder

By calculating the force required for the hydraulic cylinder, a graph will be plotted between force of cylinder and angle of leg with respect to horizontal plane. This will give us the maximum force for the selection of the cylinder which will be done on the base of length of the required cylinder from pivot to pivot (L).

Table 4 Dependency of Cylinder Force on angle α & β

Angle α (in Degrees)	Angle β (in Degrees)	Force in Cylinder (kN)
1.452	1.62	36.30618
5.838	6.561	18.08578
10.22	11.49	10.38196
14.61	16.43	7.326586
18.99	21.36	5.700346
23.38	26.29	4.699964
27.77	31.22	4.030044
32.15	36.16	3.556605

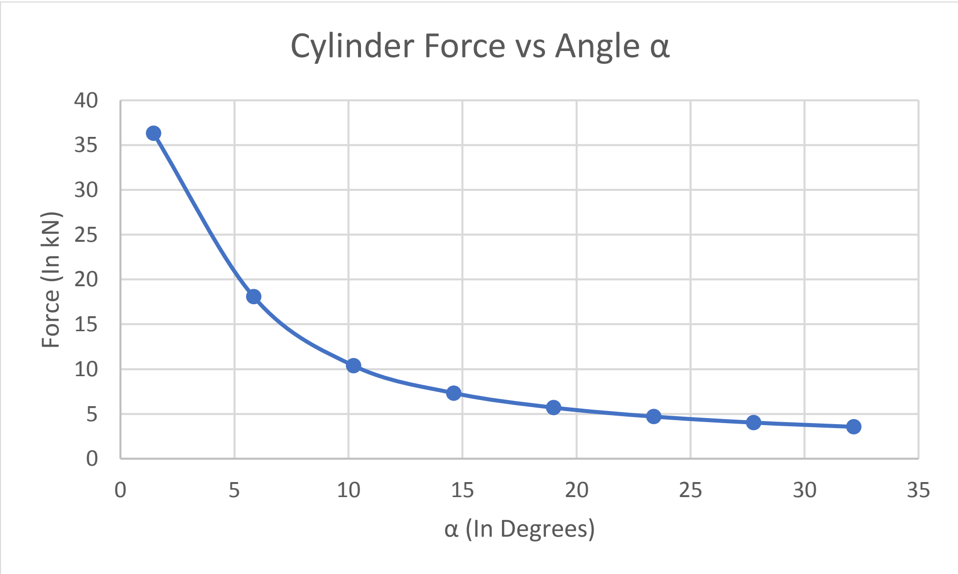

Fig 31 Graph Plotted for Cylinder Force vs Angle α

9. Selection of Hydraulic Cylinder

The system has been incorporated with twin hydraulic cylinder for high load capacity as well as for safety reasons. The complete selection process included the use of online catalog provided by Bosch Rexroth Industrial hydraulics. [25]

9.1. Inputs for selection of Hydraulic Cylinder

Table 5 Input parameters for Hydraulic Cylinder

Parameters	Value
Pressure of the system	200 bar
Required Stroke Length	300 mm
Pushing Force	40 kN
Pulling Force	0 kN
Instant Angle	1.6°
Space inside the Jack (in Diameters)	110 mm

The amount of pushing force required was given greater than the required force as a safety factor. This will ensure excessive loading will not cause any damage to the equipment or the factory user.

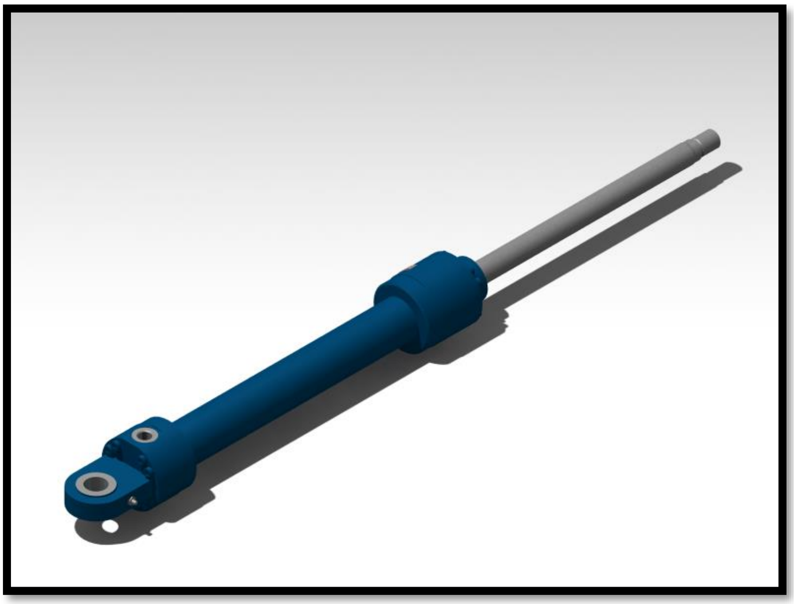

Fig 32 Bosch Rexroth Hydraulic Cylinder

The above Hydraulic Cylinder in Figure 32 was chosen for the final design and is reliable as well as cost effective. Some of the Technical Specifications are as given in the below Table 6. (Refer Annexure A)

Table 6 Technical specifications of Cylinder

Feature	Description
Model code	CDH1MP3/50/28/300A3X
Mode of operation	Single rod cylinder
Bore diameter	50 mm
Piston rod diameter	28 mm
Stroke length	300 mm
Mounting types	Plain rear clevis at cap end
Design principle	Flanged head and cap
Port connection	ISO 1179-1

9.2. Selection of other Accessories for Hydraulic Cylinder

The Online catalog provided by Bosch Rexroth was essentially helpful in selecting appropriate accessories for a specific Hydraulic Cylinder. The corresponding components were suggested by the catalog itself after selecting the hydraulic cylinder. The components used for the final assembly are given as follows.

9.2.1. Cylinder floor mounting

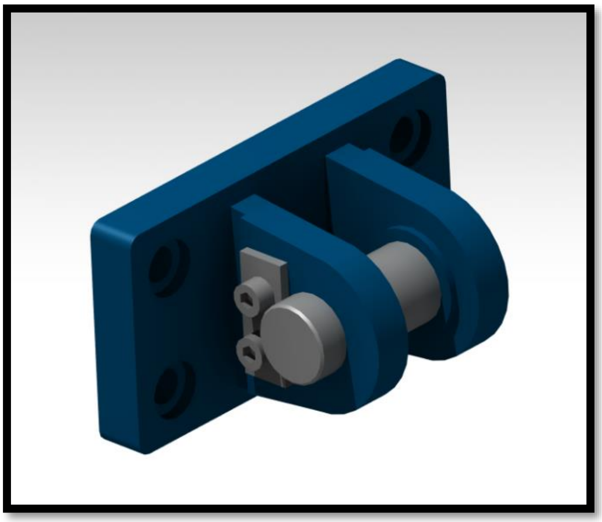

Fig 33 Fork bearing block for Cylinder Floor Mounting

This mounting is placed on the base of the jack vertically such that the axis of pin is parallel to the base. The model number of this mounting is CLCD 32 195103214 1. The technical data for the above mounting is given in Annexure B.

9.2.2. Piston rod end mounting

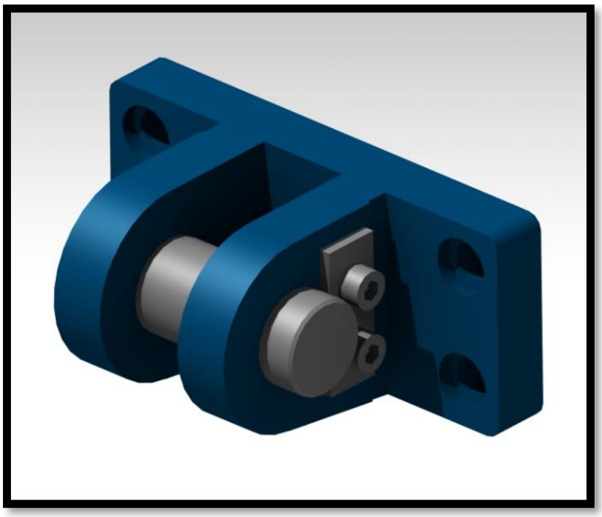

Fig 34 Fork bearing block at piston rod end mounting

This mounting is placed on the connecting rod between the two-scissor member on the left and right of the jack. The model number this mounting is CLCA 32 193045816 1. Also, this acts as the main pivot for the piston rod end clevis for rotation. The technical data for the above mounting is given in Annexure C.

9.2.3. Swivel clevis head

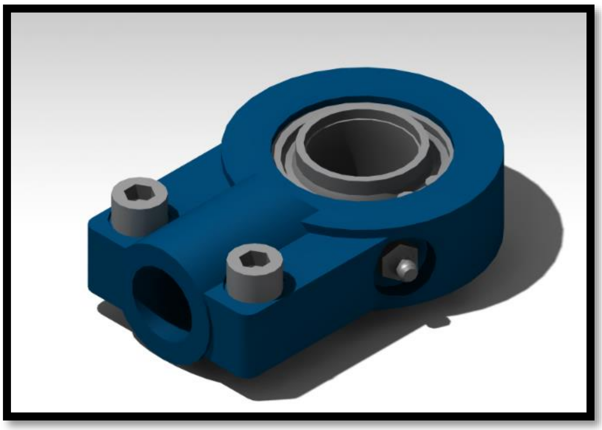

Fig 35 Swivel clevis head

This clevis head is the rod end mounting for the hydraulic cylinder which will account for rotation of the hydraulic cylinder smoothly while lifting operation is done. The model number for this swivel clevis head is CGKD32 193349798. The technical data for the above clevis head is given in Annexure D.

10. Air Cushions for Mobility

Air bearings are designed to lift loads away from the floor surface and float them off to their destination on a thin film of air. Each individual air bearing is housed in a load module which contains an air flow control valve to regulate the operation of that air bearing.

When compressed air is introduced into the air bearing, the bearing initially inflates to form a seal between the bearing and the floor surface. As the air bearing is further pressurized it is forced to expel compressed air from the exhaust holes in the air bearing diaphragm. The force of this expelled air against the floor surface causes the air bearing and load module to lift off the floor on a thin film of air. The load should now be in flotation mode and ready for action. [26]

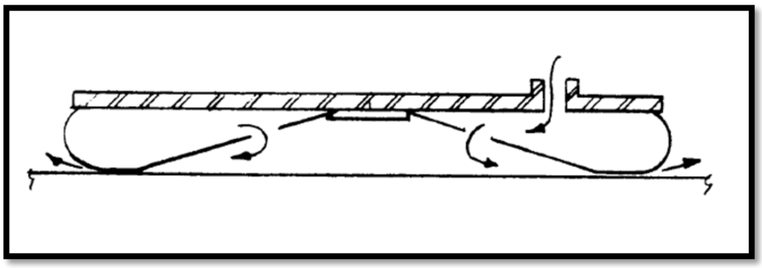

Fig 36 Air Bearing Principle

10.1.Types of Air Bearings provided by Hovair

Selection of the right air bearing for this project is probably the most important feature which has to be need to considered when moving heavy loads. All air bearings are designed to float loads across floor surfaces, and some bearings will lift the load vertically off its base before floating it to its destination. Hovair Systems offers the option of A-type or B-type bearings to suit the requirements of the application, so it is important to select the right bearing for this project.

10.1.1. Hovair A-type Air Bearings

Hovair A-type air bearings are designed to move loads laterally across floor surfaces with just enough lift to cause the load to float smoothly. The Figure 37 below highlights the three stages of an A-type bearing operation.

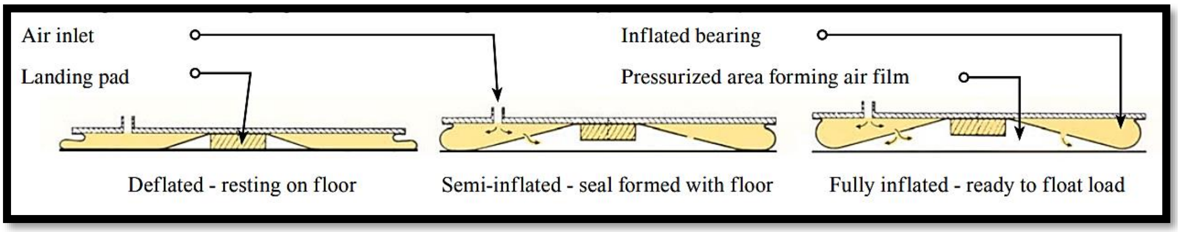

Fig 37 Three stages of an A-type bearing operation

Some Features of A-type bearings are:

- A-type air bearings are most suitable when fitted permanently to a load, such as machinery or large heavy objects that need to be floated but not lifted. Also, these are ideal for situations where loads can be placed directly onto the air bearings/load modules, therefore not requiring the load to be lifted by the air bearings before moving across the floor.
- Use A-type bearings when the load needs little lift and floor surface is smooth and level, resulting in the most efficient use of compressed air.
- A-type bearings consist of a tough urethane fabric that is securely stapled to an aluminum backplate. This bearing can withstand tougher load handling, requires lower air pressure, less air, and is generally most economical and longer wearing.
- A-type air bearings are available in round steel and aluminum load modules, air pallets, platform transporters, and air beams. These products offer a broad selection when choosing the right bearing for the job.

10.1.2. Hovair B-type Air Bearings

Hovair B-type air bearings are designed to lift loads vertically off their base, then move laterally across floor surfaces to their destination, then dropped into position. They function the same as A-type bearings but lift two to three times as much when pressurized. The Figure 38 below highlights the three stages of a B-type bearing operation.

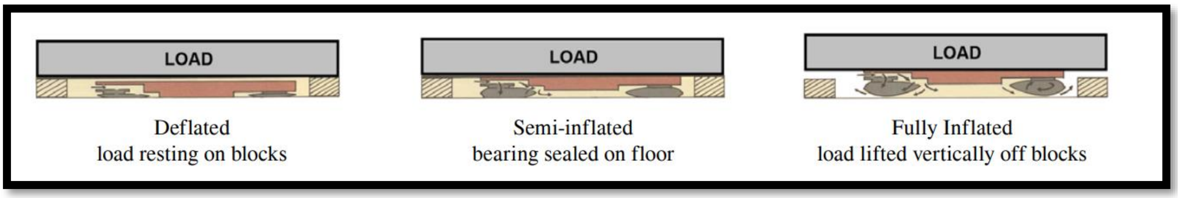

Fig 38 Three stages of a B-type bearing operation

Some features of B-type bearings are:

- B-type air bearings consist of a two-piece vulcanized body that is glued to an aluminum backing plate. This rubber diaphragm can give a relatively high lift and operates at higher air pressure.
- B-type bearings are preferred where low collapsed height, high lift, and capacity per square inch are more important than wear, stability, and air consumption efficiency.
- Superior lift height over the A-type air bearing. The B-type bearing is able to lift a load up to three times the lift height of the A-type bearing, thus making it possible to engage a load using a "lift & pick" movement similar to a regular pallet truck.
- B-type bearings stabilize at 30 psi instead of 15 psi. This enables load capacities of double the A-type bearing for the same size air bearing but requires three times the air consumption.
- B-type air bearings are also available for air pallets, platform transporters, and air beams. These products offer a broad selection when choosing the right bearing for the job.

10.2.Selection of Air Bearing

Hovair B-type Air Bearing was chosen for this thesis. The main reason behind the selection process was the low-profile specification in this type of bearing which ultimately reduces the overall height of the Jack when at lowest position.

Fig 39 B-Type air bearing fitted to low profile aluminum module

Some Tech specs for the B-type low profile Bearings are shown Below:

Table 7 B-type low profile Bearings

Model	**Capacity**	**Dimensions**			**Flow SCFM**
Number	Kilograms	Diameter (in mm)	Height off (in mm)	Height on (in mm)	(in m^3/hr)
LP12-B	910	304.8	31.75	50.8	20.4
LP15-B	1590	381	31.75	53.975	27.2
LP21-B	3175	533.4	34.93	60.325	34

$$Total\ Load\ on\ jack\ = w = 5000\ kilograms \quad \ldots (10.2.1)$$

So, $Required\ Load\ capacity\ for\ each\ bearing\ = \frac{5000}{4} = 1250\ kilograms$ … (10.2.2)

Hence, LP15-B was chosen for the Design. Refer to Annexure E for Complete Details. The schematic Circuit of the B-type Bearing is shown below in Figure 40.

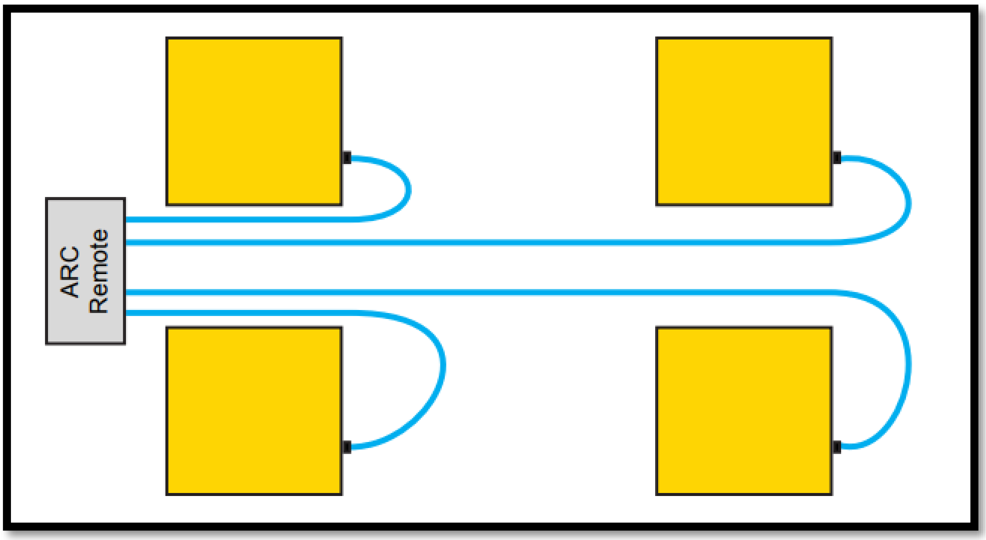

Fig 40 B-type Air bearing system circuit.

11. Final Design

11.1. Lifting Platform

The design of the platform is done such that it takes the load of the clay model as well as it accommodates the hydraulic cylinder well enough underneath it. Also, it consists of two scissor jack mounts on both left and right sides on the outer edge of one end. The lifting platform can have placed with varied dimensions of the jack points lengths of different cars or frames for clay models. This ensures flexibility in production of different models of vehicle on a single equipment.

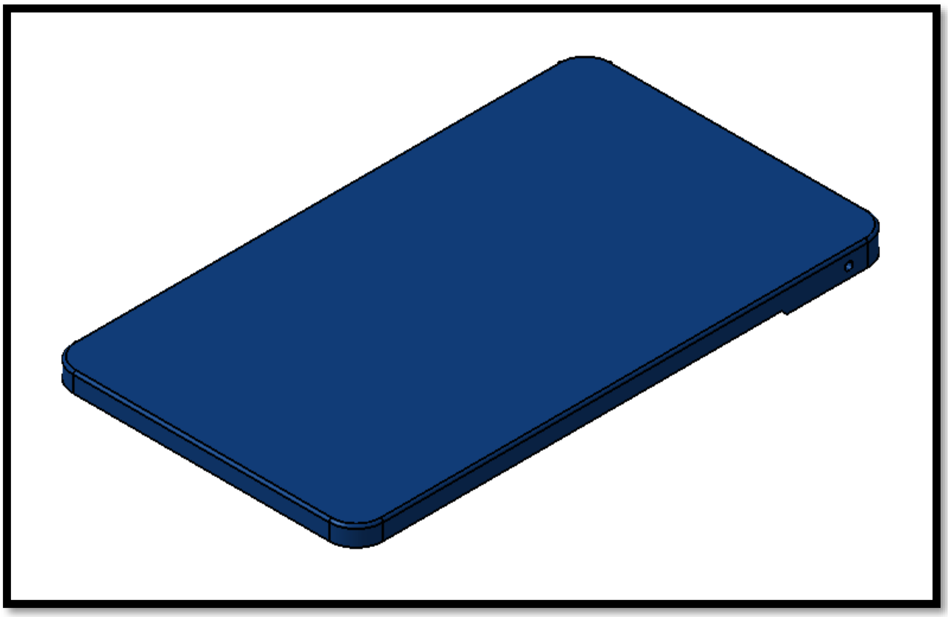

Fig 41 Lifting Platform Design Model

There were several variations of the prototypes of the platform which were modified successively to enhance the features of the platform. Some of the feature which were taken into consideration were:

- Accommodating the Hydraulic cylinder
- Minimum strength and stiffness of the platform
- Slider and pivoted crossmember assembly

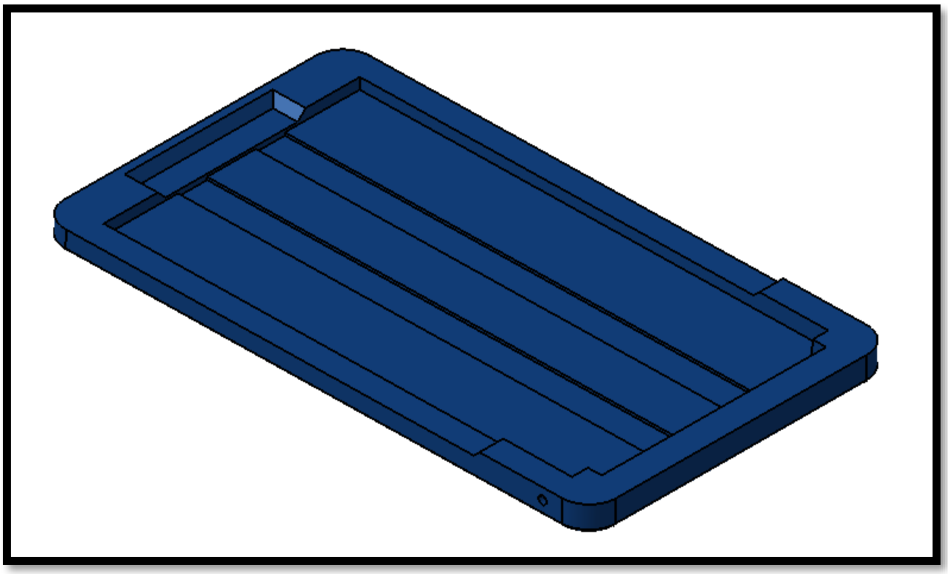

Fig 42 View on other side of platform (from bottom diagonal)

Above given is a bottom diagonal view of the platform. As we can see from the above Figure 42, there is a step on the sides of the platform which was design such as to fit the cylinder inside as well as ensuring the strength of the platform itself.

11.2. Lifting Jack Base

The base of is a very essential component of any equipment. In this thesis, the base has several different functions and features. Each of its feature has a certain priority according to which the design was made. The Isometric view of the jack base is given below in Figure 43.

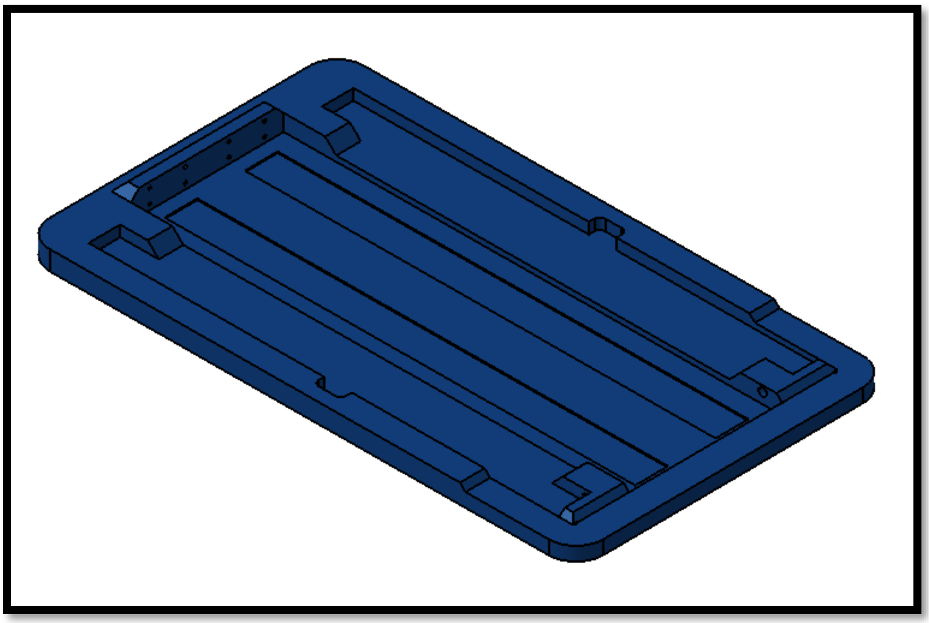

Fig 43 Lifting Jack Base design model

Some of the important considerations taken while designing the platform base were:

- Pivot base of Hydraulic cylinders
- Minimum strength and stiffness of the Base
- Slider and pivoted crossmember assembly
- Assembly of Air cushions
- Hydraulic and pneumatic hose

The base also has two pivot points on left and right as in the lifting platform. These are for the pivoted scissor members. There are guide rails on the sides to allow smooth movement on straight line for the slider cross member.

11.3. Scissor Cross Members

The scissor members which are assembled in an X-type shape at highest position, are pivoted at one end and have slider joints at the other end. One cross member is having its swivel axis at the jack base and the other cross member is having its swivel axis at the lifting platform. This allows the lifting platform to move up and down on the action of the hydraulic cylinder when actuated. Below given is the basic layout of the scissor members with the jack base.

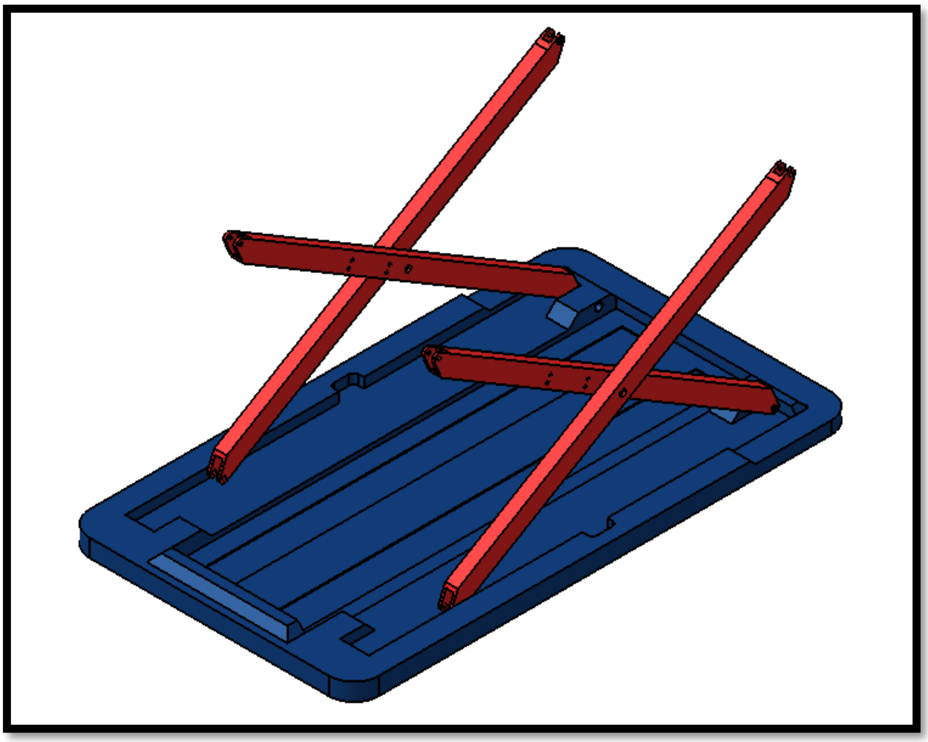

Fig 44 Scissor members with the jack base

11.4. Complete Assembly

The final design assembly consists of various parts including the above mentioned hydraulic cylinder, lifting platform, jack base etc. One more important member which connects the two scissor members transversally acts as the load taking member from the Hydraulic pushing force which is then transferred into semi-circular motion of the scissor members about their pivot points which acts as the scissor mechanism. Hence the platform is lifted by virtue of the above-mentioned mechanism. [27]

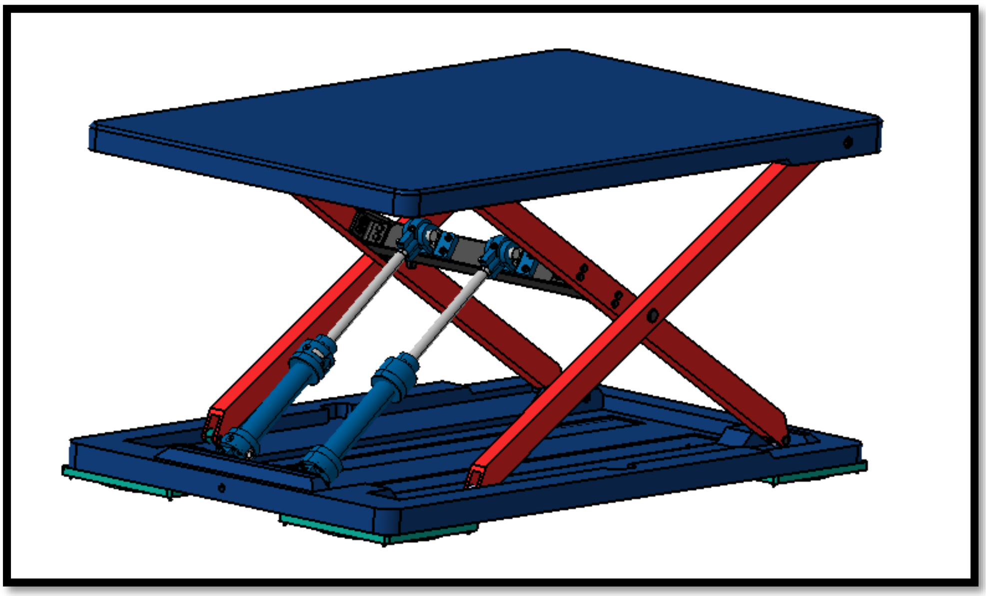

Fig 45 Isometric view of final assembly (Lifted Position)

The jack at the lowest position is the most critical state in the design point of view because that makes the space inside the jack very compact to fit a hydraulic cylinder inside. This made the design many changes and places above and below the hydraulic cylinder were cut out and reduced to accommodate the cylinder properly. Below shown is a cut section view of the Jack to show the Jack at lowest position.

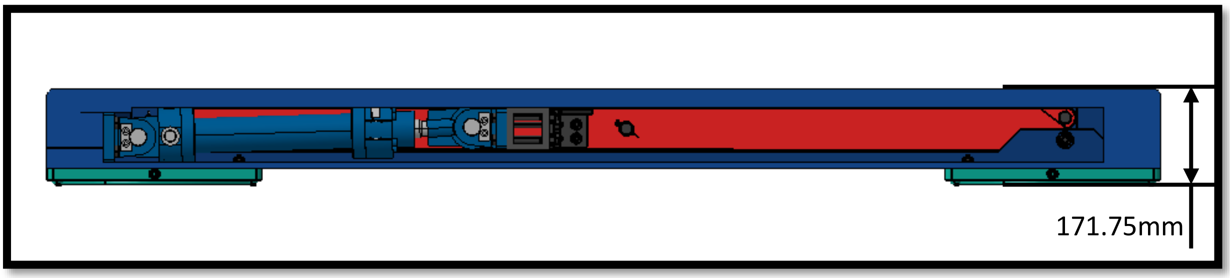

Fig 46 Cut section view of the Jack at Lowest Position

Below given is a figure is a right-side view of the jack at highest position.

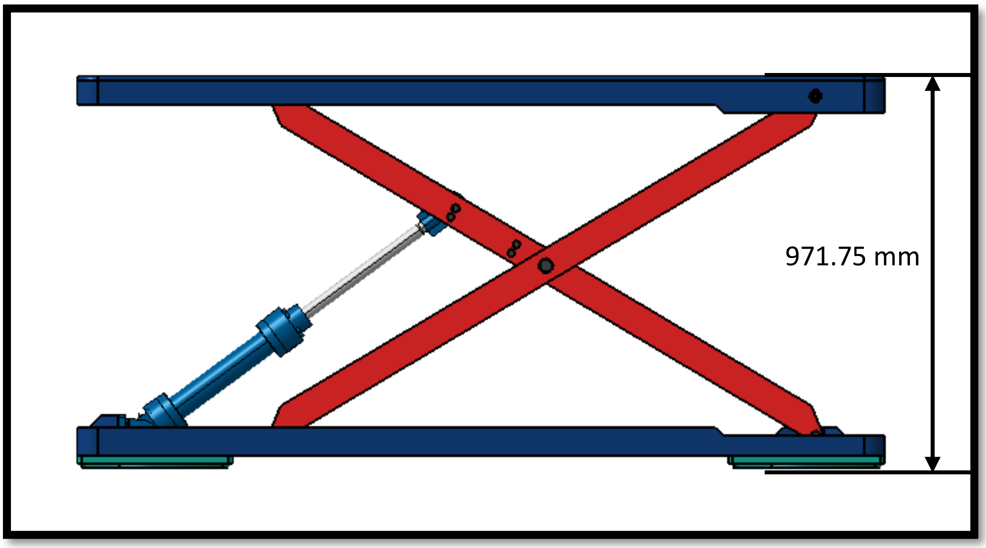

Fig 47 Right side view of final assembly

The main aim of this design was to lift vehicle frame. So below given is a lifted vehicle clay model frame placed on the lifted platform. The below used frame is completely made of steel and there are no other parts which will hinder the jack design.

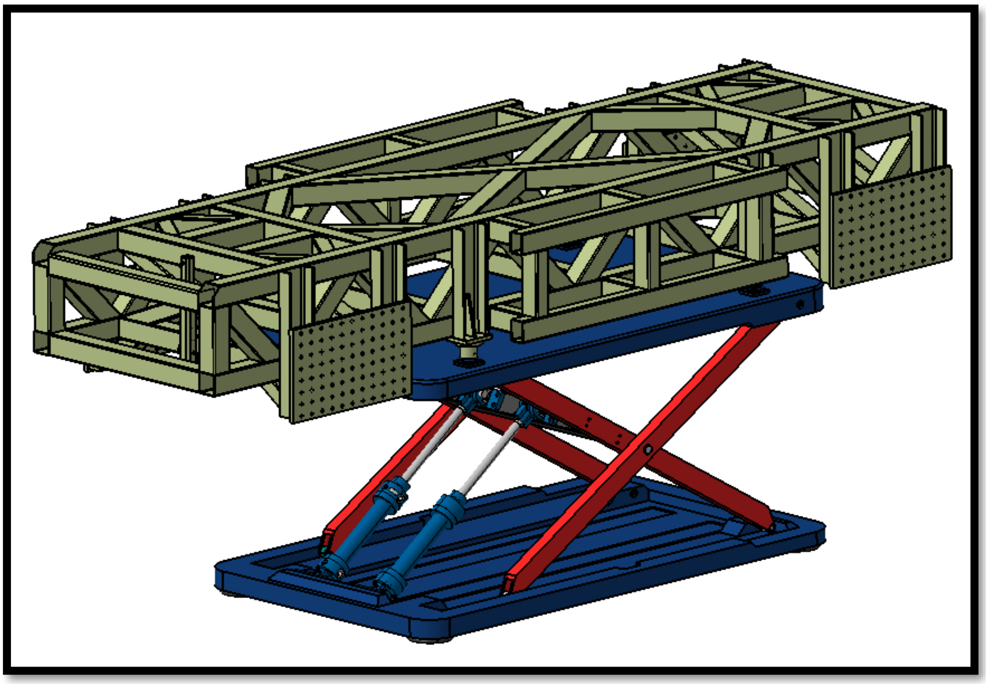

Fig 48 Assembly with lifted Clay model Frame

12. Summary of Design

The project was carried out successfully according to the given requirements. The outcome of the mobile jack lift design meets the objective of the project. The general section described the classification, purpose and technical characteristics of the lift, and the mechanism and operation principle of the designed Jack.

In the design section, the Jack calculation is done, where the forces acting in the cylinder and emerging stresses in the system were calculated. A 3D model was created.

12.1.Technical Specifications

The technical specifications of the Mobile Hydraulic Platform Jack are:

Table 8 Technical specifications of Final Design

S.No.	**Feature Name**	**Description of Feature**
1	Load Capacity	5 T
2	Max. Lifting Height of Platform	850 mm
3	Min. Headroom	171.75 mm
4	Overall Height	971.75 mm
5	Overall Width	1150 mm
6	Overall Length	2000 mm
7	Mass of Jack	670 kg
8	Lifting Time	20 Seconds
9	Lowering Time	25 Seconds
10	Mobility type	Air Casters
11	Pneumatic Connection specs	10 Bar min.

The overall Dimensions were taken from the CAD model. The lifting and lowering time were assumed on the basis of sources related to hydraulic cylinders.

12.2. Cost Summary

Table 9 Cost Summary of Final Design

S.No.	**Part Name**	**Quantity**	**Cost per part**	**Total cost (in CZK)**
1	Jack base	1	15000	15000
2	Lifting Platform	1	12000	12000
3	Scissor members	4	3500	14000
4	Load Bar cross-member	1	1000	1000
5	Hydraulic Cylinder	2	21500	43000
6	Air Caster	4	4000	16000
7	Hydraulic cylinder clevis joints	2	600	1200
8	Cylinder Frame support mountings	4	500	2000
9	Scissor member wheels	8	200	1600
10	Hydraulic Hoses	2	1200	2400
11	Pneumatic Hoses	4	1000	4000
12	Fasteners	78	50	3900
13	Miscellaneous costs	-	-	10000
	Total			$\mathbf{116100.00}\ \boldsymbol{CZK}$

The cost calculation was carried out using the help of various online sources and the industrial catalogs. Some of them were assumed such as machining costs and miscellaneous costs. This cost will be the most appropriate cost for one Jack. The cost may vary according to other factors like shipping costs, maintenance costs etc. [28] [29]

13. Conclusion

The Mobile hydraulic platform jack is a ready to use equipment with least human effort. Every factory floor for vehicle maintenance or clay modelling must have this jack since it is more reliable and cost effective at the same time. This jack has the highest load capacity in comparison to other jacks when the headroom is considered as the main factor. Hence, making it more effective at working heights.

Specifically, the air casters used here reduce the human effort to move the vehicle around the factory floor even on moderate rough floor. The air caster used in this design require very less pressure to operate. Also, different lengths of jack points can be used i.e. variable size of wheel base can be used without any difficulty to adjust anything since the platform is flat and ready to use.

Although the jack was designed to near perfection, but still there is a disadvantage of ground clearance. The headroom can be reduced in further development. The problem while keeping reduced ground clearance is that, it will reduce the load capacity of the equipment. But so as to meet the load requirements as specified by the company, it had to be designed in such a way.

Scope for improvements:

- ✓ **Jack Stand pillars**

Use of jack stand pillars to support the Equipment rigidly while working on the clay model. It makes high-altitude operations more efficient, safer and more secure. It provides a higher stability especiaaly during high altitude operations.

Fig 49 Mobile scissor jack with stand pillars [30]

✓ **Safety Lock**

A safety lock can prevent from a disaster due to a system failure such as hydraulic or Pneumatic pressure leak or a structural member failure. This safety feature can be incorporated on the scissor cross members. Below given is a safety lock from Kolb portable Lift.

Fig 50 Safety Lock Rack Gear Type

This safety lock is basically a Rack gear which locks itself onto a cross member connected between two scissor members. The connected member has an extra protrusion which locks only in one direction i.e. in the direction while platform is moving down. The safety lock is disengaged when a safe position is reached using a lever otherwise which it is kept lock for safety purpose.

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Annexures

Annexure A	-	Hydraulic Cylinder Configuration
Annexure B	-	Cylinder Floor Mounting
Annexure C	-	Piston rod end mounting
Annexure D	-	Swivel Clevis Head
Annexure E	-	B-type Air bearings
Annexure F	-	Complete Assembly and Part Drawing of Mobile Hydraulic Platform Lift (Separate Volume)

Attaching an Electronic copy in the form of CD.

Configuration documentation
Mill type cylinder

Model code CDH1MP3/50/28/300A3X/B22CGUMW

Description

Mode of operation	**CD**	Single rod cylinder
Range	**H1**	Range H1
Mounting types	**MP3**	Plain rear clevis at cap end
Bore diameter	**50**	D = 50 mm
Piston rod diameter	**28**	d = 28 mm
Stroke length	**300**	Stroke length = 300 mm
Design principle	**A**	Flanged head and cap
Component series	**3X**	30 to 39 unchanged installation and connection dimensions
Port connection / types	**B**	according to ISO 1179-1 (pipe thread ISO 228-1) EE = G 1/2 D4 = 34 (max. 0.5 mm deep)
Line connection/located at head	**2**	Right - viewed on the piston rod
Line connection/located at base	**2**	Right - viewed on the piston rod
Piston rod version	**C**	Hard chromium-plated
Piston rod end	**G**	Thread for self-aligning clevis CGA, CGAK, plain clevis head CSA KK = M22x1.5 A = 22 NV = 22
End position cushioning	**U**	Without
Seal version	**M**	Standard sealing system (for mineral oil HL, HLP and HFA)
Option	**W**	Without option

Note:
The information contained herein is intended to serve purely as a product description. The information we have provided cannot be used as evidence of a particular aspect or of suitability for a particular purpose. This information does not release the user from his responsibility to perform his own assessments and tests. Please note that our products are subject to the natural processes of aging and wear.

The stated operating pressures are valid for applications with shockfree operation. For extrem loads, as for example fast cycling, the mounting elements and piston rod thread connection must be designed for fatigue.

The specified resistances of the individual Bosch Rexroth classes only relate to primed/painted cylinder surfaces, not to piston rods, trunnions etc. Special measures may be required for these.

Configuration documentation
Mill type cylinder

Rexroth
Bosch Group

Model code CDH1MP3/50/28/300A3X/B22CGUMW

Technical data

Inputs

System press.	**200**	bar
Pushing Force	**40**	kN
Pulling Force	**0**	kN
Stroke length	**300**	mm
Inst. angle	**6**	°
With self-aligning clevis	**No**	
Load guided	**Yes**	

Result

Safety factors		
- Buckling calculation at load pressure (sf1)	**3.2**	
- Bending calculation at load pressure (sf2)	**297.7**	
- Buckling calculation at system pressure (sf3)	**2.4**	
- Bending calculation at system pressure (sf4)	**7.7**	
Load pressure p k (at p r = 0)	**153**	bar
Load pressure p r (at p k = 0	**0**	bar
Damping calculation has been taken into account	**No**	
Number of load cyles	**No limits (In contact, f=0)**	
Standards	**Bosch Rexroth AG**	
check damping capacity	**No**	

Accessories

Mounting element — Plain clevis

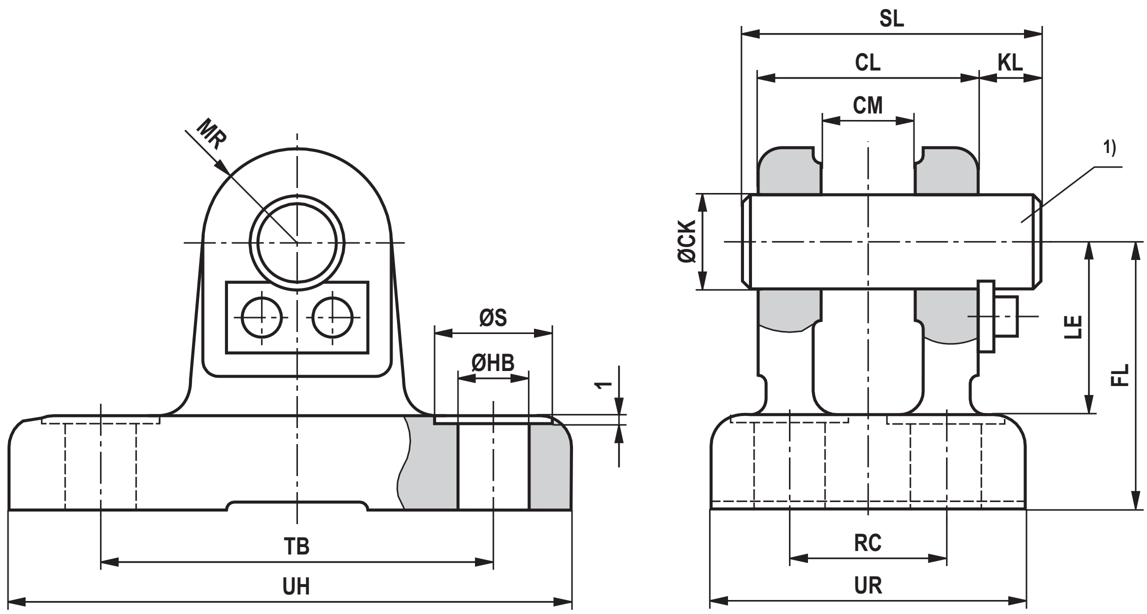
Swivel clevis head

Spare parts

Material number	**Designation**
R900850181	Seal kit

Abmessungen: Gabel-Lagerbock CLCD (klemmbar) für Baureihe CDL2 (Maßangaben in mm)

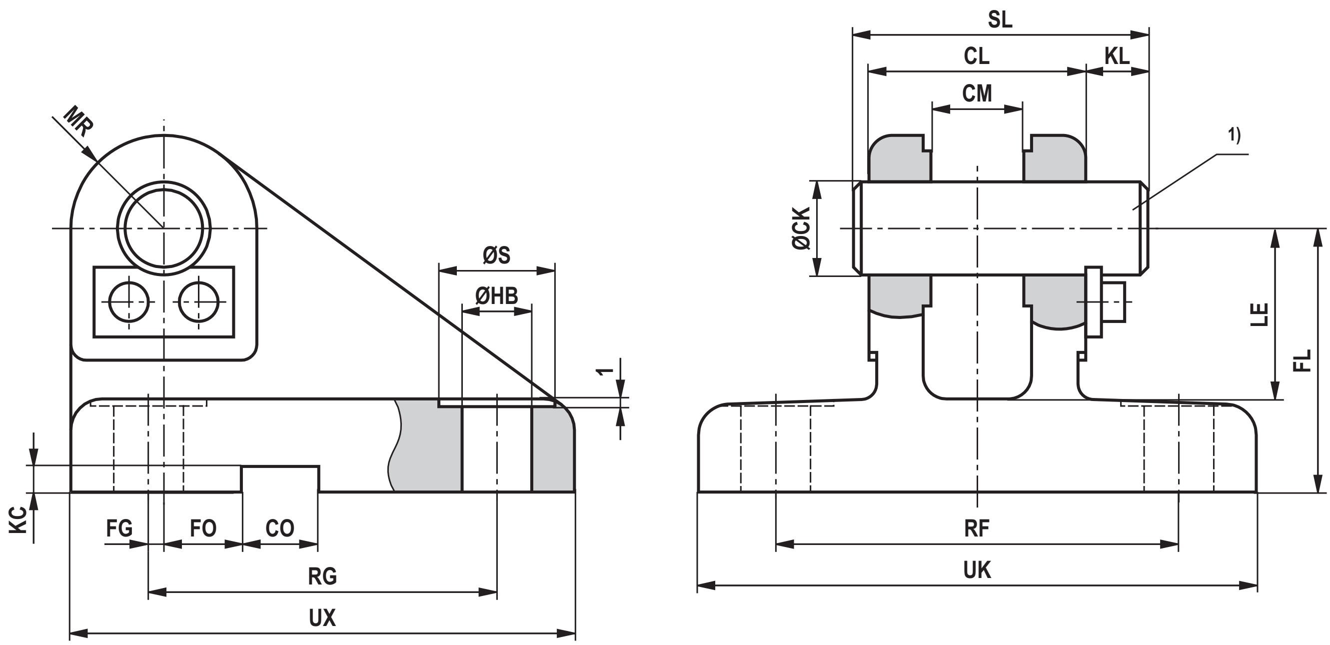
ISO 8132, Form A



Baureihe CDL2 ØAL	Baureihe CDL2 ØMM	Typ	Material-Nr.	Nennkraft kN	ØCK H9 [1]	CL h16	CM A12	FL js12	ØHB H13	KL	LE min.
25	14	CLCD 10 [2]	[3]	5	10	24	10	32	6,6	8	22
32	18	CLCD 12 [2]	R900542879	8	12	28	12	34	9	8	22
40	22	CLCD 20	R900542881	20	20	45	20	45	11	10	30
40	25	CLCD 25	R900542882	32	25	56	25	55	13,5	10	37
50	28										
50	32	CLCD 32	R900542883	50	32	70	32	65	17,5	13	43
63	36										
63	40	CLCD 40	R900542884	80	40	90	40	76	22	16	52
80	45										
80	50	CLCD 50	R900542885	125	50	110	50	95	26	19	65
100	56										
100	63	CLCD 63	R900542886	200	63	140	63	112	33	20	75
125	70										
125	80	CLCD 80	R900542887	320	80	170	80	140	39	26	95
160	100	CLCD 100	[3]	500	100	210	100	180	45	30	120
200	125	CLCD 125	[3]	800	125	270	125	230	52	32	170

Abmessungen: Gabel-Lagerbock CLCA (klemmbar) für Baureihe CDL2 (Maßangaben in mm)

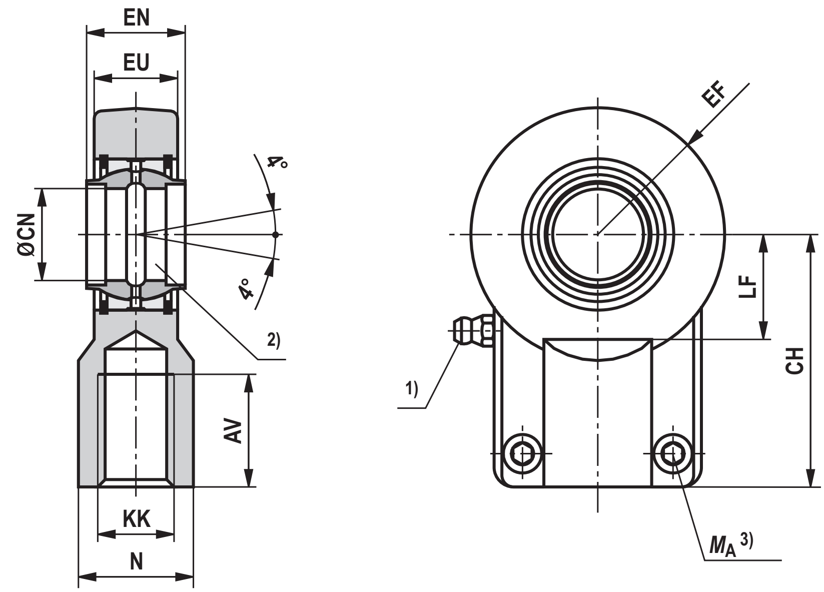
ISO 8132, Form B



Baureihe CDL2 ØAL	Baureihe CDL2 ØMM	Typ	Material-Nr.	Nenn-kraft kN	ØCK H9 [1]	CL h16	CM A12	CO N9	FG js14	FL js12	FO js14	ØHB H13
25	**14**	**CLCA 10** [2]	[3]	5	10	24	10	8	2	32	10	6,6
32	**18**	**CLCA 12** [2]	R900542861	8	12	28	12	10	2	34	10	9
40	**22**	**CLCA 20**	R900542863	20	20	45	20	16	7,5	45	10	11
40	**25**	**CLCA 25**	R900542864	32	25	56	25	25	10	55	10	13,5
50	**28**											
50	**32**	**CLCA 32**	R900542865	50	32	70	32	25	14,5	65	6	17,5
63	**36**											
63	**40**	**CLCA 40**	R900542866	80	40	90	40	36	17,5	76	6	22
80	**45**											
80	**50**	**CLCA 50**	R900542867	125	50	110	50	36	25	95	0	26
100	**56**											
100	**63**	**CLCA 63**	R900542868	200	63	140	63	50	33	112	0	33
125	**70**											
125	**80**	**CLCA 80**	R900542869	320	80	170	80	50	45	140	0	39
160	**100**	**CLCA 100**	[3]	500	100	210	100	63	52,5	180	0	52
200	**125**	**CLCA 125**	[3]	800	125	270	125	80	75	230	0	52

Abmessungen: Gelenkkopf CGKD (klemmbar) für Baureihe CDL2 (Maßangaben in mm)

ISO 8132

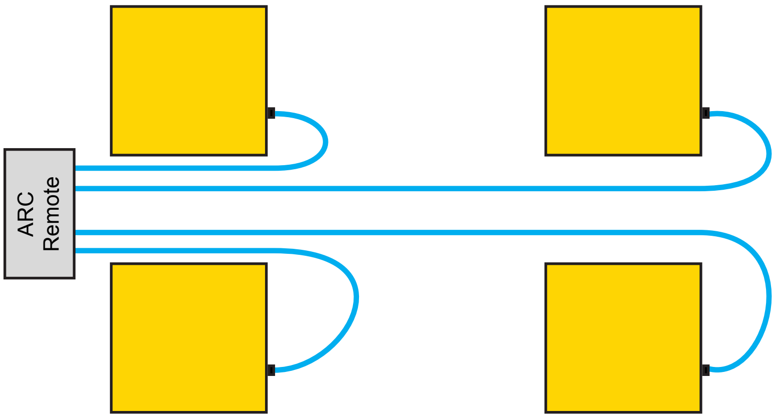


Baureihe CDL2 ØAL	Baureihe CDL2 ØMM	Typ	Material-Nr.	Nennkraft kN	AV min.	N max.	CH js13	EF max.	ØCN H7 2)	EN h12	EU max.
40	**22**	**CGKD 20**	R900308576	20	23	28	52	25	20	20	17,5
40	**25**	**CGKD 25**	R900323332	32	29	31	65	32	25	25	22
50	**28**										
50	**32**	**CGKD 32**	R900322049	50	37	38	80	40	32	32	28
63	**36**										
63	**40**	**CGKD 40**	R900322029	80	46	47	97	50	40	40	34
80	**45**										
80	**50**	**CGKD 50**	R900322719	125	57	58	120	63	50	50	42
100	**56**										
100	**63**	**CGKD 63**	R900322028	200	64	70	140	72,5	63	63	53,5
125	**70**										
125	**80**	**CGKD 80**	R900322700	320	86	91	180	92	80	80	68
160	**100**	**CGKD 100**	R900322030	500	96	110	210	114	100	100	85,5
200	**125**	**CGKD 125**	R900322026	800	113	135	260	160	125	125	105

Hovair Systems

The Load Moving Specialists

B-Type Air Bearing & Low Profile Aluminum Module Technical Specifications

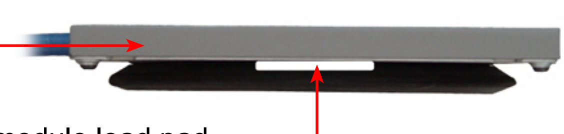


A typical B-type air bearing system footprint

B-type air bearing fitted to low profile aluminum module

MODEL	BEARING	CAPACITY	DIMENSIONS IN INCHES			FLOW - SCFM		LOAD PAD	APPROX WEIGHT IN POUNDS	
Number	Number	Pounds	Diameter	Height Air Off	Height Air On	Half Load	Full Load	Square Inches	Module	Bearing
LP12-B	B12N	2,000	12	1¼	2	6	12	7	11	1½
LP15-B	B15N	3,500	15	1¼	2⅛	8	16	19½	18	2
LP21-B	B21N	7,000	21	1⅜	2⅜	10	20	38½	30	3

Thin profile enables modules to slide under loads with clearance heights as low as 1¼". Note: black diaphragm flattens to module load pad level when in deflated state.



module load pad

Full details of these and other great load moving products can be found on our web site - www.hovair.com - or from Hovair Systems Incorporated, 6912 South 220th Street, Kent. WA 98032 • ☎ (800) 237-4518 • Email: info@hovair.com