A PROJECT REPORT

ON

# "Design and Implementation of Material Handling Trolley in Heat Treatment Section"

SUBMITTED TO

THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE

IN THE PARTIAL FULLFILMENT IN THE REQUIREMENT FOR

THE AWARD OF THE DEGREE

OF

BACHELOR IN MECHANICAL ENGINEERING

SUBMITTED BY


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UNDER THE GUIDANCE OF

Prof. S. J. CHEDE


SANDIP FOUNDATION

DEPARTMENT OF MECHANICAL ENGINEERING

SANDIP FOUNDATION'S

SANDIP INSTITUTE OF ENGINEERING

AND MANAGEMENT, NASHIK

SAVITRIBAI PHULE UNIVERSITY PUNE


2021-22

# Sandip Institute of Engineering & Management

SANDIP
FOUNDATION

## C E R T I F I C A T E

This is to certify that ***Mr. Buwa Ruturaj R.***, ***Mr. Chinchole Harshal V., Mr. Ghadoje Shubham B., Mr. Patil Shubham S.,*** has successfully completed the **Project** entitled ***"Design and Implementation of Material Handling Trolley in Heat Treatment Section"*** under my supervision, in the partial fulfilment of Bachelor of Engineering – Mechanical Engineering ofUniversity of Pune

Date :

Place : Mechanical Engineering Department, SIEM, Nashik

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(Examiner)

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(Head of the Department)

**Dr. D. P. Patil**
(Principal)

# ACKNOWLEDGEMENT

With deep sense of gratitude, we would like to thanks all the people who have lit our path with their kind guidance. We are very grateful to these intellectuals who did their best to help during our project work. We dedicate this project to those people who guided our project path with illuminations, our Parents. Ordinary thanks are inadequate for their thanking. We are truly blessed having such people.

The special gratitude goes to **Prof. S. J. Chede**, Project Guide, staff members, technicalstaff members, of Mechanical Department for their expensive, excellent and precious guidance in completion of this work. We thank **Mr. R. V. Asane, Manager Production (Birla Precision Tool)** for their appreciable help for our Project.

We are glad to receive timely guidance from **Prof. S. B. Ambekar**, Project Coordinator regarding the report formation and its contents.

We remain indebted to H.O.D **Prof. Dr. A. S. Dube**, Mechanical Department for his timely suggestion. We express deep sense of gratitude to **Prof. Dr. D. P. Patil,** Principal, Sandip Institute of Engineering and Management, Nashik, for his comments on this Project report.

With various National-International journals to help, it has been our endeavor to thorough our work to cover the project work.

Lastly, we thank to all our friends and the people who helped us directly or indirectlyin successful completion of our Project work.

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# INDIAN TOOL
**MANUFACTURERS DIVISION**

**PIR/RNS/CERT./2021-22**
**September 28, 2021**

To,

Head of Department,
Sandip Institute of Engg. & Management,
Mahiravani, Triambak Road,
Nashik - 422213

**Subject: Project Assignment Letter.**

Respected Sir,

We are glad to inform you that, the following students from Sandip Institute of Engineering & Management, Nashik have been assigned their project at Birla Precision Technologies Limited (Indian Tool Manufacturing Division) from 28th September 2021.

This is to permit the following students of B.E. Mechanical from Sandip Institute of Engineering & Management, Nashik – 422213 for their project of "Design & Implementation of Material Handling Trolley in Heat Treatment Section" for the A.Y. 2021-2022.

Name of the Student:

| Sr. No | Name of the student | Division & Roll No. |
|---|---|---|
| 1 | Buwa Ruturaj Rajendra | A-49 |
| 2 | Chinchole Harshal Vijay | A-53 |
| 3 | Ghadoje Shubham Babaji | A-62 |
| 4 | Patil Shubham Suresh | A-65 |

Wishing them all the best for their project.

**Birla Precision Technologies Limited**
**(Indian Tool Manufacturers Division)**

**Maj. R N Shiradhonkar (Retd.)**
**Vice President – (H. R.)**

PAD/-

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**Birla Precision Technologies Ltd.**
INDIAN TOOL
**MANUFACTURERS DIVISION**

**PIR/RNS/CERT./2022-23**
**June 12, 2022**

**TO WHOMSOEVER IT MAY CONCERN**

This is to certify that, the following students of B.E. (Mech.), Sandip Institute of Engineering & Management, Mahiravani, Triambak Road, Nashik.

1) Ruturaj Rajendra Buwa
2) Harshal Vijay Chinchole
3) Shubham Babaji Ghadoje
4) Shubham Suresh Patil

Has successfully completed the project work on "Design & Implementation of Material Handling Trolley in Heat Treatment Section" under the guidance of Mr. Revannath V. Asane – Manager (Production).

The period of Project work from 28.09.2021 to 05.06.2022.

We found sincere, honest & hardworking students.
We wish them best of luck & a bright future.

**Birla Precision Technologies Limited**
**(Indian Tool Manufacturers Division)**

**Maj. R N Shiradhonkar (Retd.)**
**Vice President – (H. R.)**

PAD/-

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# NOMENCLATURE

| Nomenclature | Description |
|---|---|
| KPI | Key Performance Indicators |
| AMHS | Automated Material Handling Systems |
| CMM | Coordinate Measuring Machine |
| PLC | Programmable Logic Controller |

# ABSTRACT

Heat treatment in the industry is a special process. Earlier it was observed that, Material Handling was done in a Manual Manner by using a trolley operated by 2 Operators. The distance to be covered is around 60 cms to 75 cms.

Considering various possible alternative mechanisms for Automation, like Hydraulic Piston and Cylinder Mechanism, Lead Screw Mechanism and Gear Train System and Rack and Pinion Mechanism. Considering the limitations in space and from the maintenance perspective, Rack and Pinion mechanism is selected. Plummer Blocks are also incorporated to provide the support to the shaft and to reduce the vibrations. The trolley weighs around 1000 kg (10000 N) with 4 containers of various cleansing fluids and dimensions 154 cms x 154 cms x 120 cms are selected.

By using Rack and Pinion Mechanism, time required in travelling operation reduced by 30.19% per cycle. This indicates that the reduction in travel time increases the Production rate, Less chances of Accidents, Reduction in Operators Fatigue and the number of operators required also decreased.

# 1. INTRODUCTION

The problem under our consideration is to design and fabricate the mechanism necessary for the automation of the Material Handling trolley in Heat Treatment section for Birla Precision Technologies Limited, Indian Tool Manufactures Division, MIDC Area Satpur, Nashik. The trolley which is manually operated is needed to be automated by selecting suitable drive and design of a proper mechanism [21]

## 1.1 Introduction to the Material Handling Trolley

We are implementing the rack & pinion mechanism for the automation. We are following the principle of steering mechanism. Spur pinion is driving the rack which is made up of EN24. Spur pinion is receiving the power input from gear box and converting the rotational motion to the linear motion without any kind of speed reduction. For this purpose, we required low speed high torque electric motor which will transfer the power to the gear box hence to the spur pinion.

Heat treatment section contains various Heat treatments which involves the use of heating or chilling, normally to extreme temperatures, to achieve the desired result such as hardening or softening of a material. Heat treatment techniques include annealing, case hardening, precipitation strengthening, tempering, carburizing, normalizing and quenching. There are various ways of material handling in industries like overhead crane, AGV, Manual trolleys, forklift etc. The existing way in the industry is trolley which is currently handled in manual mode. This is hectic one so to reduce it automation of the trolley is required. [22]

The problem faced by industry in material handling is time and Labor consumption. We have noticed that two workers are required for manual transfer of load from furnace in heat treatment section. The containers contain the Hydrochloric Acid (HCl), water, detergent water. This is used for cleaning purpose of the products like tools, drill bits etc. The products are kept in trolley and dipped into the containers for specific period of time. The trolley is moved outward manually and the trays are kept in containers. Then the trolley is pushed inward. Again, after completion of specific time, same movement of trolley is followed for removing of tray from containers. In case of very heavy load, overhead crane is used for handling of the products from the furnace to the containers.

As number of workers engaged in handling is large, also the time for movement is more, it results into time consumption. For the movement of the trolley, at least two workers are required. This is very tedious and time required is more. Indirectly, this result in efficiency decreases and increase in labor cost.

### 1.2 Problem Statement

The day – to – day workload of the operators in the manufacturing industry is monotonous. This leads to fatigue of the operators. Material Handling system is therefore, an integral part of the layout. It leads to minimize the operator’s fatigue. A proper material handling system reduces losses, it is meant to save time and energy requires performing the tasks as per the process sequence. A trolley with 4 containers and Rack and Pinion arrangement for movement of trolley needs to be designed considering load of 1000 kg.

There are four cuboids shape buckets containers which are containing these respective solutions for the cleaning purpose. The total mass of the setup is 500-600 kg. The trolley is rested on the triangular guide ways on which wheels are travelled. The distance to be travel is 60 cm. There are three wheels on each two guide ways. The wheels are guarded by brackets. The main parameters taken to be consideration are distance travelled by trolley and its total mass.

Use of Over - head crane is permitted for large weighted tools, but due to its travel limitations, a trolley moving unidirectional is to be designed.

Therefore, automation is required to solve the problem and reduce the time period. At primary stage we proposed three possible ways to solve this issue.

## 1.3 Objectives

The objectives of this project works are:

- To design a trolley with 4 containers,
- To design Rack and Pinion mechanism for movement of trolley up to overhead crane travel,
- To reduce the number of workers engaged in the operations,
- To reduce the time required for the operation,
- To increase the efficiency of material handling of the heat treatment section,
- To reduce the fatigue of the operators in the heat treatment sections.

## 1.4 Scope

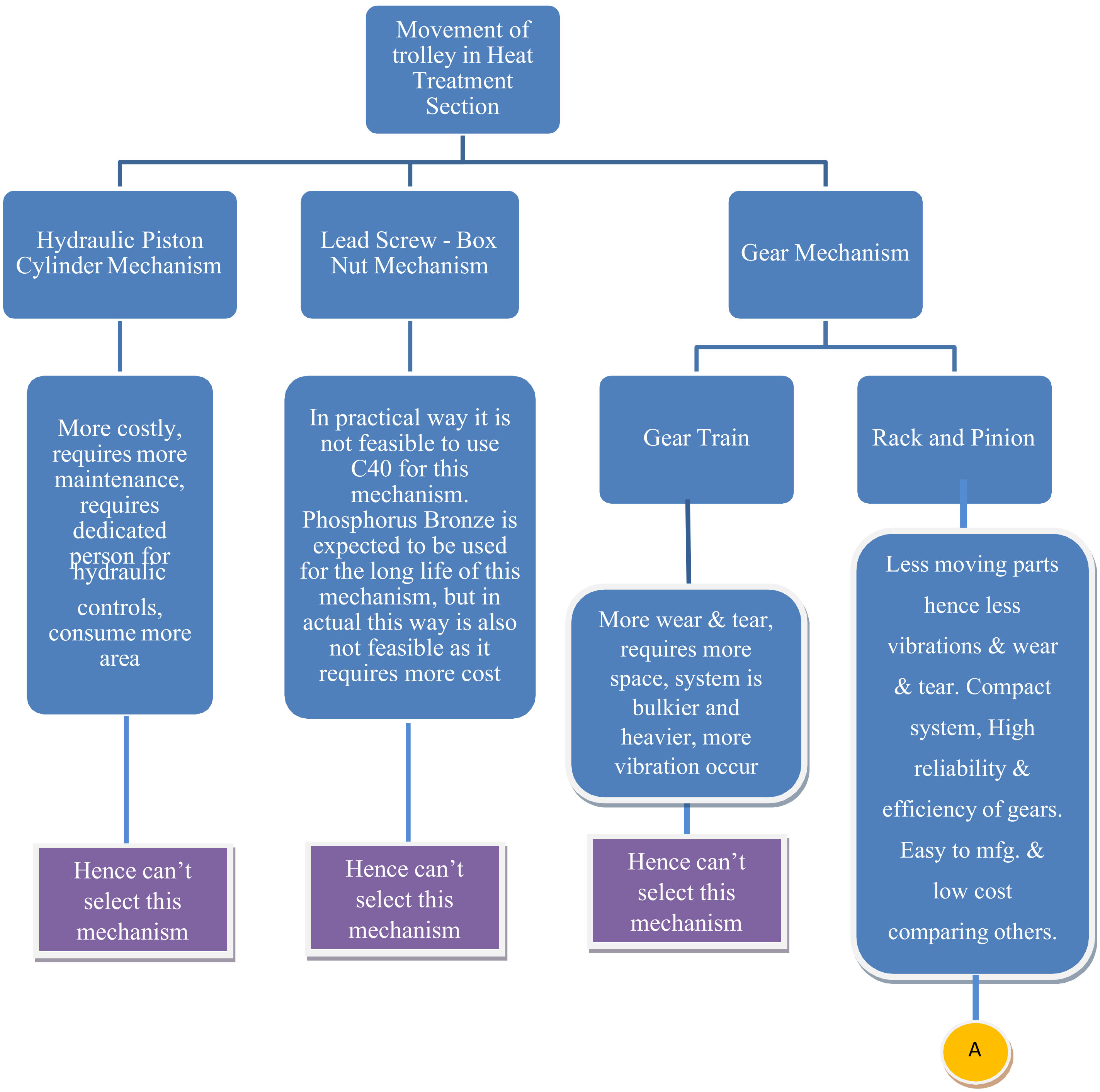
The Scope of the project to reduce to time required and human efforts. By implementing the automation human efforts are reduced. The conventional method used human efforts and man power, which means trolley is pulled by the labors. After the implementation of the mechanism, automation, time is reduced to an extent.

To establish an appropriate Material Handling System consisting of a trolley with containers, driven by Rack and Pinion mechanism. To move load in containers up to overhead crane travel.

## 1.5 Methodology

Methodology is the specific procedures or techniques used to identify, select, process, and analyze information about a topic.
Here the methodology is sorted on the basis of the cost saving and reduction in number of labors involved in the whole operation hence increased efficiency of the system.

All the possible methodologies which can be implemented in the movement of the Trolley are discussed here.



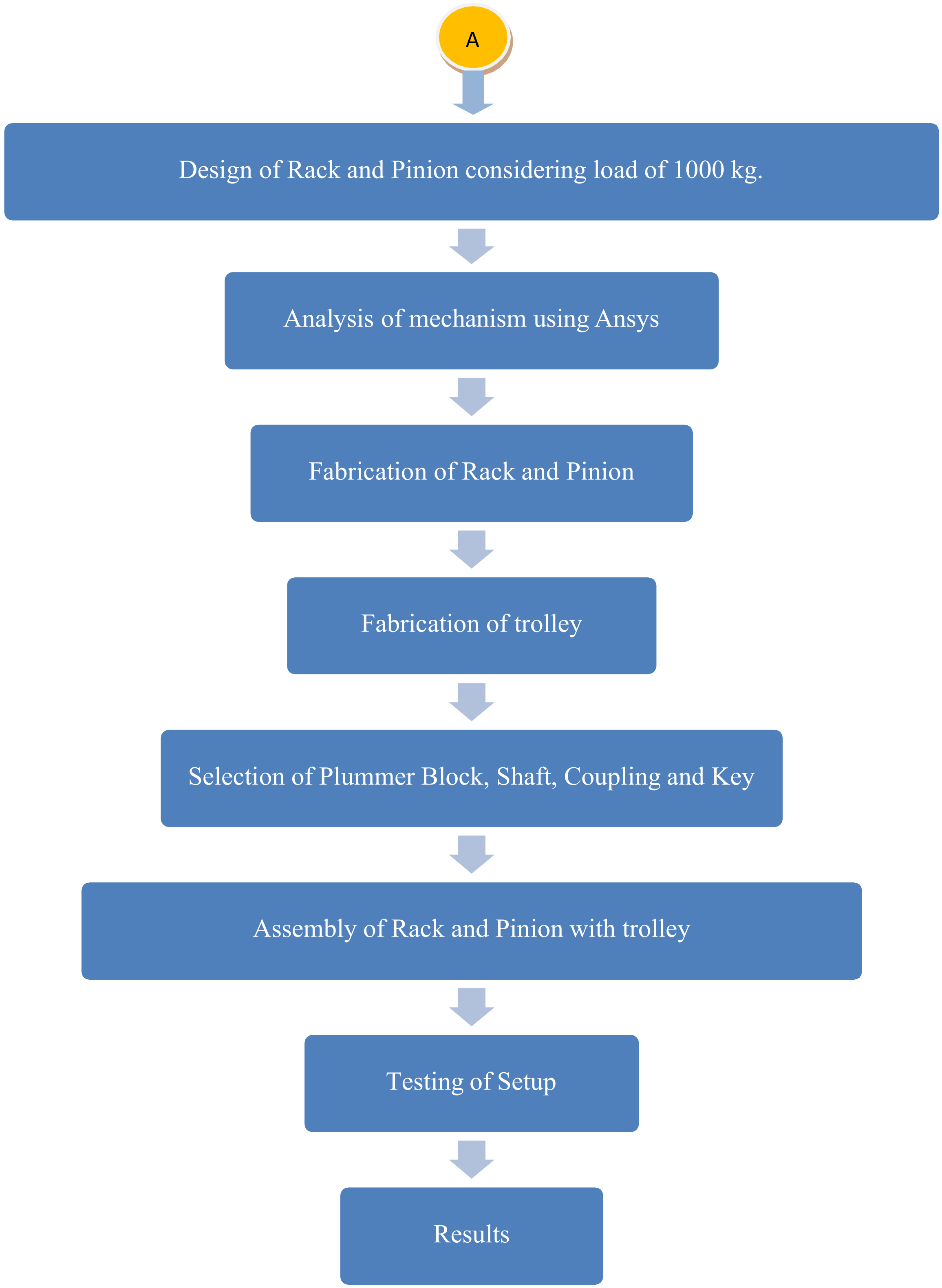



Fig 1.1 : Methodology Flowchart

Gear Mechanisms.

Rack & Pinion:

By studying the rack & pinion mechanism used as steering mechanism in automobiles and the automatic gate opening mechanism, we designed the mechanism which will convert the rotary motion into linear motion. The mechanism will contain a spur pinion and a rack where spur pinion will drive the rack. Low speed high torque motor is required for the setup as well as the gearbox to reduce the output speed of motor as the distance to be travel is not so much. Following are the reasons proving that this mechanism will be more suitable than prescribed. Taking into consideration the flow chart available and the industrial requirements, in Fig. 1.1, it is cleared that Rack and Pinion must be implemented.

- Less moving parts hence less vibrations & wear & tear.
- Compact system
- High reliability & efficiency of gears.
- Easy to manufacture and low cost as compare to others

Fig 1.2: Rack & Pinion Mechanism

# 2. LITERATURE REVIEW

This chapter is a brief explanation on the extent of the research done so far. The major topic keywords are : Material Handling, Rack and Pinion, Lead Screw, Spur Gear, etc.

Paraskos Maniatis," Automated material handling and just-in-time". The author briefly gives some information about material handling Equipments wherein Material handling is the handling of any material anywhere by any means that involve these factors: Motion parts, material, and finished products must be moved from location to location. Material handling is concerned with moving them in the most efficient manner, at the lowest cost. Each step in any manufacturing process requires that supplies are on hand the moment they are needed. Materials handling must assure that no production process or customer need will be hampered by having material arrive on location too late or too early. Material is of little value in any industrial activity unless it is in the proper location. Material handling has the responsibility of delivering the desired material to the right place. The rate of demand varies between steps in the manufacturing process. Materials handling must make sure that each location continually receives the correct quantity of material parts, pounds, or gallons. Storage space, both active and dormant, is a major consideration in any building, since space costs money. Space requirements are greatly influenced by the efficiency of materials handling planning. The author further describes about Just in Time technology, its history and future. This paper is a deep discussion on Material Handling Equipment. [1]

Aditya A. K. et.al, "Selection of Material Handling Equipment: Classifications & Attributes", "International Journal for Innovative Research in Science & Technology". This research is related to storage and controlling of materials throughout the manufacturing process. The main purpose of using a material handling system is to ensure that the material in the right amount is carefully delivered to the desired destination. He functions performed by MH equipment can be classified into four broad categories, that is, (a) transport, (b) positioning, (c) unit formation, and (d) storage. Usually, all the MH functions are composed of one or more combinations of these four primary functions. Right selection and planning of MH improves productivity, efficiency and profit of a company. He use Robots, index tables, rotary tables, and so forth are the examples of this type of equipment. Unit formation equipment is used for holding or carrying materials in standardized unit load forms for transport and storage and generally includes bins, pallets, skids, and containers. Storage equipment is used for holding or buffering materials over a period of time. Typical examples that perform this function are AS/RS, pallet racks, and shelves. This paper focuses on the key points of the material handling equipments. [2]

Corina Pop et.al, "Automated Material Handling Systems (AMHS) In Libraries and Archives Automated Storage/Retrieval and Return/Sorting Systems". The author discussed, some examples of commonly used automated material handling processes include robotics in manufacturing and toxic environment; computerized inventory system; scanning, counting and sorting machinery; and shipping and receiving equipment. These resources allow humans to perform work faster, safer, and with less need for additional personnel to manage routine tasks and time-consuming aspects of producing goods from raw materials. Automated Material Handling Systems (AMHS) facilities significantly increases the efficiency of library collection storing and handling while enhancing archives productivity and performance. [3]

Jessica O. Matson et.al, "Operational Research and Material Handling". The author defines material handling as simply handling material. Today, material handling is defined much more broadly. His say material handling as using the right method to provide safely the right amount of the right material without damage at right place, at the right time, in right condition, and at the right cost. In this review paper, the coverage of operational research applied to material handling is limited to following ten categories: robotics, conveyor theory, transfer lines, flexible manufacturing system, equipment selection, storage alternatives, automated storage and retrieval systems, warehouse layout, palletizing, and order picking and accumulation. [4]

Malini Natarajarathinam et.al, "Measuring Performance of Material Handling Systems: A Conveyor System Analysis". The author discussed the importance of key performance indicator system, in this paper his say a complete set of KPIs for material handling systems are not readily available. The lack of KPIs makes it harder to assess efficiency and track progress in systems. We develop a list of KPIs to measure the efficiency of a material handling system and specifically discuss the case of a conveyor system. Also, considering a single KPI and ignoring others will lead to a myopic approach to improvement. A strategic five step procedure is introduced to refine and define actual KPIs for any system under consideration. This model will provide a structural framework which can be used to evaluate performances of different systems and also Measuring performance of material handling systems 169 rationalize better design recommendations for prospective systems. This work will also demonstrate how discussed methodology could be used to develop KPIs for conveyor systems. The five steps involved are: Scrutinizing the system for initial KPIs, Gathering and ranking KPIs, performing external and internal assessment, analyzing inter-dependencies of KPIs, tracking performance and Making decisions. [5]

Sera Akincilar et.al “Material Handling System Design: A Case-Study in Bosch Rexroth Japan” conducted in 2013 proposed four transportation concepts; manual, forklift, milk run, AGV. Empirical findings from the trials indicated several benefits that can be gained through adapting each concept. They are twenty fundamental guidelines and principles that can be used to effectively plan and control material handling. Originally these principles were formed by the College-Committee on Material Handling in Pittsburgh USA in 1990, and later these principles have been used and modified by several authors like Tompkins *et al.* (1996), Nyman (1992), and Coyle *et al.* (2008). They merged two transportation concepts, embedded AGVs as transportation vehicles into the Milkrun. Using AGVs instead of classical transportation vehicles such as in-plant trucks or forklifts etc., increased delivery performance drastically, since their arrival time can be programmed exactly without any disturbances such as human factor. [6]

Ramkumar R. et.al, “Optimization of Material Handling Trolley using Finite Element Analysis”. The author discussed about optimization in material handling equipment by using finite element analysis method. The main intention of author is to reduce the weight of the structural design of the base welded structure which is the only component that bears the whole load plus the weight of the trolley and then it transfers to the wheel. All design is carried out using CREO software & analysis of the trolley is performed using finite element commercial code ANSYS Workbench. He uses the Von-mises yield principle that been used to determine the distribution of stress intensity. His also gives the information about the Ergonomic improvement. Author say Engineering improvements and administrative improvements are two types of ergonomic improvements. Engineering improvements include modifying, Remodeling the design, providing or replacing equipment, tools, workstations, packaging, products, or materials, parts and processes. Administrative improvements include altering from heavy tasks to light tasks, adjusting the work schedules and work practices, providing revival time, providing variety in jobs to eliminate or reduce repetition (i.e., allotting same nature of work to same muscle groups), Modifying work practices so that workers perform work within their control zone (i.e., below the shoulders, above the knees, and close to the body) and Rotate workers through jobs that use different muscles, body parts, or postures. [7]

Riyaz Ahmed et.al, “A Review Paper of Various Industrial Material Handling Systems”. The author studied various material handling equipment & systems used in an Industry for various material handling, and studied various Modern Technique. Material handling involves short-distance movement within the confines of a building or between a building and a transportation vehicle. The main goal here is to study the various types of material handlings, the role of material handling, Design of material handling systems, The unit load concept, In-process handling, Distribution, Types of material handling, Manual handling, Automated handling. Material handling plays an important role in manufacturing and logistics, which together represent over 20% of the economy Almost every item of physical commerce, was transported on a conveyor or lift truck or other type of material handling equipment in manufacturing plants, warehouses, and retail stores. The unit load concept is production batch can be split into a smaller transfer batch containing several unit loads, each of which can contain multiple parts. A unit load is either a single unit of an item, or multiple units so arranged or restricted that they can be handled as a single unit and maintain their integrity. Narrow-aisle lift truck used in distribution Selecting a unit load size for distribution can be difficult because containers/pallets are usually available only in standard sizes and configurations; truck trailers, rail boxcars, and airplane cargo bays are limited in width, length, and height; and the number of feasible container/pallet sizes for a load may be limited due to the existing warehouse layout and storage rack configurations and customer package/carton size and retail store shelf restrictions. [8]

Mahesh Kadam et.al "Design and Development of Weight Operated Material Handling Device". The author stated that the system is designed for material handling in commercial area which uses potential energy of load for the handling purpose. The heart of the system is rack & pinion arrangement & compound gear train for power and motion transmission. When weight is loaded then spring get compressed and rack move downwards. This results in rotation of pinion which is driving sprocket mechanism for the purpose of movement of the load. The system is so much economical as it not requires any external power supply. [9]

Mr. A. S. Chavan et.al, "Material Handling System – A Case Study For Small Scale Industry", "International Journal of Advanced Technology in Engineering and Science". The author stated that designed a efficient material handling system for Pipe cutting company. The problem faced by Selected Pipe Industry in material handling is time and labor consumption. He had notice that around 3 to 4 hours are required to unloading the truck as well as 6 labors are required for manual transfer of pipes. As no of worker engaged in transferring the raw material towards cutting machine is large and also the time for transferring is more. It results into more working cost. To minimize this cost & time He was going to Design the Material Handling system. he was minimized the cycle time by using new design of production and also reduced the no. of labors from 6 to 2 which indirectly increases productivity as well as profit of the organization. he was save 66% manpower required for material handling and saving 89% of cost of material handling .The team designed a rotary rack considering the safety which can be operated by 2 persons instead of 6 which resulted in 66% manpower saving and 89% handling cost saving with increased safety of the personnel. [10]

Guilherme Bergmann Borges Vieira et.al, “Materials Handling Management : A Case Study”, “Journal of Operations and Supply Chain Management”. The author implemented a solution to material handling problem by constructing several cargo (pallets) units with special wheels with suitable suspension and cage for cargo. The train was operated by a driver where an identification status was displayed for the train driver to know when material was ready for transportation. The driver also had a mobile phone with him to work as per priority. Due to development of new markets, manufacturing demands for a large variety of components and final product assemblies increased. This demand growth led to speed increases and changes in how materials and tools were being handled and transported in or-der to monitor manufacturing requirements. It was identified that the overall satisfaction percentage shows that 50% of the respondents to the data collection noticed improvements in the process after its implementation. [11]

Larry M. STRECKER et.al, “Material Handling Case Study, Optimizing Material Handling System costs”. In this alternative product he will be automatically transferred to the storage area with an automated guided vehicle system (AGVS). Put-away and retrieval from storage will occur with an automated storage and retrieval system (AS/RS) and the products will be transferred to the dock area by the AGVS. In that Standard forklift aisle widths are 11 feet. Perimeter aisles are 15 feet wide. The maximum distance between adjacent aisles for access purposes should be no greater than 60 feet. All conventional storage is on a flow track that is eight pallets deep or less due to needs for product selectivity. The AS/RS system requires a 5-foot storage and retrieval machine aisle width and 30 feet of clear space at the back end of the AS/RS system for access and maintenance. The AS/RS system can support storage 8 pallets high. Product is stored on 40' by 48' four-way entry GMA type pallets. The duo designed an automated guided vehicle system (AGVS) to automated store and retrieval of the products. By implementing the material handling system shown in Fig.8.. They estimated USD $1,000,000 savings annually. [12]

Abhishek M. B. et.al. “Fabrication of Automatic Screw Jack”, The authors describe that, the lead screw is used to convert rotary motion into translation motion. The screw jack is a device used for lifting the load with the application of small force. The effort required to operate the screw is eliminated by using 12 V DC Motor. The motor operates by 12V DC power supply which is drawn from the vehicle battery itself. The rotary motion transfer from the motor to lead screw through worm gear drive. The driver gear (pinion) located on the motor shaft and the driven gear located on the lead screw causes to transfer rotary motion. The calculations and design procedure of a Lead Screw is also done. The main objectives of this project are: To Increase in fuel economy, to minimize human effort, to reduce time, Minimization of lifting and tilting/twisting forces, to reduce fatigue. [13]

Aman B. K. et.al "Design and Analysis of Lead Screw for Fixture", this paper is a describing report on design of Lead Screw for Material Handling Trolley. The authors make the calculations using SFD and BMD and are designing accordingly. The author also describes the main objective of analysis of lead screw is to determine various types of stress and deflection at different mode shapes. The output needs from this work to investigate strength of lead screw for various loading condition. The Finite element method is effective discretization technique in structural mechanism. The finite element method is numerical method which can be used for accurate solution of problems arise during design. After calculating the lead screw dimensions by analytical method it verifies by the finite element model. Discussion on result obtained by theoretical analysis is carried out for statement of conclusion. From this work the statement of conclusion is lead screw safe to work against the given value of load considering deformation and stresses producing in lead screw. [14]

Prabhakar V. P. et.al "Critical Review of Design of Planetary Gears and Gear Box". The authors states that, the extensive research in the field of planetary gear design has already been done. Many researchers reported study on single stage planetary gears arrangement. The advantages of planetary gear trains are higher torque capacity, lower weight, small size and improved efficiency. Planetary Gear Box weighs 60%, and half the size of a conventional gear box. In design of planetary gear box, iterative considerations need to be given for composite arrangement to have minimum number of components, higher transmission efficiency, and higher load carrying capacity. High reductions ratios are possible in single stage differential planetary gear arrangement but will work for low torque applications only like positioning systems in robotics, aerospace. Multi criteria Mathematical modeling methods can be applied to planetary gears and it determines a set of Pareto optimal solution for various objective functions. [15]

Dario Croccolo et.al “A Practical Approach to Gear Design and Lubrication”. The author stated interesting tips and guidelines for gear design, including both its dimensioning and its lubrication, as gears are so much in demand now for their high reliability &efficiency. This practical procedure must also account for the possible need for profile shifting (both with or without center distance variation). Along with this some practical design rules based on the analyses of the power losses also provided in the paper to select the most proper lubricant for Gear transmission designer. Following the previous points this review is also consist of gear quality and tolerances for better quality manufacturing of gears. [16]

Jonny Harianto et.al “A Methodology for Obtaining Optimum Gear Tooth Micro topographies for Noise and Stress Minimization Over a Broad Operating Torque Range”, The author has derived that this paper presents a method for evaluating the effect of micro geometric or micro topographic variation on various gear performance parameters, i.e., noise excitations, gear contact and root stresses, film thickness and surface temperature under loaded conditions. Micro geometries that are considered are profile crown, profile slope, lead crown, lead slope and bias modifications variations. Various combinations of these micro geometries are considered in analytical simulations in which respective gear design metrics are evaluated based on the calculated load distributions. This paper will provide a walk-through analysis for a helical gear design in order to describe the procedure. Perfect involutes profiles of both spur and helical gears only exhibit conjugate motion at no load conditions. Once load is applied to a gear pair, deflections occur and the motion transfer is no longer conjugate. In order to get the motion back to some semblance of conjugacy, the tooth profile is modified, usually by the removal of material from portions of the tooth surface. Profile modifications in the form of tip or root relief compensate for tooth bending deflections, and lead modifications in the form of either lead crown or end relief compensate for manufactured lead errors, shaft misalignments and shaft deflections. This paper has presented an interactive, graphical procedure for determining gear tooth topography designs that minimize the noise and stresses of gears. The method is also a valuable educational tool for understanding the effects of numerous topographical changes of the tooth surface on gear performance. [17]

Thirugnanam, Praphul et.al "Design and Fabrication of Rack and Pinion Lift". The author discussed Car lifting mechanism manufactured by them consists of rack & pinion mechanism to convert rotary motion into the linear motion. Pinion used is of spur gear which is driven by the electric motor with 12 v battery. The system is also consisting macro computer. The material used for rack & spur pinion is cast iron. The conclusion of this system compared to another ways of car lift is the compactness &saving of time & energy though this is having high installation cost. [18]

R. Rajasekar et.al "Design and Fabrication of Variable Rack and Pinion Steering Geometry". The authors explained that, system is consisting of variable rack and pinion with higher to lower ratio in order to sensitize the steering for better maneuverability for Indian road condition or urban road condition. A spur gear is designed and manufactured along with the rack for the purpose of rotary to linear motion conversion. In the middle of the rack, you will have a sensitive ratio and the response becomes a-base as you turn the steering wheel towards lock. This makes the steering more sensitive, when the steering wheel is close to its center position and makes it easier for the driver to steer at low speeds. [19]

Callum Oglieve et.al "Study on Lubricated loaded tooth contact analysis for spur gear pair". The author combined FEA-based TCA model with a lubricated contact mechanics analysis for real gear pairs measured from coordinate measuring machine (CMM) for improving the prediction of gear pair efficiency, NVH and durability. A coordinate measuring machine (CMM) is used for accurate representation of the complex gear tooth profile. The raw data output from the machine can be used as an input into the CAD software (NX 8.5) and a spline tool can be used to interpolate between measurement points. Abaqus FEA software is utilized for the simulations. Loaded tooth contact analysis is done and it is validated by using commercially available TCA software

CALYX. The variation of the contact force acting on a single tooth throughout the meshing cycle is used as a comparison between the two models. Mesh sensitivity study was carried out to understand the mesh densities effect on the contact forces. Overall, the TCA model described was able to accurately analyze gear contact behavior whilst taking in to account the real geometry. The coupling of LTCA with analytical lubrication models led to improved contact conditions and the use of CMM geometrical data provides a means of improving gear interaction predictions. Due to the flexibility offered by FEA software, the model can be modified to work with various other types of complex gear systems such as; helical, bevel and hypoid. [20]

## 2.1 Comments on Literature Review

Various kinds of Material Handling Systems are studied suggested by various authors. After studying the research papers, mechanisms are sorted out which can be used for implementing the automation. Hydraulic piston cylinder mechanism used in hydraulic lifts, rack & pinion mechanism used in steering mechanism, lead screw and carriage mechanism used in the lathe bed movement and gear trains used in gearbox these mechanisms are sorted.

"Design and Fabrication of Variable Rack and Pinion Steering Geometry", this paper is used to take guidance of the design calculations for the proposed system. In "Design and Development of Weight Operated Material Handling Device", author discussed the material handling system using the potential energy of the object. In this system author used the rack & pinion and gear trains for the movement. When weight is loaded then spring get compressed and rack move downwards. This results in rotation of pinion which is driving sprocket mechanism for the purpose of movement of the load. The system is so much economical as it does not requires any external power supply. From this paper the proposed system is designed.

# 3. Design of Rack and Pinion Mechanism

The below chapter is the detail explanation of the various design procedure undertaken in order to implement the further fabrication of the mechanism.

## 3.1. Gear Terminology

**Pitch circle** The pitch circle is the curve of intersection of the pitch surface of revolution and the plane of rotation. It is an imaginary circle that rolls without slipping with the pitch circle of a mating gear. The pitch circles of a pair of mating gears are tangent to each other.

**Pitch circle diameter (d)** The pitch circle diameter is the diameter of pitch circle. The size of the gear is usually specified by pitch circle diameter. It is also called 'pitch diameter'.

**Base circle** The base circle is an imaginary circle from which the involute curve of the tooth profile is generated. The base circles of two mating gears are tangent to the pressure line.

**Addendum circle** The addendum circle is an imaginary circle that borders the tops of gear teeth in the cross section.

**Addendum (ha)** The addendum (ha) is the radial distance between pitch and the addendum circles. Addendum indicates the height of tooth above the pitch circle.

**Dedendum circle** The dedendum circle is an imaginary circle that borders the bottom of spaces between teeth in the cross section. It is also called 'root' circle.

**Dedendum (hf)** The dedendum (hf ) is the radial distance between pitch and the dedendum circles. The dedendum indicates the depth of the tooth below the pitch circle.

**Clearance (c)** The clearance is the amount by which the dedendum of a given gear exceeds the addendum of its mating tooth.

**Face width (b)** Face width is width of the tooth measured parallel to the axis.

**Circular tooth thickness** The length of the arc on pitch circle subtending a single gear tooth is called circular tooth thickness. Theoretically, circular tooth thickness is half of circular pitch.

**Tooth space** The width of the space between two adjacent teeth measured along the pitch circle is called the tooth space. Theoretically, tooth space is equal to circular tooth thickness or half of circular pitch.

**Working depth (hk)** The working depth is the depth of engagement of two gear teeth, that is, the sum of their addendums.

**Whole depth (h)** The whole depth is the total depth of the tooth space, that is, the sum of addendum and dedendum.

Whole depth is also equal to working depth plus clearance.

**Centre distance** The centre distance is the distance between centres of pitch circles of mating gears. It is also the distance between centres of base circles of mating gears.

**Pressure angle (a)** The pressure angle is the angle, which the line of action makes with the common tangent to the pitch circles. The pressure angle is also called the angle of obliquity.

**Circular pitch (p)** The circular pitch is the distance measured along the pitch circle between two similar points on adjacent teeth.

**Diametral pitch (P)** The diametral pitch is the ratio of the number of teeth to the pitch circle diameter

**20° Full depth involute systems**

The basic rack for this system is also composed of straight sides except for the fillet arcs. In this system, interference occurs when the number of teeth on pinion is less than 17. The 20°-pressure angle system with full depth involute teeth is widely used in practice. It is also recommended by Bureau of Indian Standards.

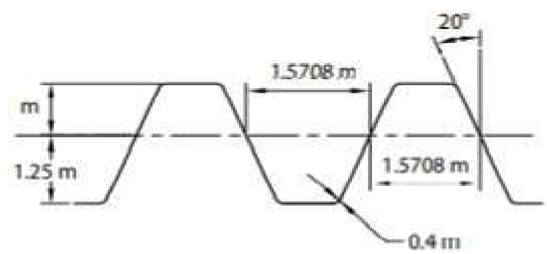



Fig. 3.1 : Empirical Dimensions of $20^0$ Full Depth Involute System

Table 3.1: Standard proportions of gear tooth for 20° full depth involute system

| Dimensions | Notations | Proportion |
|---|---|---|
| **Addendum** | $h_a$ | $h_a = m$ |
| **Dedendum** | $h_f$ | $h_f = 1.25m$ |
| **Clearance** | $C$ | $C = 0.25m$ |
| **Working Depth** | $h_d$ | $h_d = 2m$ |
| **Whole Depth** | $H$ | $h = 2.25m$ |
| **Tooth Thickness** | $S$ | $s = 1.5708m$ |
| **Tooth Space** | - | $1.5708m$ |
| **Fillet Radius** | - | $0.4m$ |

Table 3.2 : Tolerances on the adjacent pitch

| Dimensions | Notations |
|---|---|
| **1** | *0.80 +0.06□* |
| **2** | *1.25 +0.10□* |
| **3** | *2.00 +0.16□* |
| **4** | *3.20 +0.25□* |
| **5** | *5.00 +0.40□* |
| **6** | *8.00 +0.63□* |
| **7** | *11.00 +0.90∅* |
| **8** | *16.00 +1.25□* |
| **9** | *22.00+1.80□* |
| **10** | *32.00 +2.50□* |
| **11** | *45.00 +3.55□* |
| **12** | *63.00 +5.00□* |

### 3.2. Design Calculations :

Assumptions/Considerations :

No of teeth on pinion ($z_P$) = 21

No of teeth on rack ($z_R$) =64

FOS=2

Speed of gear = 85rpm

Standard system of gear tooth - $20^{\circ}$ full depth involutes

Power = 1.5HP

Material- Spur Pinion = EN24

(Sut)p = 1075N/mm² , (BHN)p=313,

Reference of PSG Design Data Book Page No. 1.15

Solution-

As pinion is moving and rack is stationery, we are taking pinion weaker.

**Beam strength of spur gear:**

Beam strength of the gear is the maximum tangential load the gear tooth can take without tooth breakage.

It is given as

Beam strength ( Fb ) = (σ)b b m Y

Where ( σ )b = Bending endurance strength (N/mm2)

b = face width

m = module

Y = Lewis form factor

Now we have,

Thus $(\sigma)_b$ of gear = Sut/3= 1075/3 = 358.33 N/mm2

Lewis form factor (Y) is given by

(Y)gear = 0.484 – [ 2.87/ (Z)g ]

(Y)gear = 0.4795

(Y)pinion = 0.484 – [ 2.87/ (Z)p ]

(Y)pinion = 0.4703

To find out the weaker member between gear and pinion in bending we have to compare the product of :

[ (Y)gear × (σ)b of gear]and [ (Y)pinion × (σ)b of pinion ]

[ (Y)gear × (σ)b of gear] = [ 0.4795× 358.33]= [ 171.899 ]

[(Y)pinion×(σ)b of pinion]=[0.4703×358.33]=[ 168.522]

[ (Y)gear × (σ)b of gear] < [ (Y)pinion × (σ)b of pinion]

Thus gear is weaker than pinion in bending , we have to check the beam strength of gear.

Beam strength ( Fb )gear = (σ)b b m Y = [ (358.33) ( 10m ) (m) ( 0.4703 ) ] N

= [ 1685.23 m^2 ] N

**Wear strength of spur gear:**

Wear strength of spur gear is the maximum tangential load the gear tooth can take without pitting failure.

It is given by,

Wear strength ( Fw ) = dp b Q K

Where dp = pitch circle diameter of pinion

b = Face width

Q = Ratio factor

K = Load stress factor

Ratio factor ( Q ) is given by [ 2 Zg / ( Zg + Zp ) ]

Q = 1.50588

Load stress factor ( K ) for the Cast iron gear and steel pinion is given by,

K = { 0.18 [ BHN / 100 ] ^2 }

We have BHN for the pinion as 217 Thus,

K = { 0.18 [313 / 100 ] ^2 }

K = 1.568

Wear strength ( Fw ) = dp b Q K

( Fw) = 21m × 10m × 1.50588  1.568

( Fw ) = $495.237m^2$ N

Here, wear strength < beam strength

As wear strength is less than the beam strength of the gear pairs, the design should be based on wear strength.

Effective load on spur gear:

P = 1.5 HP

Now pitch line velocity (V) = V = π Dp Np / 60 (V) = 0.09346mm/s

We have theoretical tangential force acting on the gear tooth

Ft = P/V = (11968.2217 / m ) N

But we have to consider the maximum tangential force acting on gear tooth which is given by

( Ft )max = Ka Km Ft

Taking

Ka = 1

Km = 1.25

Thus( Ft )max = [1×1.25×11968.2217/m] N

(Ft)max=[ 14,960.277 /m ] N

Now we have to calculate the dynamic load by Preliminary estimation considering the velocity factor (Kv)

The velocity factor depends on the manufacturing method of gears and accuracy level. So considering the gears are finished by grinding with medium accuracy the velocity factor will be:

$$( Kv ) = [ 6 / 6 + (V)]$$

Effective load is given by

( F )eff = ( Ft )max / Kv

( F )eff = { [ 11968.2217/m ]/[ 6 / 6 +0.09346m ]}

Safety factor against bending failure

In order to avoid the pitting failure the wear strength of the gear tooth must be greater than effective load between the mating teeth. Thus, factor of safety comes into the play.

(Fb )= F.O.S. × ( F )effective

[ 1685.23 m^2 ] = 2 × [ 11968.2217/m ]/[ 6 / 6 +0.09346m]

Thus, the module comes equal to be **3mm**

**Dimension of gear pair:**

m = 3mm

Zg= 64;            dg = m× Zg = 63mm

Zp =21;            dp = m× Zp = 192 mm

Face width (b) = 10m = 30 mm

Addendum (ha) = 1m = 3 mm

Dedendum (hf) = 1.25m = 4.5mm

Central distance (a) = (dp + dg )/2 = 127.5mm

Beam strength =[1685.23 m^2 ]N=15167.07 N

Wear strength =[ 495.237m^2 ] N=4457.133 N

Precise estimation of dynamic load by Buckingham's equation (check for the design )

Buckingham's equation for dynamic load in tangential direction is given by,

(F d) = 21V [ bC + (Ft)max]

21 V + [ bC + (Ft)max ]^(1/2)

We have (Ft)max =3989.407 N, V = 0.28038 m/s , b = 30 mm

C is deformation factor (N/mm)

Standard value of C for EN24 is C = 10,000 e, where e is pitch error.

As we have considered the gears are finished by grinding with medium accuracy and also the gear speed is low so IS grade 6 is best suitable for our application.

Thus for IS grade 10 we have pitch error formula as :

e = 8 + 0.63 Øp

Øp is tolerance factor and given by

Øp = m + 0.25 (d)^(1/2)

Pitch error (e) = (e)p + (e)g

(e)gear =12.70 (e)pinion =11.77

e = 12.70 + 11.77 = 24.47micron

C = 10,000 × ( 24.47× 10 ^ -3 )

C = 244.7 N/mm

Now putting values in

(F d) = 580.8423 N

(F) effective = ( Ft ) max + ( F d )

(F) effective = 3989.407 N + 580.8423 N = 4570.262 N

We have F.O.S. =(Fw)/(F)

effective F.O.S = (4457.133)/(4570.262)

F.O.S. = 0.9752< 2

As available F.O.S. is less than the required F.O.S. Our design is unsafe. We can modify our design by either increasing the module to make it safe.

**Increasing the module to 4**

New dimensions

m = 4mm

Zg= 64; dg = m× Zg = 256 mm

Zp =21; dp = m× Zp = 64 mm

Face width (b) = 10m = 40 mm

Addendum (ha) = 1m = 4 mm

Dedendum (hf) = 1.25m = 6 mm

Central distance (a) = (dp + dg )/2 = 160 mm

Beam strength = [1685.23 m^2 ] N = 26963.68N

Wear strength = [ 495.237 m^2 ] N = 7923.792N

Precise estimation of dynamic load by Buckingham's equation (check for the design)

Buckingham's equation for dynamic load in tangential direction is given by,

(F d) = 21V [ bC + (Ft)max]
21 V + [ bC + (Ft)max ]^(1/2)
(F d) = 837.178 N
(F) effective = ( Ft ) max + ( F d )
(F) effective = 3929.233 N
We have F.O.S. = (F w ) / ( F ) effective

F.O.S = (7923.792)/ (3929.233)

F.O.S. = 2.069> 2

As Available F.O.S. is slightly More than the required F.O.S. Our design is slightly safe.

**Taking Module 4.5**

m = 4.5 mm

Zg= 64; dg = m× Zg = 288 mm

Zp =21; dp = m× Zp = 94.5 mm

Face width (b) = 10m = 45 mm

Addendum (ha) = 1m = 4.5 mm

Dedendum (hf) = 1.25m = 6.625 mm

Central distance (a) = (dp + dg )/2 = 191.25 mm

Beam strength = [1685.23 m^2 ] N = 34125.9075 N

Wear strength = [ 495.237 m^2 ] N = 10028.54 N

Precise estimation of dynamic load by Buckingham's equation (check for the design)

Buckingham's equation for dynamic load in tangential direction is given by,

(F d) = 21V [ bC + (Ft)max]

21 V + [ bC + (Ft)max ]^(1/2)

(F d) = 973.1309 N

(F) effective = ( Ft ) max + ( F d )

(F) effective = 3632.7357 N

We have F.O.S. = (F w ) / ( F ) effective

F.O.S = (10028.54)/ (3632.7357)

F.O.S. = 2.76> 2

As Available F.O.S. is More than the required F.O.S. Our design is safe.

Final Dimensions

m = 4.5 mm

Zg= 64; dg = m× Zg = 288 mm

Zp =21; dp = m× Zp = 94.5 mm

Face width (b) = 10m = 45 mm

Addendum (ha) = 1m = 4.5 mm

Dedendum (hf) = 1.25m = 6.625 mm

Central distance (a) = (dp + dg )/2 = 191.25 mm

Working Depth = 9 mm

Whole Deptth = 10.125 mm

Tooth Thickness = 7.0686 mm

Tooth Space = 7.0686 mm

Fillet Radius = 2 mm

Friction Angle = 20°

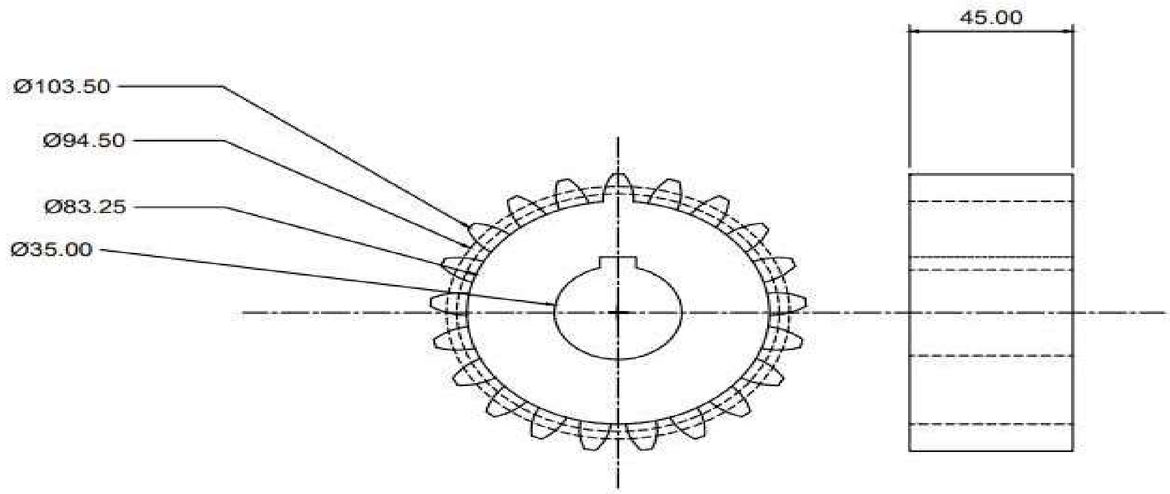



Fig. 3.2 : Dimensions of Spur Pinion

**3.3 Selection of Plummer Block**

Design Inputs

Gearbox Output shaft diameter = 31.78 mm

Hence by the reference of V. B. Bhandari Design Data book page no. 15.61 we have selected the Light series Plummer block having shaft bore diameter of 35 mm

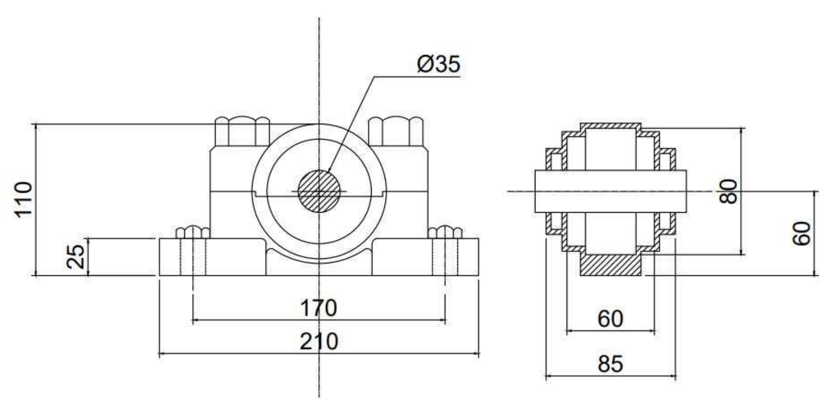



Fig. 3.3 : Plummer Block Diagram

## 3.4. Selection of Shaft

Design Inputs

Gearbox Output shaft diameter = 31.78 mm

Shaft bore diameter of Plummer block Selected = 35 mm

Hence by the reference of V. B. Bhandari Design Data book page no. 9.4 we have selected the Plummer block having shaft bore diameter of 35 mm

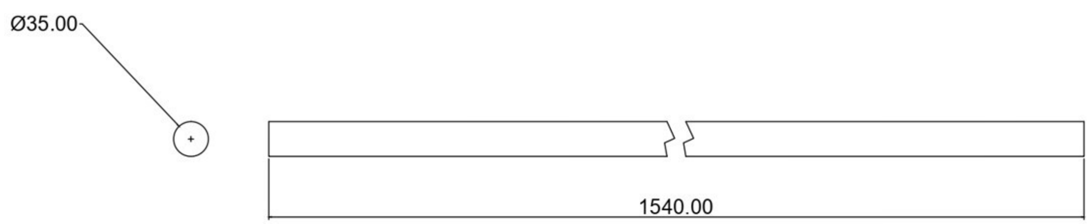



Fig. 3.4:Shaft

## 3.5. Design of C-Channel

Thickness of Channel = 5 mm

Internal Length of channel = Width of the Rack = 45 mm

Outer Length of Channel = 50 mm

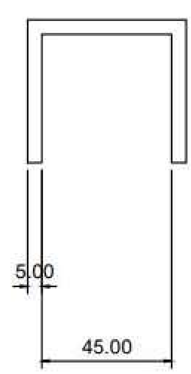



Fig. 3.5: C Channel Design

### 3.6. Selection of Key

Design Inputs

Transmission shaft diameter = 35 mm

Shaft bore diameter of Plummer block Selected = 35 mm

Hence by the reference of V. B. Bhandari Design Data book page no. 9.9 we have selected the key having following dimensions

Key Dimensions

B = 10 mm

H = 8 mm

Keyway depth

In shaft (t1) = 5 mm

In hub (t2) = 3.3 mm

Keyway radius (r)

Minimum = 0.25 mm

Maximum = 0.40 mm

Chamfer of key (s)

Minimum = 0.40 mm

Maximum = 0.60 mm

Key length

Minimum = 22 mm

Maximum = 110 mm

Length taken as per width of spur pinion = 45 mm

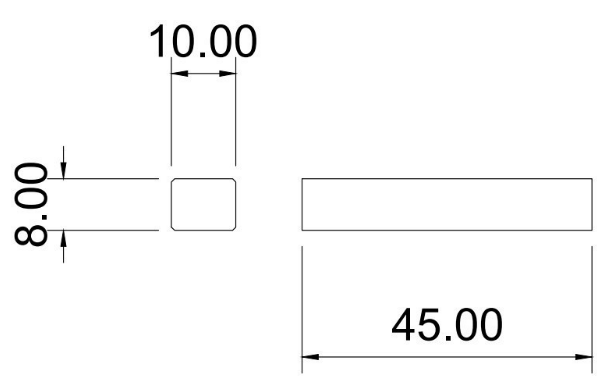



Fig. 3.6: Key

## 3.7. Selection of Coupling

Design Inputs

Gearbox Output shaft diameter = 31.78 mm

Shaft bore diameter of Plummer block Selected = 35 mm

Hence by the reference of V. B. Bhandari Design Data book page no. 9.33 we have selected the Coupling having shaft bore diameter of 35 mm

Selecting the Bush Type Flexible Coupling Minimum bore diameter 25 mm and maximum bore diameter 35

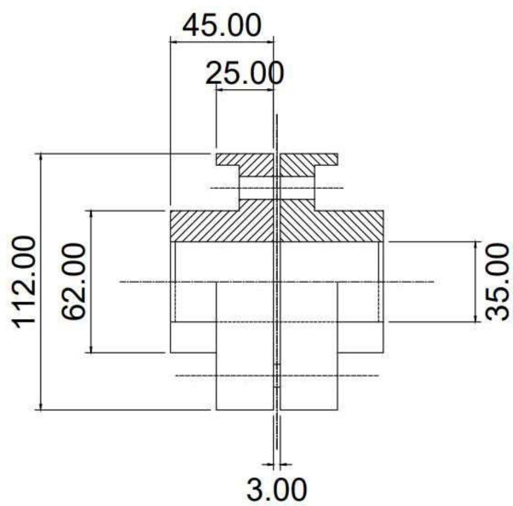



Fig. 3.7: Bush Type Flexible Coupling

# 4. Assembly and Testing

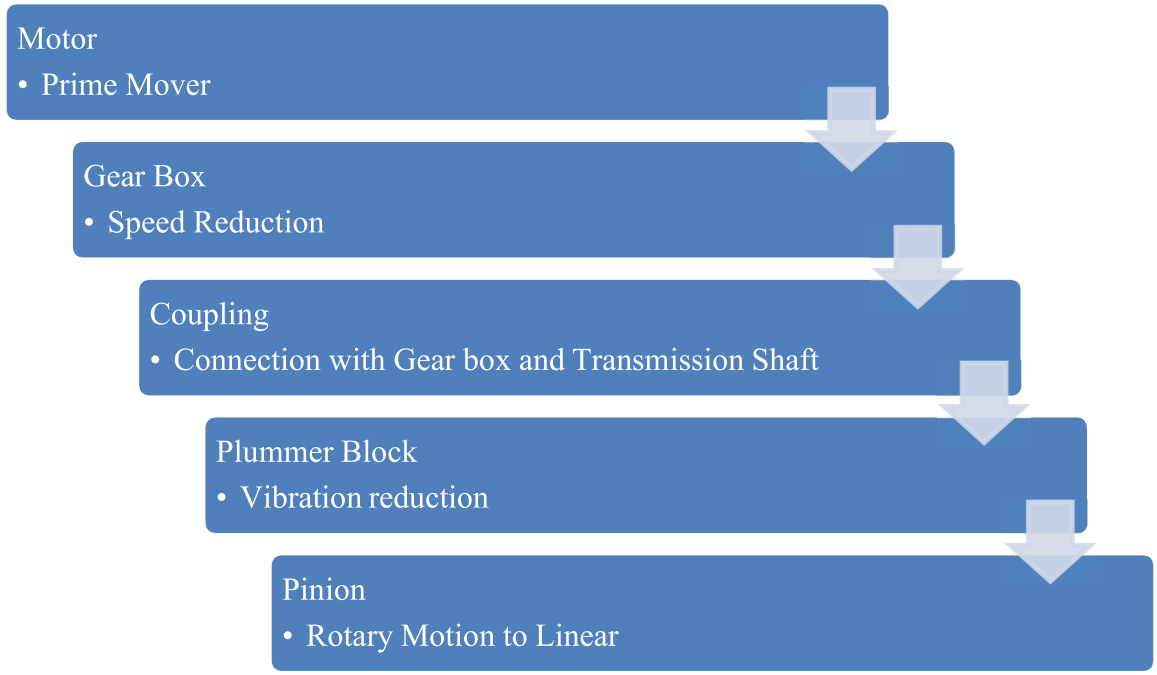



Fig 4.1 Components of Assembly

The proposed designed is assembled in such a way that, the three-phase induction motor is driving the Gearbox by means of pulley drive which is reducing the speed of the motor of 1440 rpm to 85 rpm.

The 35 mm shaft is attached to the output shaft of the gearbox by means of the bush type flexible coupling. The plummer block is added on the shaft followed by the spur pinion again followed by the plummer block to its end. The plummer block is added to the system to reduce the vibrations produced due to the rotating elements.

The rack is placed inside the C-channel having inside length of 45 mm and the component is welded in the centre of the trolley from bottom side.

The power is supplied to the motor which is transmits to the gearbox hence to the transmission shaft. The spur pinion is mounted on the shaft and rack is attached to the upper side pinion such that rotary motion get converts into liner motion led to the movement of the trolley.

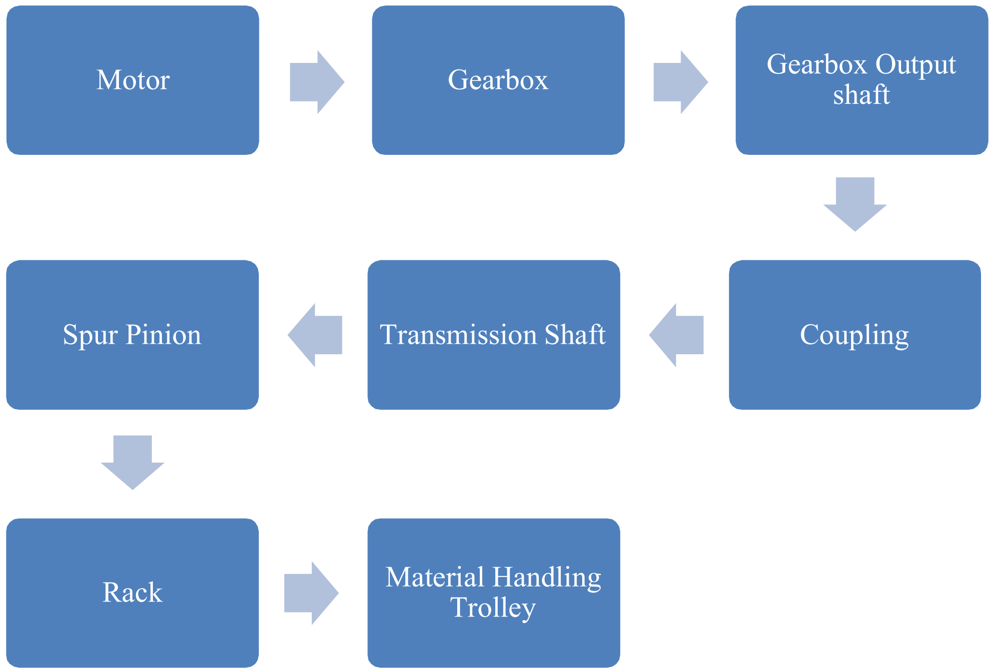



Fig 4.2 Motion Transmission Flowchart

## 5. Results and Discussions

Table 5.1 Result Table

| Sr. No. | Total time required for the complete process (Before Automation) (in sec) | Total time required for the complete process (After Automation) (in sec) |
|---|---|---|
| 1 | 264 | 186 |
| 2 | 268 | 185 |
| 3 | 270 | 186 |
| 4 | 262 | 184 |
| 5 | 261 | 185 |
| 6 | 264 | 188 |
| 7 | 265 | 187 |
| 8 | 265 | 185 |
| 9 | 265 | 185 |
| 10 | 265 | 188 |
| 11 | 265 | 186 |
| 12 | 269 | 189 |
| 13 | 271 | 187 |
| 14 | 267 | 185 |
| 15 | 262 | 184 |
| 16 | 263 | 184 |
| 17 | 263 | 185 |
| 18 | 266 | 186 |
| 19 | 260 | 186 |
| 20 | 263 | 188 |
| **Average Time** | 264.6 | 185.7 |

The average time for the whole process before implementing the system was 265 secs i.e., 4 mins 25 secs and that after implementing the proposed system was 185 secs i.e., 3 mins 05 secs.

The system is now automated and the time required for the whole process of cleaning is saved as compare to manual. As vibrations are reduced due to the involvement of the Plummer block at the both end of transmission shaft. This provides additional stability and strength to the mechanism. The system is designed and implemented by taking the actual space limitation in consideration. The components designed and selected while designing the whole system are having less wear and tear which is led into less maintenance, cost saving for maintenance and result in economic system.

As physical efforts of the operators are reduced and the trolley is now switch operated hence the fatigue of the operators is reduced. The reduced number of engaged operators will lead into the increase in the productivity and cost saving.

# 6. Conclusions and Future Scope

## 6.1 Conclusions

Taking several trials before and after implementing the mechanism, it can be concluded that, the net save in time for the whole cleaning process was found 30.19% per cycle. Fatigue of the operators is reduced as previous Material Handling Method was monotonous and is now automated. Now the operator just needs to operate the switches. Probabilities of the accidents are reduced as automation is implemented. As number of operators engaged in the operation is reduced, it ultimately results in cost saving. Saving in time for the whole process is ultimately increasing the process output which leads to increase the productivity of the system.

## 6.2 Future Scope

Currently the implemented proposed system is semiautomatic. At further stage the system can be developed as fully automatic by addition of sensors, actuators, timer-circuits, relays which can be controlled by PLC (Programmable Logic Controller) or Microcontroller.

## References

1. Paraschos Maniatis," Automated material handling and just-in-time", "International Journal of Materials and Product Technology, Vol. 13, Nos. 3- 6, (1998)".
2. Aditya A. K. et.al, "Selection of Material Handling Equipment: Classifications & Attributes", "International Journal for Innovative Research in Science & Technology", Volume 5 | Issue 8 | January 2019
3. Corina Pop et.al, "Automated Material Handling Systems (AMHS) in libraries and archives Automated Storage/retrieval and Return/sorting Systems", Recent Researches in Neural Networks (2011)
4. Jessica O. Matson et.al, "Operational Research and Material Handling", "North-Holland Publishing Company European Journal of Operational Research" (1982).
5. Malini Natarajarathinam et.al, "Measuring Performance of Material Handling Systems: A Conveyor System Analysis", Inderscience Enterprises Ltd. Vol. 3, No. 2, (2011).
6. Sera Akincilar et.al, "Material Handling System Design : A case study in Bosch Rexroth Japan".
7. Ramkumar R. et.al, "Optimization of Material Handling Trolley using Finite Element Analysis" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE). e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 13, Issue 6 Ver. V (Nov. - Dec. 2016), PP 137-148.
8. Riyaz Ahmed et.al, "A Review Paper of Various Industrial Material Handling Systems" International Journal of Innovations in Engineering and Science, Vol. 2, No.10, 2017.
9. Mahesh Kadam et.al "Design and Development of Weight Operated Material Handling Device", Journal of Modern Mechanical Systems and Machining Volume 1 Issue 2.
10. Mr. A. S. Chavan et.al, "Material Handling System – A Case Study For Small Scale Industry", "International Journal of Advanced Technology in Engineering and Science", Volume No.03, Issue No. 03, March 2015
11. Guilherme Bergmann Borges Vieira et.al, "Materials Handling Management : A Case Study", "Journal of Operations and Supply Chain Management", Volume 4 | Issue 2 | July - December 2011

12. Larry M. S. et.al "Material Handling Case Study : Optimizing Material Handling System Costs"
13. Abhishek M. B. et.al. "Fabrication of Automatic Screw Jack", "International Journal of Advance Research and Development" | Volume 3, Issue 4 (2018).
14. Aman B. K. et.al "Design and Analysis of Lead Screw for Fixture", "International Journal of Modern Trends in Engineering and Research" | Volume 2, Issue 7 (July 2015).
15. Prabhakar V. P. et.al "Critical Review of Design of Planetary Gears and Gear Box", "International Journal of Mechanical Engineer and Information Technology" | Volume 3, Issue 3 (March 2015).
16. Dario Croccolo et.al "A Practical Approach to Gear Design and Lubrication", Journal Lubricants (MDPI).
17. Jonny Harianto et.al "A Methodology for Obtaining Optimum Gear Tooth Micro topographies for Noise and Stress Minimization Over a Broad Operating Torque Range", "International Design Engineering Technical Conferences & Computers and Information in Engineering Conference" (2007)
18. Thirugnanam, Praphul et.al "Design and Fabrication of Rack and Pinion Lift", Middle-East Journal of Scientific Research 20 (6): 744-748, 2014 ISSN 1990-9233.
19. R. Rajasekar et.al "Design And Fabrication Of Variable Rack And Pinion Steering Geometry", International Conference on Energy Efficient Technologies for Automobiles (EETA' 15) Journal of Chemical and Pharmaceutical Sciences.
20. Callum Oglieve et.al "Study on Lubricated loaded tooth contact analysis for spur gear pair", International Journal of Powertrains", Volume 8, Issue. 1, (2019).
21. https://www.birlaprecision.com/
22. Design Data Data Book Of Engineers By PSG College Kalaikathir Achchagam.
23. Machine Design Data Book by V. B. Bhandari.

# Annexure A

Existing System



Fig. A. Existing System of Material Handling

# Annexure B

Catia & CAD Drawings

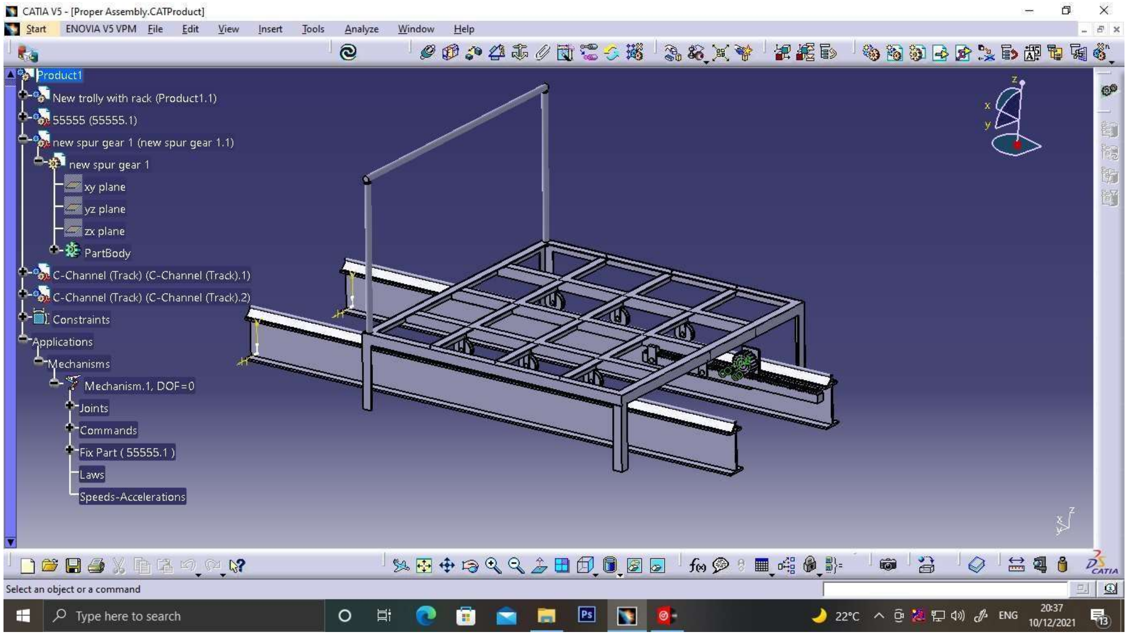



Fig B.1 Trolley in CAD Software (CATIA)

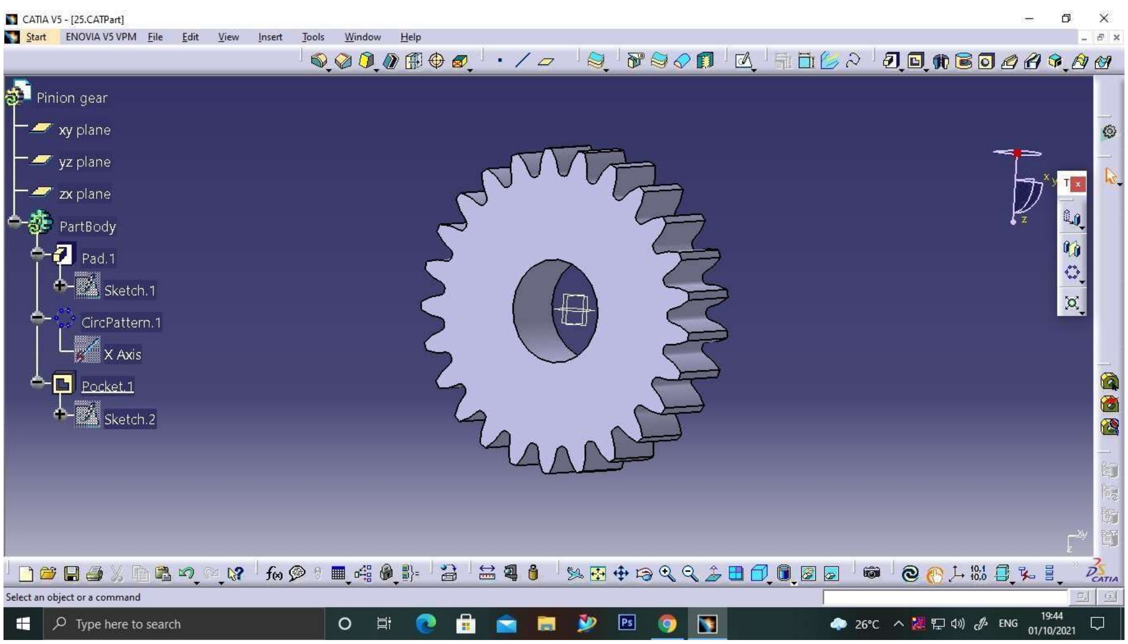



Fig B.2 Spur Pinion in CAD Software (CATIA)

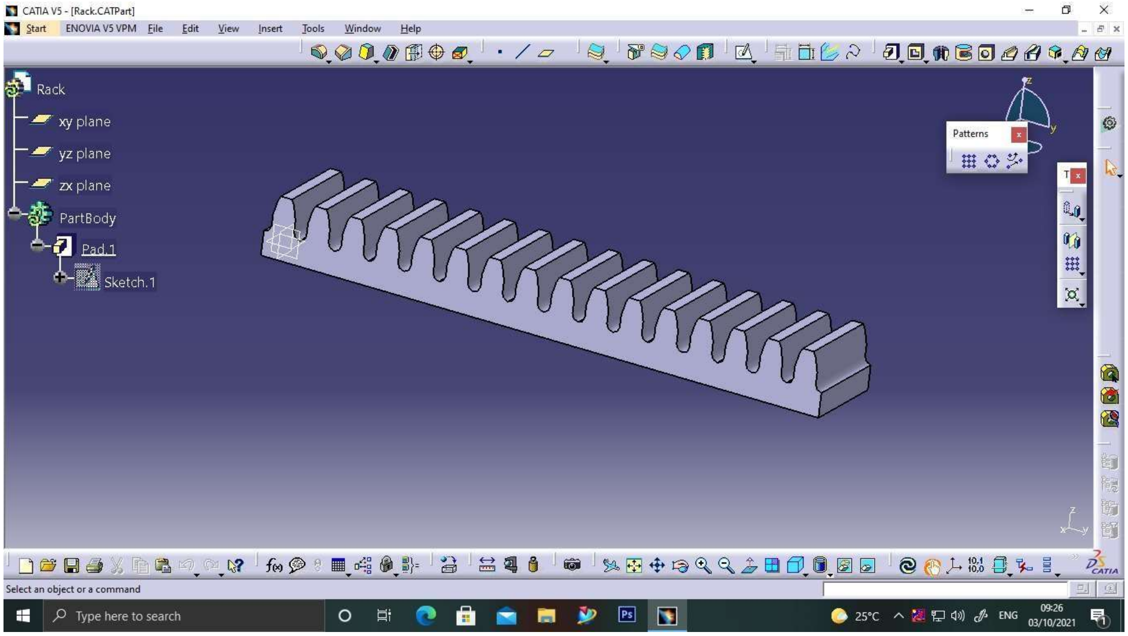



Fig B.3 Rack in CAD Software (CATIA)

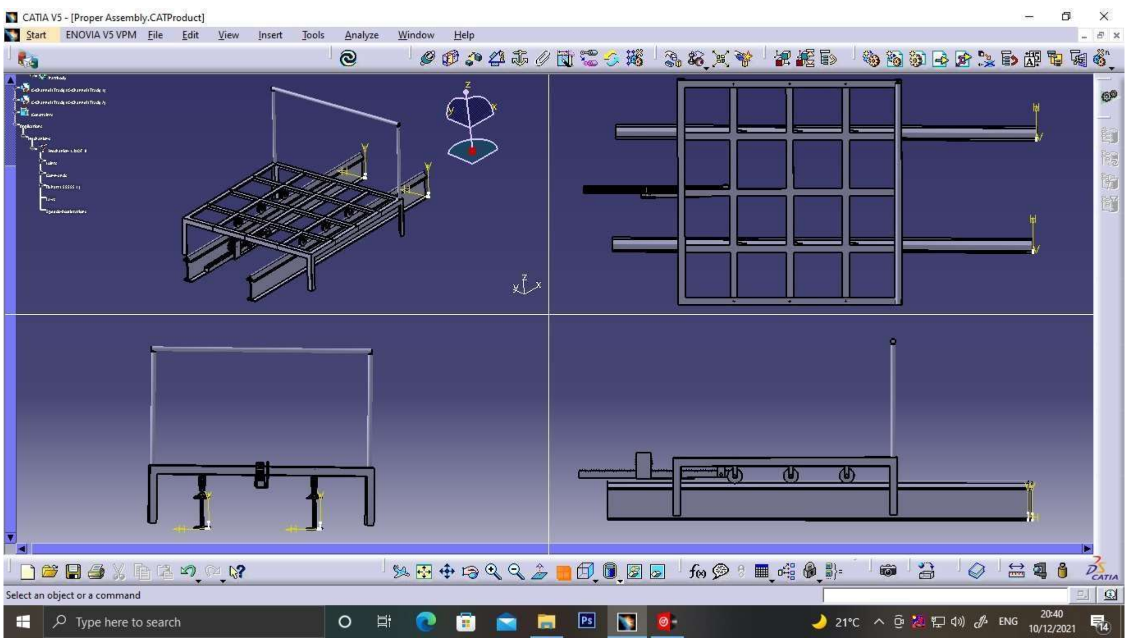



Fig B.4 Implementation of Rack & Pinion in CAD Software (CATIA)

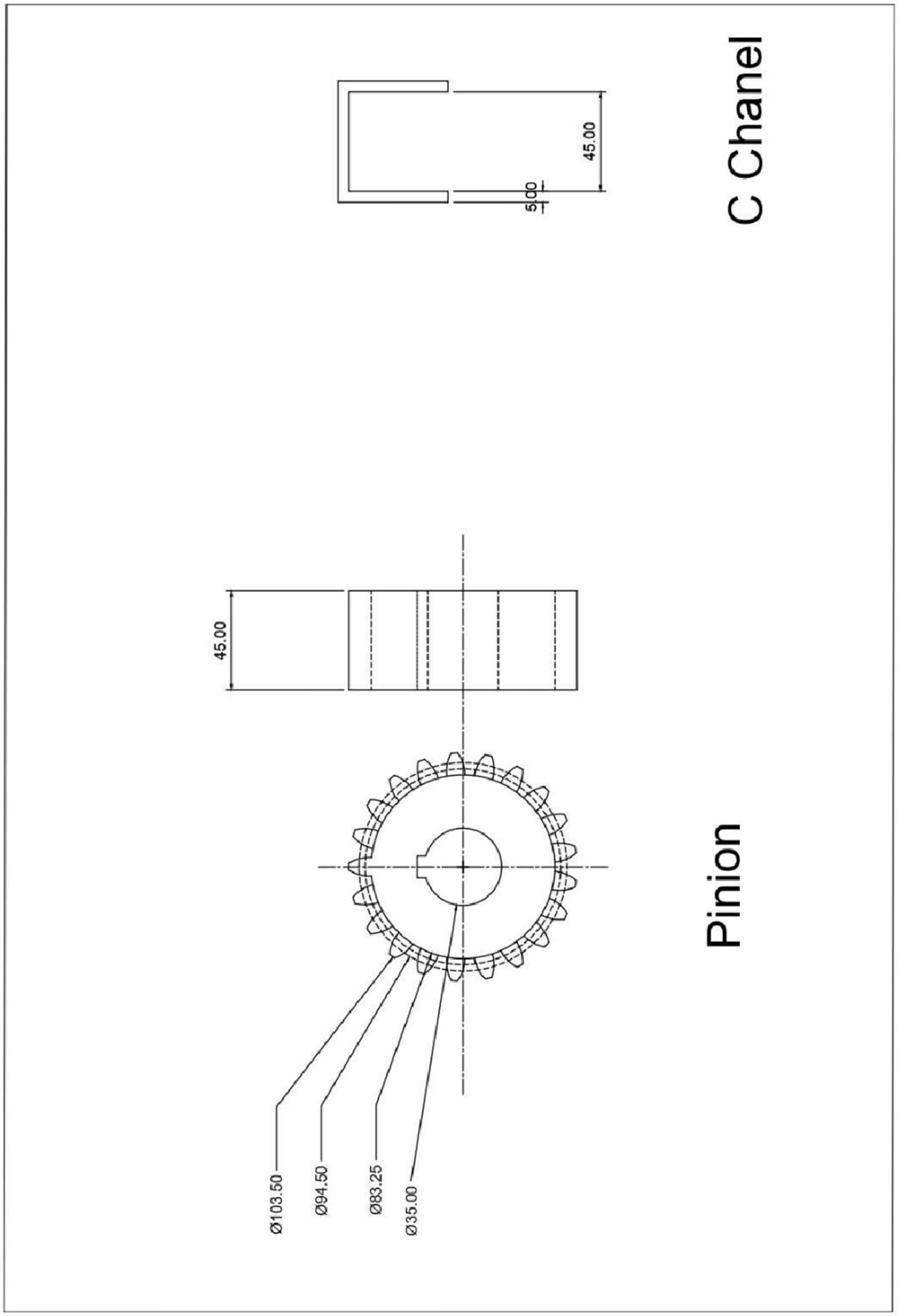



Fig B.5 Spur Pinion and C-Channel in CAD Software (AUTOCAD)

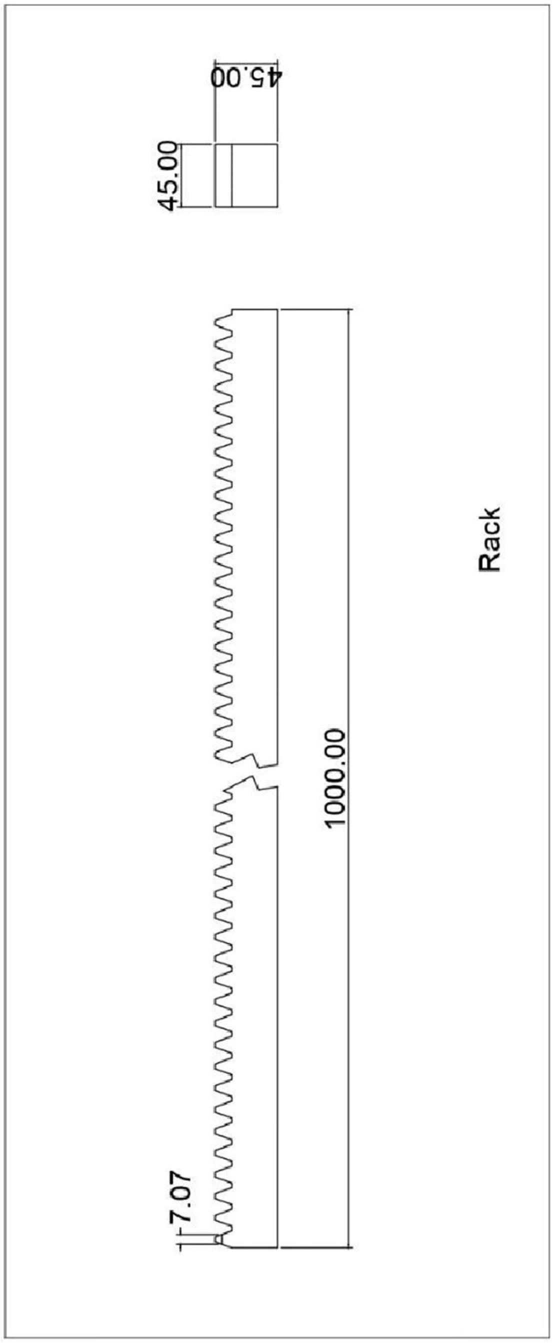



Fig B.6 Rack in CAD Software (AUTOCAD)

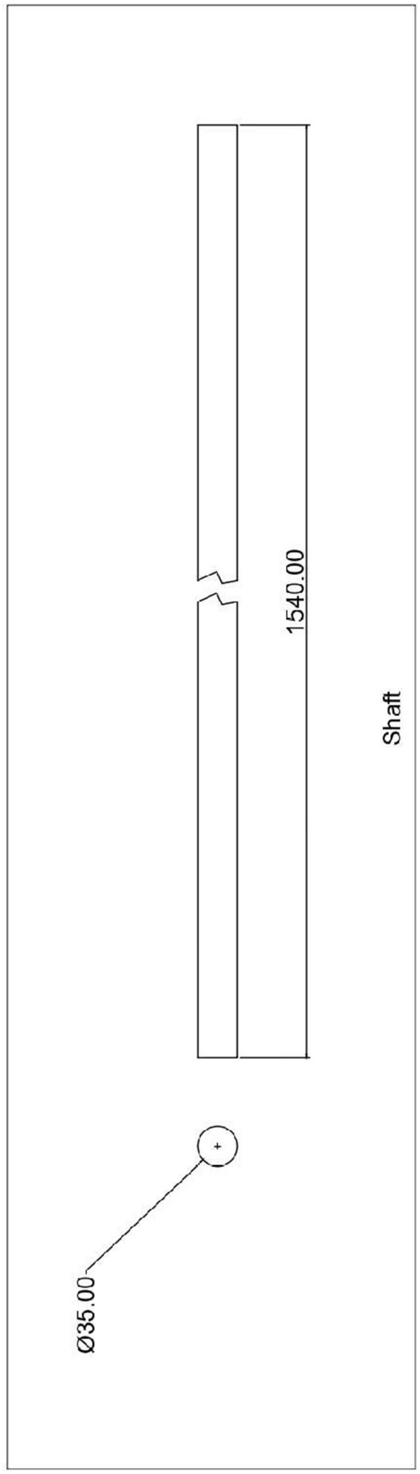



Fig B.7 Transmission Shaft in CAD Software (AUTOCAD)

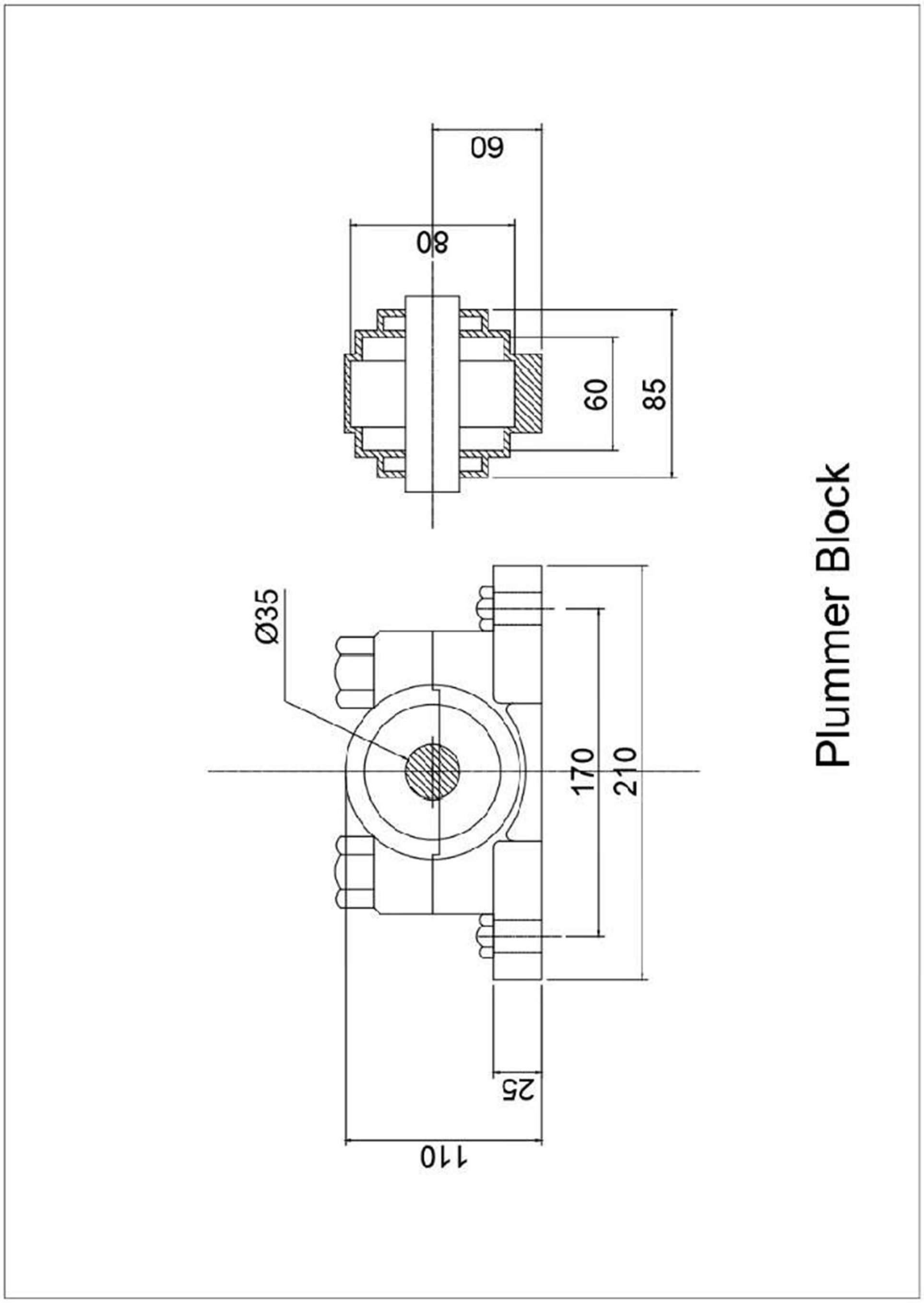



Fig B.8 Plummer Block in CAD Software (AUTOCAD)

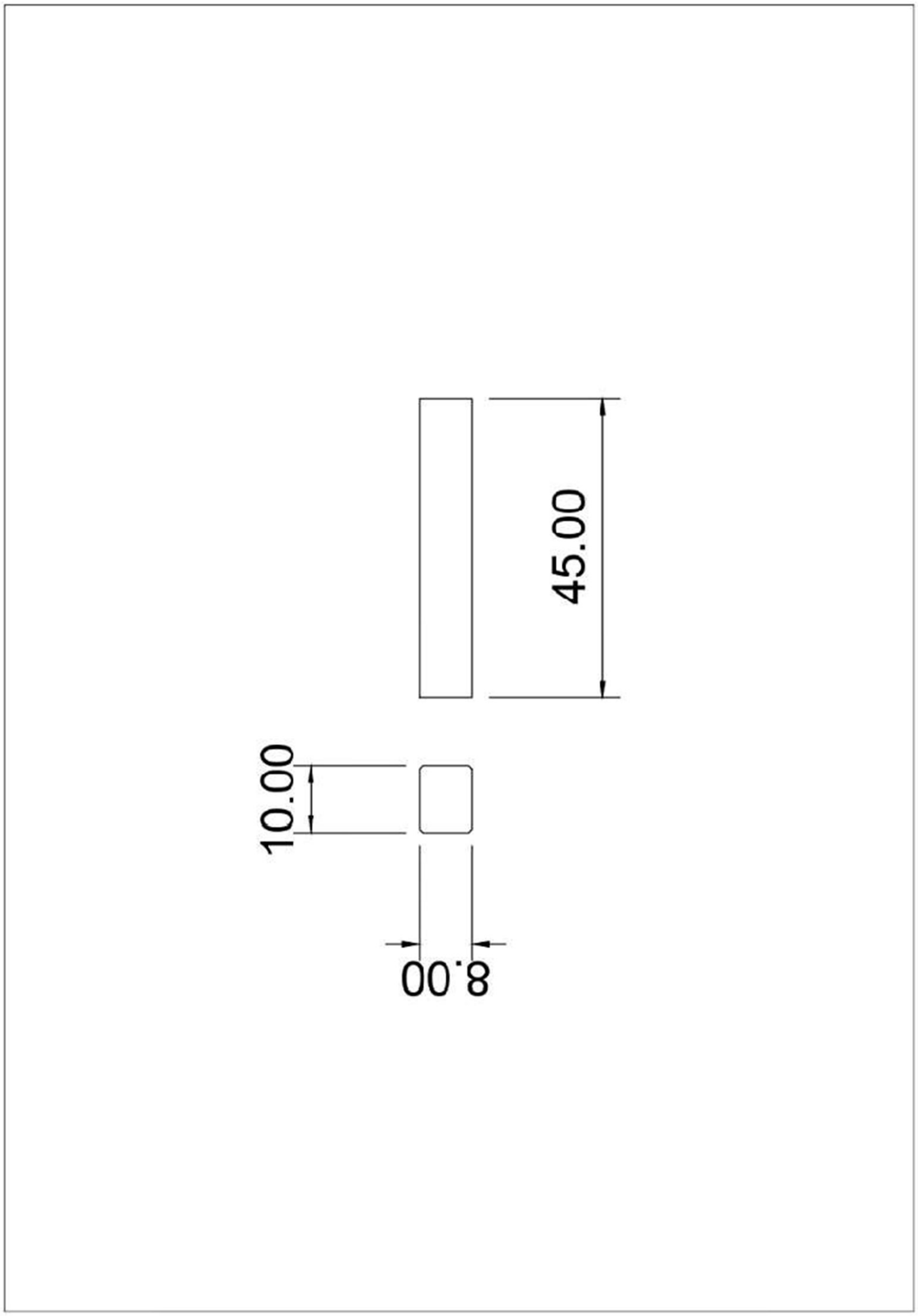



Fig B.9 Key in CAD Software (AUTOCAD)

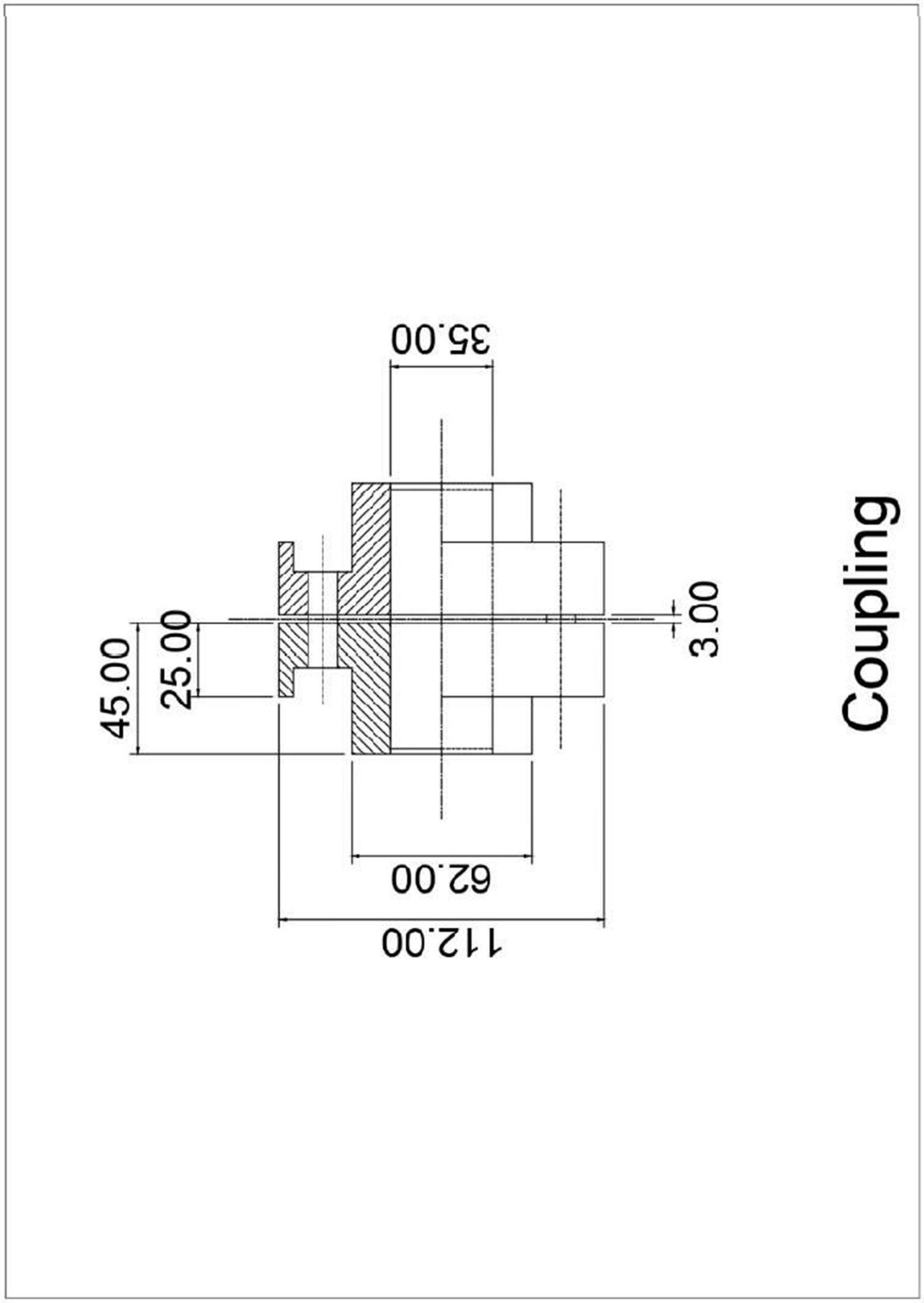



Fig B.10 Bush Type Flexible Coupling in CAD Software (AUTOCAD)

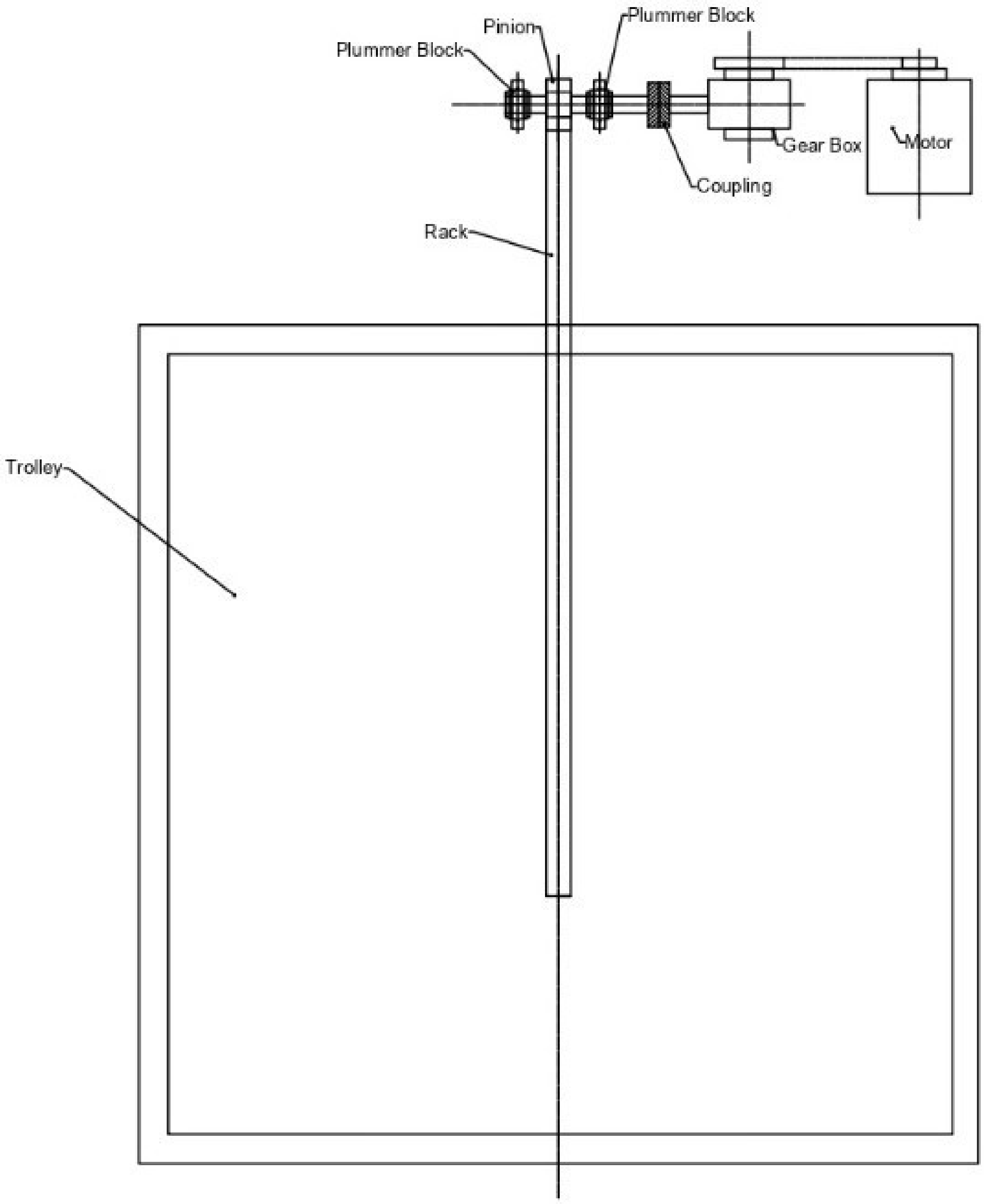



Fig B.11 Assembly of Rack & Pinion Mechanism in CAD Software (AUTOCAD)

# Annexure C

Analysis of Mechanism in Ansys

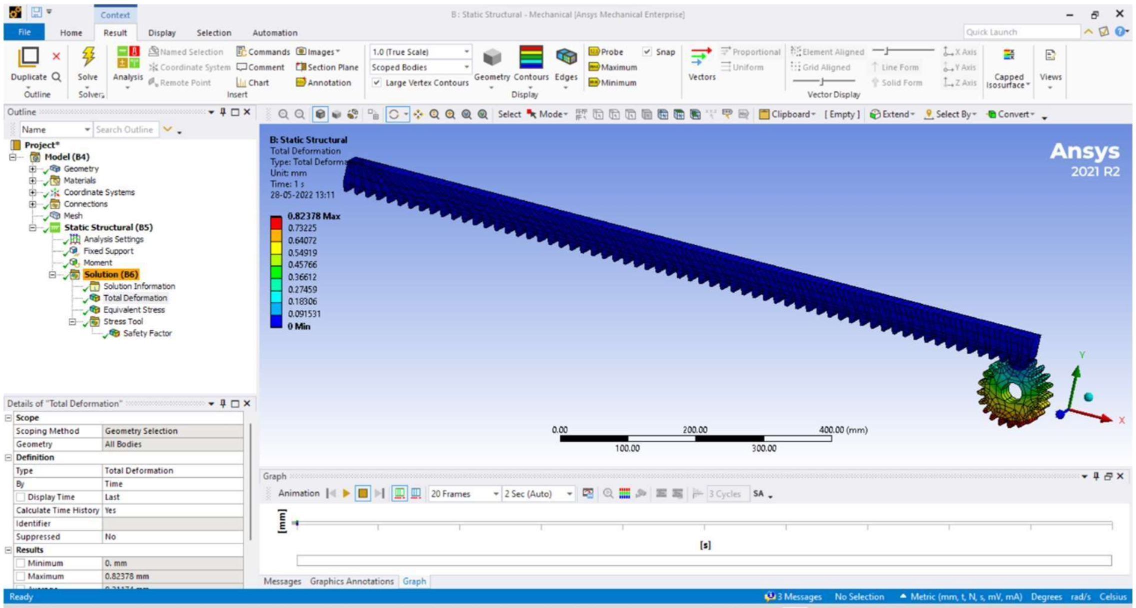


Fig C.1 Analysis of Rack & Pinion Mechanism in Ansys (Total Deformation)

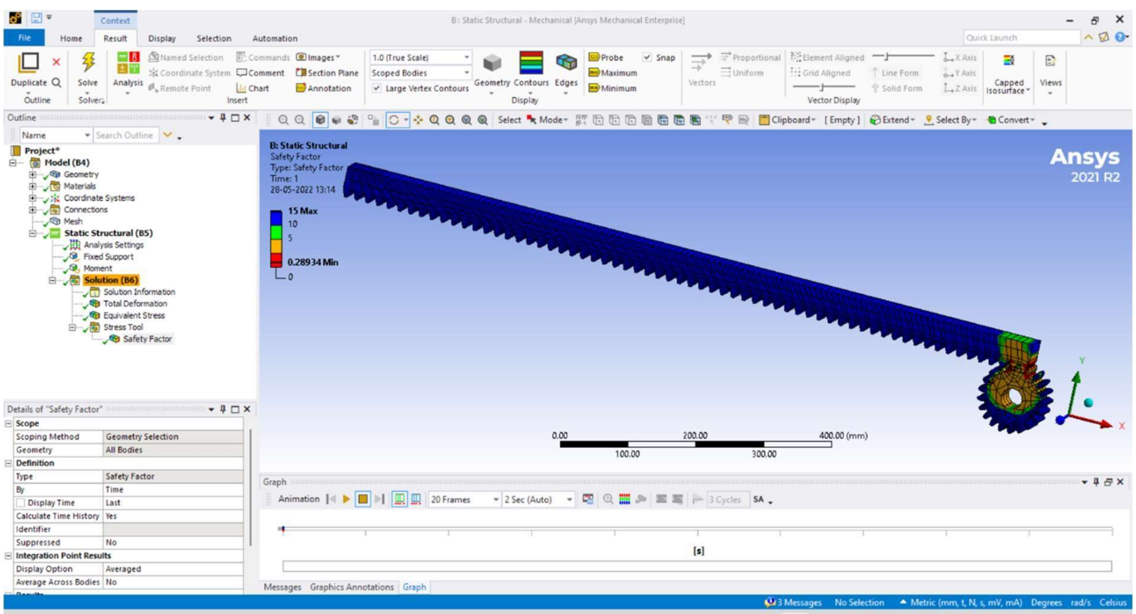


Fig C.2 Analysis of Rack & Pinion Mechanism in Ansys (Safety Factor)

# Annexure D

Refrences from Design Data Book

TYPICAL USES OF ALLOY STEELS

| Designation | Uses |
|---|---|
| 20 Mn 2<br>27 Mn 2 | Welded structures, crank shafts steering, levers, shafting, spindles, etc. |
| 37 Mn 2 | Axles, shafts, crank shafts, connecting rods etc. |
| 35 Mn 2 Mo 28<br>35 Mn 2 Mo 45 | Crank shafts, bolts, levers, connecting rods etc. |
| 40 Cr 1 | Gears, connecting rods, wear resistant plates etc. |
| 40 Cr 1 Mo 28 | Shafts, gears, high tensile bolts and studs. |
| 15 Cr 3 Mo 55<br>25 Cr 3 Mo 55 | Components requiring medium to high tensile strength in the nitrided condition for parts requiring high surface hardness and wear resistance. |
| 40 Cr 3 Mo 1 V 20 | Components requiring high tensile strength. |
| 40 Cr 2 Al 1 Mo 18 | Nitrided — components requiring high surface hardness and core strength |
| 40 Ni 3 | Cold tough steel - used at low temperatures such as in refrigerators and compressors. For heavy forgings, turbine blades, highly stressed screws, bolts and nuts. |
| 35 Ni 1 Cr 60 | Aircrafts and heavy vehicle componets. |
| 30 Ni 4 Cr 1 | Highly stressed gears and other components requiring ultimate tensile strength of the order of 160 $kgf/mm^2$ and where minimum distortion in heat treatment is essential. |
| 40 Ni 1 Cr 1 Mo 15 | General machine parts like bolts, gears etc. |
| 40 Ni 2 Cr 1 Mo 28 | High strength machlne parts like collets. spindles, bolts, gears etc. |
| 31 Ni 3 Cr 65 Mo 55 | Highly stressed bolts, shafts, gears, mandrels, aircraft power units and for low temperature service. |
| 14 Mn 1 S 14 | Parts where good machinability and finish are important. |
| 40 Mn 2 S 12 | Heat treated axles and shafts (not recommended for forgings in which transverse properties are important.) |
| 17 Mn 1 Cr 95 | Small gear wheels, shafts, cardan joints and chain wheels. |
| 15 Ni 2 Cr 1 Mo 15 | Heavy duty components, gears and super charger gears. |
| 13 Ni 3 Cr 80 | Heavy duty gears, pinions etc. Very highly stressed machine parts which are to be hardened with high strength and toughness in core after hardening. |
| 55 Si 2 Mn 90<br>50 Cr 1 V 23 | Used for springs in the hardened and tempered condition. |

DESIGN DATA—PSG TECH 1.17

Fig. D.1 PSG Design Data Book Page No. 1.17

DESIGN DATA—PSG TECH

**INDIAN STANDARD STEELS FOR MACHINE TOOLS AND THEIR EQUIVALENT IN OTHER COUNTRIES**

| IS INDIAN | CSN CZECH | DIN GERMAN | BS BRITISH | ASTM AMERICAN | JIS JAPANESE | GOST RUSSIAN | UNI ITALIAN | AFNOR FRENCH |
|---|---|---|---|---|---|---|---|---|
| 14Mn1S14* | 11110 | 15S20 | En 1A | C 1113 | SUM2 | A12 | — | 15 F2 |
| 40Mn2S12* | 11140 | 45S20 | En 8M | C 1140 | SUM5 | A40G | — | 35MF 4 |
| C40 | 12040 | C35 K | — | — | S35C-D | — | — | — |
| C 45* | 12050 | CK 45 | En 8D | 1040 | S45C | MCr6 | C 40 | XC45f |
| C 75 | 12081 | 2076 | En 42 | — | — | — | — | — |
| 17Mn1Cr95 | 14220 | 16MnCr5 | — | 5115 | — | 20XGA | 16MC5 | 16MC5 |
| T50Cr1V23 | 15260 | 50CrV4 | En 47 | 6150 | SUP10 | 50XFA | 50CV4 | 50CV4 |
| 15Ni2Cr1Mo15* | 16220 | — | En 325 | 4317 | SNCM22 | — | 17NCD7 | 18NCD6 |
| 40Ni2Cr1Mo 28* | 16341 | 36CrNiMo4 | En 24 | 4340 | SNCM8 | 40HXMA | 40NCD7 | — |
| 13Ni3Cr80 | 16420 | ECN35 | En 36 | 3315 | SNC22 | 12HX3A | 15NC11 | 14NC12 |
| 30Ni4Cr1 | 16640 | VCN45 | En 30A | — | — | — | — | 35NC15 |
| T215Cr12 | 19436 | 210Cr46 | — | — | SKD1 | X12 | UX200C13 | Z200C12 |
| T110W2Cr1 | 19710 | 105WCr6 | — | — | SKS31 | XBG | U100WC | 105WC15.04 |
| T83MoW6Cr4V2 | 19800 | DMo 5 | — | M 2 | SKH9 | — | UX82WD65 | Z85WD0606 |
| T123W14Co5CrV4 T75W18Co6Cr4 | 19810 | EV4Co | — | — | — | P14F4 | — | Z125WV15-03 |
| V1Mo75 | 19885 | E18Co5 | — | T 4 | SKH3 | P18VK5F2 | UX80WK185 | Z85WK1805 |

* Preferred Steels.

1.23

Fig. D.2 PSG Design Data Book Page No. 1.23

DESIGN DATA—PSG TECH

**COMPOSITION AND RELATED MECHANICAL PROPERTIES OF ALLOY STEELS (Contd.)**

| Designation | % C | % Si | % Mn | % Ni | % Cr | % Mo | Tensile strength kgf/mm² | Yield strength kgf/mm² | % Min Elongation l=5.65 √a⊙ | Min. izod impact value kgf m | Brinell hardness number HB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 Ni 1 Cr 1 Mo 15* | 0.35–0.45 | 0.1–0.35 | 0.4–0.7 | 1.2–1.6 | 0.9–1.3 | 0.1–0.2 | 80–95 | 60 | 16 | 5.5 | 229–277 |
| | | | | | | | 90–105 | 70 | 15 | 5.5 | 255–311 |
| | | | | | | | 100–115 | 80 | 13 | 4.8 | 285–341 |
| | | | | | | | 110–125 | 88 | 11 | 4.1 | 311–363 |
| 40 Ni 2 Cr 1 Mo 28* | 0.35–0.45 | 0.1–0.35 | 0.4–0.7 | 1.25–1.75 | 0.9–1.3 | 0.2–0.35 | 80–95 | 60 | 16 | 5.5 | 229–277 |
| | | | | | | | 90–105 | 70 | 15 | 5.5 | 255–311 |
| | | | | | | | 100–115 | 80 | 13 | 4.8 | 285–341 |
| | | | | | | | 110–125 | 88 | 11 | 4.1 | 311–363 |
| | | | | | | | 120–135 | 100 | 10 | 3.0 | 341–401 |
| | | | | | | | 155 min | 130 | 6 | 1.1 | 444 min |
| 31 Ni 3 Cr 65 Mo 55* | 0.27–0.35 | 0.1–0.35 | 0.4–0.7 | 2.25–2.75 | 0.5–0.8 | 0.4–0.7 | 90–105 | 70 | 15 | 5.5 | 255–311 |
| | | | | | | | 100–115 | 80 | 12 | 4.8 | 285–341 |
| | | | | | | | 110–125 | 80 | 11 | 4.1 | 311–363 |
| | | | | | | | 120–135 | 100 | 10 | 3.5 | 341–401 |
| | | | | | | | 155 min | 130 | 8 | 1.4 | 444 min |
| 40 Ni 3 Cr 65 Mo 55 | — | — | — | — | — | — | 100–115 | 80 | 12 | 4.8 | 285–341 |
| | | | | | | | 110–125 | 88 | 11 | 4.1 | 311–363 |
| | | | | | | | 120–135 | 100 | 10 | 3.5 | 341–401 |
| | | | | | | | 155 min | 130 | 8 | 1.4 | 444 min |
| 55 Si 2 Mn 90 | 0.5–0.6 | 1.5–2 | 0.8–1.0 | — | — | — | 160–200 | 150 | 6 | — | 440–510 |
| 50 Cr 1 V 23 | 0.45–0.55 | 0.1–0.35 | 0.5–0.8 | — | 0.9–1.2 | — | 190–240 | 180 | 4 | — | 500–580 |

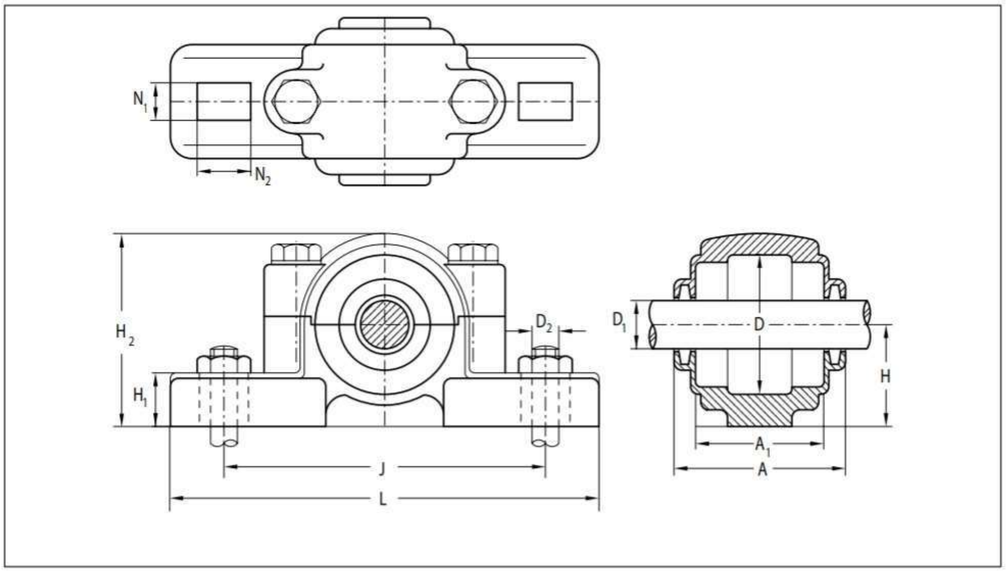
*, †, δ, ⊙ see foot note on page 8.    1 kgf = 10 N

1.15

Fig. D.3 PSG Design Data Book Page No. 1.15

## 15.16 PLUMMER BLOCKS

**Table 15.63** *Notations for plummer blocks*




**Note:** Grease nipple wherever desired, should be provided off centre. It is fitted on the side away from locknuts to ensure the grease supply reaching the bearing.

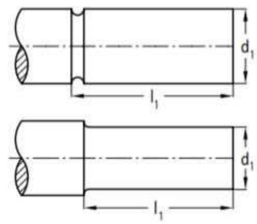


**Table 15.64** *Dimensions for light series plummer blocks*

| Housing seat dia. *D* (H7) | $D_1$ | $H$ | $H_2$ Approx. | $J$ | $D_2$ | $N_1$ | $N_2$ Min. | $A$ Max. | $L$ Max. | $A_1$ | $H_1$ Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | 17 | 35 | 65 | 115 | M10 | 12 | 12 | 66 | 155 | 45 | 19 |
| 52 | 20 | 40 | 75 | 130 | M12 | 15 | 15 | 67 | 170 | 46 | 22 |
| 62 | 25 | 50 | 90 | 150 | M12 | 15 | 15 | 77 | 190 | 52 | 22 |
| 72 | 30 | 50 | 95 | 150 | M12 | 15 | 15 | 82 | 190 | 52 | 22 |
| 80 | 35 | 60 | 110 | 170 | M12 | 15 | 15 | 85 | 210 | 60 | 25 |
| 85 | 40 | 60 | 110 | 170 | M12 | 15 | 15 | 85 | 210 | 60 | 25 |
| 90 | 45 | 60 | 115 | 170 | M12 | 15 | 15 | 90 | 210 | 60 | 25 |
| 100 | 50 | 70 | 130 | 210 | M16 | 18 | 18 | 95 | 270 | 70 | 28 |

Fig. D.4 V.B. Bhandari Design Data Book Page No. 15.61 & 15.62

**Table 9.5** *Dimensions of cylindrical shaft ends*



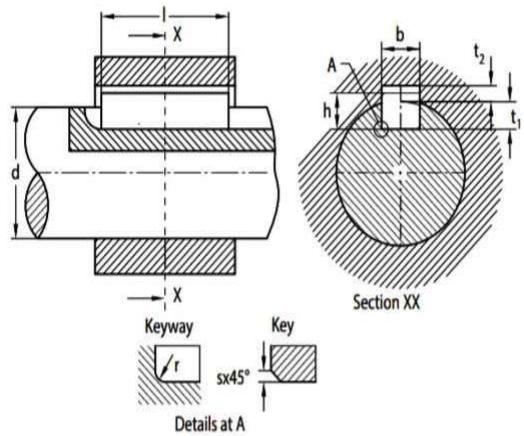

| Diameter ($d_1$) (mm) | Length ($l_1$) (mm) | | Diameter ($d_1$) (mm) | Length ($l_1$) (mm) | |
|---|---|---|---|---|---|
| | Long series | Short series | | Long series | Short series |
| 6, 7 | 16 | – | 80, 85, 90, 95 | 170 | 130 |
| 8, 9 | 20 | – | 100, 110, 120, 125 | 210 | 165 |
| 10, 11 | 23 | 20 | 130, 140, 150 | 250 | 200 |
| 12, 14 | 30 | 25 | 160, 170, 180 | 300 | 240 |
| 16, 18, 19 | 40 | 28 | 190, 200, 220 | 350 | 280 |
| 20, 22, 24 | 50 | 36 | 240, 250, 260 | 410 | 330 |
| 25, 28 | 60 | 42 | 280, 300, 320 | 470 | 380 |
| 30, 32, 35, 38 | 80 | 58 | 340, 360, 380 | 550 | 450 |
| 40, 42, 45, 48, 50, 55, 56 | 110 | 82 | 400, 420, 440, 450, 460, 480. 500 | 650 | 540 |
| 60, 63, 65, 70, 71, 75 | 140 | 105 | 530, 560, 600, 630 | 800 | 680 |

9.4 *Machine Design Data Book*

Fig. D.5 V.B. Bhandari Design Data Book Page No. 9.4

## 9.3 KEYS AND KEYWAYS

**Table 9.10** *Dimensions of parallel keys and keyways*



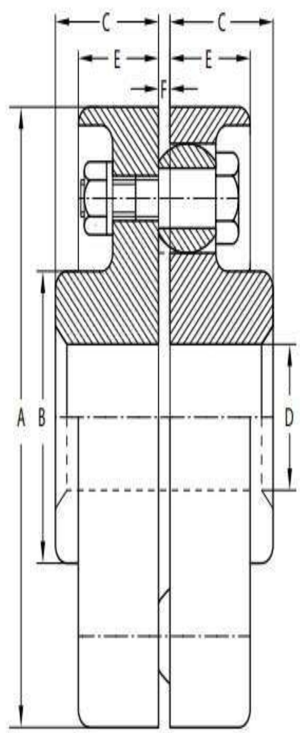

| Shaft diameter | | Key dimensions | | Keyway depth | | Keyway radius (r) | | Chamfer of key (s) | | Key length | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Above | Up to | *b* | *h* | In shaft ($t_1$) | In hub ($t_2$) | Min. | Max. | Min. | Max. | Min. | Max. |
| 6 | 8 | 2 | 2 | 1.2 | 1.0 | 0.08 | 0.16 | 0.16 | 0.25 | 6 | 20 |
| 8 | 10 | 3 | 3 | 1.8 | 1.4 | 0.08 | 0.16 | 0.16 | 0.25 | 6 | 36 |
| 10 | 12 | 4 | 4 | 2.5 | 1.8 | 0.08 | 0.16 | 0.16 | 0.25 | 8 | 45 |
| 12 | 17 | 5 | 5 | 3.0 | 2.3 | 0.16 | 0.25 | 0.25 | 0.40 | 10 | 56 |
| 17 | 22 | 6 | 6 | 3.5 | 2.8 | 0.16 | 0.25 | 0.25 | 0.40 | 14 | 70 |
| 22 | 30 | 8 | 7 | 4.0 | 3.3 | 0.16 | 0.25 | 0.25 | 0.40 | 18 | 90 |
| 30 | 38 | 10 | 8 | 5.0 | 3.3 | 0.25 | 0.40 | 0.40 | 0.60 | 22 | 110 |
| 38 | 44 | 12 | 8 | 5.0 | 3.3 | 0.25 | 0.40 | 0.40 | 0.60 | 28 | 140 |
| 44 | 50 | 14 | 9 | 5.5 | 3.8 | 0.25 | 0.40 | 0.40 | 0.60 | 36 | 160 |
| 50 | 58 | 16 | 10 | 6.0 | 4.3 | 0.25 | 0.40 | 0.40 | 0.60 | 45 | 180 |
| 58 | 65 | 18 | 11 | 7.0 | 4.4 | 0.25 | 0.40 | 0.40 | 0.60 | 50 | 200 |
| 65 | 75 | 20 | 12 | 7.5 | 4.9 | 0.40 | 0.60 | 0.60 | 0.80 | 56 | 220 |
| 75 | 85 | 22 | 14 | 9.0 | 5.4 | 0.40 | 0.60 | 0.60 | 0.80 | 63 | 250 |
| 85 | 95 | 25 | 14 | 9.0 | 5.4 | 0.40 | 0.60 | 0.60 | 0.80 | 70 | 280 |
| 95 | 110 | 28 | 16 | 10.0 | 6.4 | 0.40 | 0.60 | 0.60 | 0.80 | 80 | 320 |
| 110 | 130 | 32 | 18 | 11.0 | 7.4 | 0.40 | 0.60 | 0.60 | 0.80 | 90 | 360 |
| 130 | 150 | 36 | 20 | 12.0 | 8.4 | 0.70 | 1.00 | 1.00 | 1.20 | 100 | 400 |
| 150 | 170 | 40 | 22 | 13.0 | 9.4 | 0.70 | 1.00 | 1.00 | 1.20 | 110 | 400 |
| 170 | 200 | 45 | 25 | 15.0 | 10.4 | 0.70 | 1.00 | 1.00 | 1.20 | 125 | 400 |
| 200 | 230 | 50 | 28 | 17.0 | 11.4 | 0.70 | 1.00 | 1.00 | 1.20 | 140 | 400 |
| 230 | 260 | 56 | 32 | 20.0 | 12.4 | 1.20 | 1.60 | 1.60 | 2.00 | 160 | 400 |
| 260 | 290 | 63 | 32 | 20.0 | 12.4 | 1.20 | 1.60 | 1.60 | 2.00 | 180 | 400 |

(*Contd.*)



Fig. D.6 V.B. Bhandari Design Data Book Page No. 9.9

**Table 9.35** *Dimensions for bush-type flexible couplings*




| Coupling No. | Load rating per 100 rev/min-kW (*) | Bore diameter *D* | | A | B | C | E | F |
|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | | | | | |
| FB 1 | 0.368 | 15 | 22 | 80 | 40 | 32 | 18 | 2 |
| FB 2 | 0.441 | 18 | 25 | 90 | 44 | 35 | 25 | 3 |
| FB 3 | 0.736 | 20 | 30 | 100 | 50 | 40 | 25 | 3 |
| FB 4 | 1.18 | 25 | 35 | 112 | 62 | 45 | 25 | 3 |
| FB 5 | 1.84 | 28 | 40 | 125 | 65 | 50 | 28 | 3 |
| FB 6 | 2.94 | 32 | 45 | 140 | 76 | 55 | 28 | 3 |
| FB 7 | 4.63 | 35 | 50 | 160 | 85 | 60 | 38 | 3 |
| FB 8 | 7.36 | 42 | 60 | 180 | 102 | 70 | 38 | 3 |
| FB 9 | 10.3 | 50 | 70 | 200 | 120 | 80 | 38 | 4 |

*(Contd.)*

Shafts, Keys and Couplings 9.33

Fig. D.7 V.B. Bhandari Design Data Book Page No. 9.33

# Annexure E

Actual Photographs



OPPO Reno7 5G


BPT
BIRLA
PRECISION
Birla Precision Technologies Ltd.
(Indian Tool Manufacturers Division)
62/63 MIDC Satpur, Nashik- 422007.
GSTIN : 27AAACB2046A1ZF
OPPO Reno7 5G