DESIGN OF MULTI STRENGTH LEVER GYM EQUIPMENT

A mini project (Project-I) report submitted to

Jawaharlal Nehru Technological University Hyderabad

in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

In

MECHANICAL ENGINEERING

Submitted By

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2022-2023

CERTIFICATE

This is to certify that the mini project (Project-I) entitled **“Design and Analysis of Multi Strength Lever Gym Equipment”** is being submitted by **RAHUL YADGIRKAR (19WJ1A03E9), YARADESI VENKATESWARLU (19WJ1A03K1), SEETHA ARVIND and (19WJ1A03G0)** in partial fulfillment for the award of the **Degree of Bachelor of Technology in Mechanical Engineering to the Guru Nanak Institutions Technical Campus, Ibrahimpatnam** is a record of bonafide work carried out by them under my guidance and supervision.

The results embodied in this mini project (Project-I) report have not been submitted to any other University or Institute for the award of any other Degree.

Internal Guide

Mr. G Sanjeevkumar
Assistant Professor

Head of the Department
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DECLARATION

We wish to express our sincere thanks to Dr. H.S SAINI, Managing Director, Guru Nanak Institutions and Dr. KODUGANTI VENKATA RAO, Director, Guru Nanak Institutions Technical Campus, School of Engineering and Technology, for providing us with all the necessary facilities and their support.

We place on record our sincere thanks to Dr. A. RAJ KUMAR, Professor and Head of the Department, Mechanical Engineering for their wholehearted co-operation, providing excellent lab facility, constant encouragement and unfailing inspiration. We would like to say sincere thanks to Mr. V. Shaymu, Assistant Professor, Department of Mechanical Engineering for coordinating Projects.

We would like to say sincere thanks to our guide Mr. G. Sanjeev Kumar, Assistant Professor, Department of Mechanical Engineering for Coordinating Projects for the suggestions and constant guidance in every stage of the project, we also like to thank all our lecturers helping us in every possible way. On a more personal note, we thank our beloved parents and friends for their moral support during our project.

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YARADESI VENKATESWARLU 19WJ1A03K1

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ABSTRACT

The objective of the project is to determine and evaluate maximum loads that can be applied and the anticipated lifespan of the gym equipment. Additionally, this project enables flexibility in the geometry and materials employed, allowing the best option to be chosen for the study's application.

SolidWorks will be used to develop the product design, and ANSYS will be used to assist with the FEA simulations. Starting with the proper mesh size and the requirement that the Von Mises stress should be lower than the yield point of the chosen material, static load analysis and fatigue analysis will begin in order to calculate the lifespan of the equipment. Similarly, the users safety shouldn't be in jeopardy due to the equipment members deforming.

The outcome of this research offers a design method for the gym equipment validation (theory vs. simulation) and optimization in order to ensure improved performance and make it easier to produce its component parts and assemble it.

1 INTRODUCTION

Weight lifting gym equipment, also known as resistance training equipment, is a type of fitness equipment that is used for strength training and muscle building. These types of equipment typically involve using weights or resistance in order to provide resistance for the muscles to work against. One advantage of weight lifting gym equipment is that it can be used to perform a wide variety of exercises, targeting different muscle groups and allowing for a well-rounded strength training routine.

There are many different types of weight lifting gym equipment available, including barbells, dumbbells, weight machines, and cable machines. These types of equipment can be used to perform exercises such as bicep curls, tricep extensions, shoulder press, leg press, and more. Some weight lifting gym equipment is designed to be multi-functional, allowing for the performance of multiple exercises on a single piece of equipment. This can be especially convenient for those who are short on space or time and want to get the most out of their strength training workouts.

Overall, weight lifting gym equipment is a valuable tool for those looking to improve their strength, build muscle, and enhance their overall physical fitness. By offering a wide range of exercises and the ability to target specific muscle groups, weight lifting gym equipment can be a key component of any strength training routine.

1.1 Problem Statement

Currently, there is a lack of equipment on the market that can provide a comprehensive leg workout and accommodate high loading capacities, as legs tend to be stronger than other upper body muscles. This results in a need for multiple pieces of equipment to perform different exercises, leading to an inefficient and potentially costly workout experience. A device that offers a variety of leg exercises while also being able to withstand high loading capacities is needed to improve the fitness of users and streamline the leg workout process.

1.2 Project Objective

There are fundamental goals of the project are the following:

1. Design the equipment to be safe and effective for use in strength training.
2. Meet certain performance criteria, such as being able to support a certain amount of weight or allowing for a range of exercises to be performed.
3. Evaluate the performance of the equipment through testing or simulation.
4. Make adjustments to the design as needed to optimize its performance.
5. Create a product that can be marketed and sold to consumers for use in their own strength training programs.
6. Ensure that the equipment is durable and able to withstand repeated use over time.
7. Consider the ergonomics of the design to make it comfortable and easy to use for a variety of users.
8. Take into account any relevant safety standards or regulations that apply to weight lifting equipment.
9. Consider the cost and feasibility of manufacturing the equipment at scale.

1.3 Design Requirements

1.3.1 Strength and stability

The equipment should be strong enough to support the weight being lifted and stable enough to prevent tipping or other accidents.

1.3.2 Range of motion

The equipment should allow for a range of motion that is appropriate for the exercises being performed, and should not restrict movement in any way.

1.3.3 Comfort and ergonomics

The equipment should be comfortable to use and should be designed in a way that is ergonomically sound, to reduce the risk of injury and improve the user's experience.

1.3.4 Safety features

The equipment should have safety features such as weight limits, safety bars, or other mechanisms to prevent accidents.

1.3.5 Ease of use

The equipment should be easy to use, with clear instructions and simple controls.

1.3.6 Durability

The equipment should be able to withstand repeated use over time and should be made with high-quality materials.

1.3.7 Cost and feasibility

The equipment should be cost-effective to manufacture and should be feasible to produce at scale.

1.3.8 Compatibility with other equipment

The equipment should be compatible with other weight lifting equipment, such as weights, bars, or benches.

1.3.9 Aesthetics

The equipment should be visually appealing and should fit in with the overall aesthetic of the gym or home gym.

1.4 Classification of Gym equipment

There are many different types of weight lifting equipment that can be found in gyms, and they can generally be classified into a few main categories

1.4.1 Strength training equipment

This category includes equipment such as barbells, dumbbells, and weight plates, which are used for exercises that build muscle strength and size.

1.4.2 Cardio equipment

This category includes equipment such as treadmills, stationary bikes, and ellipticals, which are used for cardiovascular exercise to improve endurance and burn calories.

1.4.3 Flexibility and stretching equipment

This category includes equipment such as yoga mats, foam rollers, and stretching bands, which are used to improve flexibility and mobility.

1.4.4 Multi-purpose equipment

This category includes equipment such as cable machines, Smith machines, and multi-station gyms, which are designed to allow for a variety of exercises to be performed.

1.4.5 Accessory equipment

This category includes equipment such as weight belts, gloves, and wraps, which are used to enhance the performance or safety of weight lifting exercises.

1.4.6 Specialized equipment

This category includes equipment such as power racks, Olympic lifting platforms, and sleds, which are used for specific types of exercises or sports.

1.5 Gym equipment Testing

Weight lifting equipment can be tested both traditionally and using computer aided engineering (CAE).

Traditional testing methods for weight lifting equipment typically involve physically loading the equipment with weights and measuring its performance under various conditions. This could include testing for strength, stability, and durability. Testing may also involve subjecting the equipment to simulated use or wear and tear, to ensure that it can withstand the rigors of regular use.

CAE, on the other hand, involves using computer simulations to analyze and test the performance of the equipment. This can be done using finite element analysis (FEA) or other computer-based modeling and simulation techniques. CAE allows for the testing of the equipment under a wide range of conditions and scenarios, without the need for physical testing. It can also be used to identify potential design weaknesses or areas for improvement, and to optimize the design of the equipment for maximum performance and safety.

Overall, both traditional testing and CAE can be useful tools for evaluating the performance and safety of weight lifting equipment. Traditional testing can provide valuable real-world data, while CAE can provide insights and predictions that would be difficult or impossible to obtain through physical testing alone.

Some examples of testing that can be performed on weight lifting equipment:

1.5.1 Strength testing

This involves applying loads to the equipment and measuring its ability to withstand the forces without breaking or failing. This can be done using traditional testing methods, such as applying weights or using a hydraulic press to apply a load, or using CAE to simulate the application of various loads.

1.5.2 Stability testing

This involves evaluating the equipment's ability to remain upright and stable under different conditions, such as when it is loaded with weights or when it is subjected to external forces. This can be tested using physical methods, such as tilting or rocking the equipment, or using CAE to simulate the effects of external forces.

1.5.3 Durability testing

This involves subjecting the equipment to simulated wear and tear, such as repeated use or exposure to harsh conditions, to determine its longevity and reliability. This can be done using physical testing methods, such as using the equipment repeatedly over a set period of time, or using CAE to simulate the effects of long-term use.

1.5.4 Safety testing

This involves evaluating the equipment's safety features, such as its ability to prevent accidents or injuries, and ensuring that it meets relevant safety standards. This can be tested using physical methods, such as inspecting the equipment for any potential hazards, or using CAE to simulate the effects of various safety-related scenarios.

Overall, these tests can help to ensure that weight lifting equipment is safe, durable, and reliable for its intended use.

2 LITERATURE REVIEW

The book "Finite Element Applications: A Practical Guide to the FEM Process," written by Keates and Okereke[1] in 2018, provides a comprehensive overview of the finite element method (FEM) and its various applications in engineering. The authors discuss the fundamental principles of FEM and how it can be used to solve a wide range of problems in fields such as structural analysis, heat transfer, and fluid dynamics. They also provide practical examples and case studies to illustrate the concepts discussed in the book.

The book "The Finite Element Method in Engineering," written by Rao, S. S.[2] in 2017, also covers the principles and applications of FEM in engineering. In this book, the author focuses on the use of FEM in solving problems related to structural analysis, including the analysis of beams, frames, and plates. The book also includes chapters on FEM applications in the fields of heat transfer and fluid dynamics. The author provides numerous examples and exercises throughout the book to help readers understand the concepts and apply them to real-world problems.

The study by Sharratt, M., et al.[3] (2013) compared muscle activation and joint kinematics during back extension exercises using three different types of equipment: a stability ball, a Roman chair, and a back extension machine. The authors found that muscle activation was highest in the back extension machine group, followed by the Roman chair and stability ball groups. Joint kinematics were similar among the three groups, with some slight differences in the trunk and hip angles. These findings suggest that the back extension machine may be the most effective for activating the muscles of the back and improving muscle strength and endurance.

The study by Zourdos et al.[4] (2017) evaluated the biomechanics of various leg press machines, including horizontal, vertical, and diagonal machines. The authors found that muscle activation varied among the different machines, with the horizontal leg press producing the highest muscle activation. The authors also noted that the vertical and diagonal leg press machines produced similar muscle activation patterns. These results suggest that the choice of leg press machine may affect muscle activation and exercise performance.

The study by Kraemer et al.[5] (2010) examined the effects of rowing exercise training on muscle strength and endurance. The authors found that rowing exercise training led to significant improvements in muscle strength and endurance, as well as other physical performance measures. These findings suggest that rowing exercise may be an effective way to improve muscle strength and endurance.

The study by Ratamess et al.[6] (2014) compared muscle activation and joint kinematics during a traditional lat pulldown exercise and a suspension trainer exercise. The authors found that muscle activation was similar between the two exercises, but joint kinematics were different, with the suspension trainer exercise producing a greater range of motion at the shoulder joint. These results suggest that the choice of exercise equipment may affect joint kinematics and may need to be considered when designing exercise programs.

One study that could be included in the review is a paper published in the Journal of Sports Science and Medicine by Zourdos et al.[7], 2017, which evaluated the biomechanics of various leg press machines and found that those with a fixed footplate angle and a variable resistance load produced the greatest muscle activation in the quadriceps and hamstrings. This suggests that leg press machines with these design features may be more effective at targeting these muscle groups.

Another relevant study is a paper published in the Journal of Strength and Conditioning Research by Sharratt M et al[8]., 2013, which examined the muscle activation and joint kinematics of different back extension exercises, including the use of a Roman chair, a back extension machine, and a stability ball. The authors found that the Roman chair and back extension machine produced similar levels of muscle activation, but the stability ball resulted in lower activation and greater spinal flexion. This suggests that back extension machines may be a more effective and safer option for targeting the back muscles.

Other research that could be included in the literature review includes a study published in the Journal of Orthopaedic & Sports Physical Therapy by Hrysomallis et al.[9], 2016, which compared the effectiveness of various leg curl exercises using different pieces of equipment, including the prone leg curl machine, the seated leg curl machine, and the

Swiss ball. The authors found that the prone leg curl machine produced the greatest muscle activation in the hamstrings, while the seated leg curl machine and Swiss ball resulted in lower activation.

One study by Kim et al.[10] (2015) used FEA to evaluate the performance of different materials for use in the belt of a treadmill. The authors found that belts made of elastomeric materials, such as natural rubber and neoprene, performed well in terms of shock absorption and energy dissipation, while belts made of polyurethane had the best durability.

Another study by Kwon et al.[11] (2016) used FEA to compare the performance of different materials for use in the frame of a weightlifting bench. The authors found that frames made of steel had the highest strength and stiffness, while frames made of aluminum had the best weight-to-strength ratio. However, the authors also noted that aluminum frames had lower fatigue resistance compared to steel frames.

A study by Zhang et al.[12] (2017) used FEA to evaluate the performance of different materials for use in the pedals and crank arms of a bicycle exercise machine. The authors found that pedals and crank arms made of titanium had the highest strength and stiffness, while pedals and crank arms made of aluminum had the best weight-to-strength ratio. However, the authors also noted that aluminum pedals and crank arms had lower fatigue resistance compared to titanium pedals and crank arms.

The study by Gao et al.[13] (2018) investigated the corrosion resistance of electroless nickel plating on gym equipment. Electroless nickel plating is a process in which a thin layer of nickel is deposited onto a substrate using a chemical reduction reaction. The authors found that the electroless nickel plating provided good corrosion resistance and improved the overall performance of the gym equipment. Corrosion is a major concern in gym equipment, as it can lead to the failure of the equipment and pose a safety risk to users. The use of corrosion-resistant finishes, such as electroless nickel plating, can help to extend the service life of gym equipment and improve user safety.

The study by Singh, N. K.[14] (2018) discussed the importance of surface finish in gym equipment. A good surface finish is essential for the safety and comfort of users, as it determines the smoothness and grip of the equipment. Smooth, durable, and corrosion-resistant finishes are particularly important for gym equipment, as they can help to reduce the risk of injuries and skin irritation. The authors also noted that the choice of surface finish may depend on the specific type of equipment and the intended use, as different finishes may be more suitable for different applications.

The study by Li et al. [15](2019) examined the influence of surface finish on gym equipment on human skin. The authors found that smooth and non-irritating surface finishes were preferred by users and reduced the risk of skin irritation and allergic reactions. The skin is an important factor to consider when designing gym equipment, as it can be affected by the materials and finishes used in the equipment.

3 METHODOLOGY

The methodology for design and analysis using finite element method (FEM) for a multi-functional weight lifting equipment can include the following steps:

3.1 Define the design requirements and specifications

The first step in the design process is to define the requirements and specifications for the multi-functional weight lifting equipment. This may include the load capacity, dimensions, materials, and other relevant requirements. The design requirements and specifications should be based on the intended use of the equipment, as well as any relevant standards or regulations that apply.

3.2 Create a 3D model of the equipment

Next, a 3D model of the equipment should be created using computer-aided design (CAD) software. This model should include all the components and details of the equipment, such as beams, columns, brackets, and welds. The model should accurately represent the geometry of the equipment and the connections between the different components.

3.3 Discretize the model

The next step is to discretize the model by dividing it into smaller elements. This is done using meshing software, which creates a mesh of small elements (called finite elements) that represent the continuous structure of the equipment. The size and shape of the elements should be chosen to accurately represent the geometry of the equipment and to capture the stresses and strains that will be experienced during use.

3.4 Assign material properties

Material properties, such as Young's modulus and density, should be assigned to each element in the model. These properties are used to calculate the stress and strain in the elements under load. The material properties should be based on the actual materials that will be used in the construction of the equipment.

3.5 Apply loads and boundary conditions

Loads and boundary conditions, such as loads acting on the equipment and constraints on the movement of the equipment, should be applied to the model. These can be applied to specific nodes or elements in the model. The loads and boundary conditions should reflect the expected loading conditions during use of the equipment.

3.6 Solve for element stresses and strains

The model is then solved using FEM software, which calculates the element stresses and strains in the model under the applied loads and boundary conditions. The software uses mathematical equations to solve for the stresses and strains at each element in the model.

3.7 Analyze the results

The results of the analysis can be analyzed to assess the performance of the equipment under the applied loads and to identify any potential failure points or areas of high stress. The results can be plotted or visualized using post-processing software, which allows for a more detailed analysis of the stresses and strains in the model.

3.8 Optimize the design

Based on the results of the analysis, the design can be optimized to improve the performance and safety of the equipment. This may involve modifying the dimensions or materials of the equipment, or adding additional components to redistribute stresses. The optimization process may involve repeating the analysis with different design parameters to determine the optimal solution.

3.9 Validate the design

Finally, the design should be validated through testing to ensure that it meets the required specifications and performs as expected. This may involve physical testing of prototypes or simulations using the FEM model to validate the results.

4 INTRODUCTION FOR CAD AND SOLIDWORKS

4.1 Computer-Aided Design (CAD)

It is otherwise called PC helped plan and drafting (CAD), is the utilization of PC innovation for the procedure of outline and plan documentation. PC Aided Drafting depicts the way toward drafting with a PC. CAD programming, or conditions, furnishes the client with input-apparatuses with the end goal of streamlining configuration forms; drafting, documentation, and assembling forms. CAD yield is used regularly as electronic documents for print or machining operations. The advancement of CAD-based programming is in coordinate connection with the procedures it looks to streamline; industry-based programming (development, producing, and so forth.) normally utilizes vector-based (straight) situations while realistic based programming uses raster-based conditions.

CAD situations frequently include something other than shapes. As in the manual drafting of specialized and building illustrations, the yield of CAD must pass on data, for example, materials, procedures, measurements, and resiliency, as indicated by application-particular traditions.

Computer aided design might be utilized to configure bends and figures in two-dimensional (2D) space; or bends, surfaces, and solids in three-dimensional (3D) objects.

Computer aided design is a vital mechanical workmanship broadly utilized as a part of numerous applications, including car, dispatch building, and aviation enterprises, modern and structural plan, prosthetics, and some more. Computer aided design is additionally generally used to create PC movement for embellishments in motion pictures, promoting and specialized manuals. The present day pervasiveness and energy of PCs implies that even scent containers and cleanser allocators are composed utilizing procedures incomprehensible by designers of the 1960s. Due to its gigantic financial significance, CAD has been a noteworthy main impetus for inquiring about computational geometry, PC illustrations (both equipment and programming), and discrete differential geometry.

Current PC helped plan programming bundles run from 2D vector-based drafting frameworks to 3D strong and surface modelers. Current CAD bundles can likewise as often as possible permit turns in three measurements, permitting survey of a composed question from any coveted point, even from within watching out. Some CAD programming is fit for dynamic mathematical demonstrating, in which case it might be showcased as CAD — PC helped outline and drafting.

Computer aided design is utilized as a part of the outline of apparatuses and hardware and in the drafting and plan of a wide range of structures, from little private sorts (houses) to the biggest business and modern structures (doctor's facilities and manufacturing plants).

Computer aided design is primarily utilized for itemized building of 3D models and additionally 2D illustrations of physical segments, however it is likewise utilized all through the designing procedure from theoretical outline and format of items, through quality and dynamic examination of congregations to meaning of assembling techniques for parts. It can likewise be utilized to configure objects.

Computer aided design has turned into a particularly critical innovation inside the extent of PC supported advances, with advantages, for example, bringing down item improvement costs and an extraordinarily abbreviated outline cycle. Computer aided design empowers creators to lay out and create chips away from the screen, print it out and spare it for future altering, sparing time on their illustrations.

4.2 Introduction To SolidWorks

SolidWorks is a 3D computer-aided design (CAD) software that is widely used in the engineering and manufacturing industries. It allows users to create and manipulate 3D models of parts, assemblies, and products, as well as simulate their behavior and performance. With its advanced features and capabilities, SolidWorks has become a key tool for design, prototyping, and engineering analysis.

One of the major benefits of SolidWorks is its user-friendly interface, which makes it easy for engineers and designers to create and edit complex 3D models. It also has a robust set of tools for modeling, simulation, and analysis, allowing users to test and optimize the design of their products. Additionally, SolidWorks has a strong community of users and developers, who contribute to the development of the software and share best practices and tips for using it effectively.

In summary, SolidWorks is a powerful and versatile CAD software that is essential for the design and analysis of products in the engineering and manufacturing industries. It offers a range of features and tools to help users create and optimize their designs, and has a strong user community to support them in their work.

SolidWorks is a comprehensive 3D computer-aided design (CAD) software that offers a range of functions and capabilities for creating, manipulating, and analyzing 3D models. Some of the main functions of SolidWorks include:

4.2.1 3D modeling

SolidWorks allows users to create and edit 3D models of parts, assemblies, and products. It includes a range of tools for sketching, extrusion, sweeping, lofting, and more, as well as a library of standard parts and features.

4.2.2 Simulation and analysis

SolidWorks has a range of tools for simulating and analyzing the behavior and performance of 3D models. This includes tools for stress analysis, motion simulation, and fluid flow analysis, as well as tools for calculating mass properties and creating technical drawings.

4.2.3 Collaboration and data management

SolidWorks has features for collaborating with team members and managing data, including tools for sharing and reviewing 3D models, as well as tools for managing version control and revision history.

4.2.4 Customization and automation

SolidWorks allows users to customize and automate various aspects of their workflows, including the creation of custom features and macros, as well as the integration of SolidWorks with other software and tools.

4.2.5 Add-on modules

In addition to its core functions, SolidWorks offers a range of specialized add-on modules for specific industries and applications, such as sheet metal design, electrical wiring and routing, and plastic injection molding.

Overall, SolidWorks is a powerful and versatile software that offers a range of functions and capabilities for designing, simulating, and analyzing 3D models in the engineering and manufacturing industries.

4.3 Modeling of The Parts

Modeling the parts in Solidworks involves creating a digital representation of an object using 3D computer-aided design (CAD) software. This process allows engineers and designers to visualize and analyze the form, function, and fit of a part before it is physically manufactured.

4.3.1 Initiating of a sketch in solidworks

1. Open SolidWorks and create a new part or open an existing part.
2. In the CommandManager, click the "Sketch" drop-down menu and select "Sketch."
3. In the Sketch PropertyManager, select the plane or face on which you want to create the sketch.
4. In the graphics area, use the sketching tools to draw the desired shape. You can use tools such as lines, arcs, circles, and splines to create the sketch.
5. As you draw the sketch, use the dimensions and constraints tools to fully define the sketch. This will ensure that the sketch is fully defined and can be used to create solid geometry.
6. When you are finished sketching, click the "Finish Sketch" button in the Sketch PropertyManager.
7. You can now use the sketch to create features such as extrudes, revolves, and lofts. You can also edit, dimension, and annotate the sketch as needed.

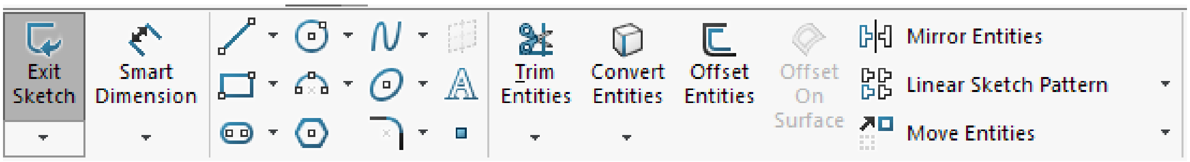

Figure 4.1 SOLIDWORKS Sketch tab

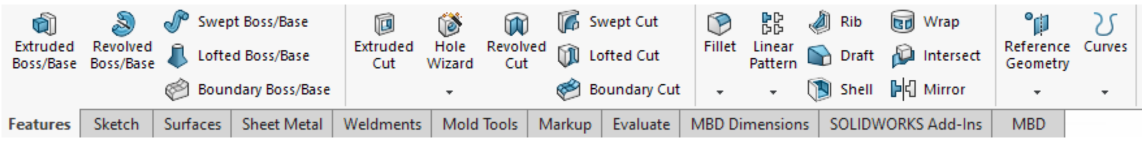

Figure 4.2 SOLIDWORKS Features tab

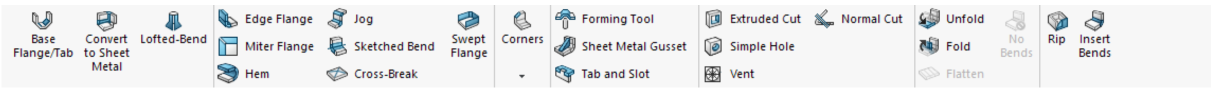

Figure 4.3 SOLIDWORKS Sheet Metal tab

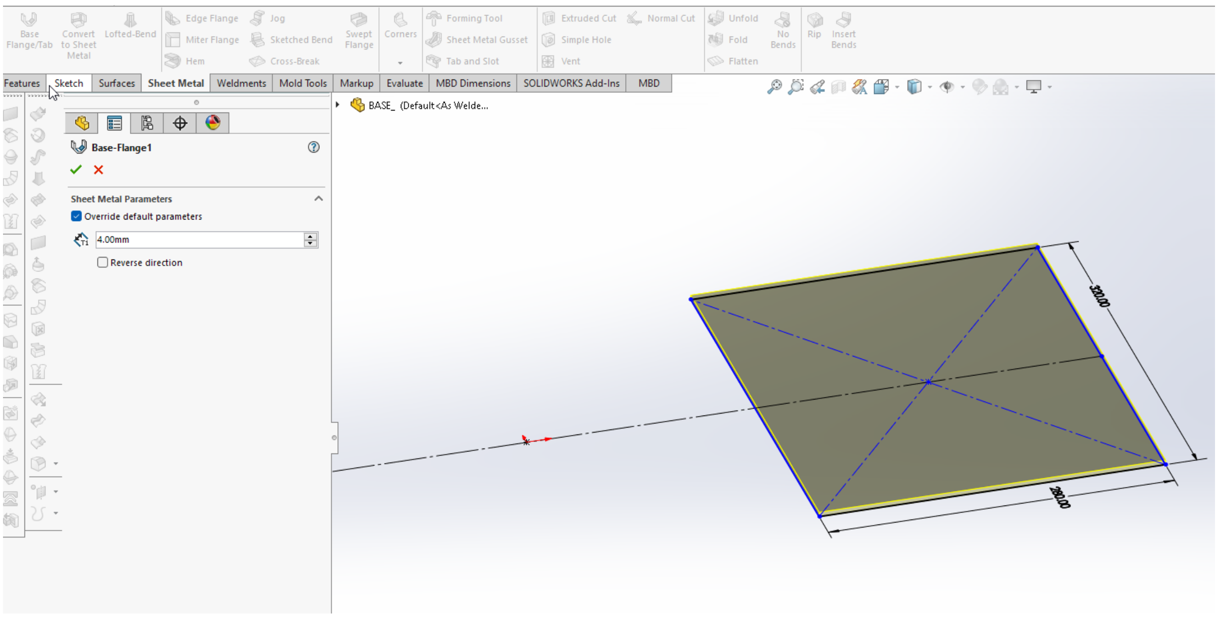

Figure 4.4 Sheet Metal base flange

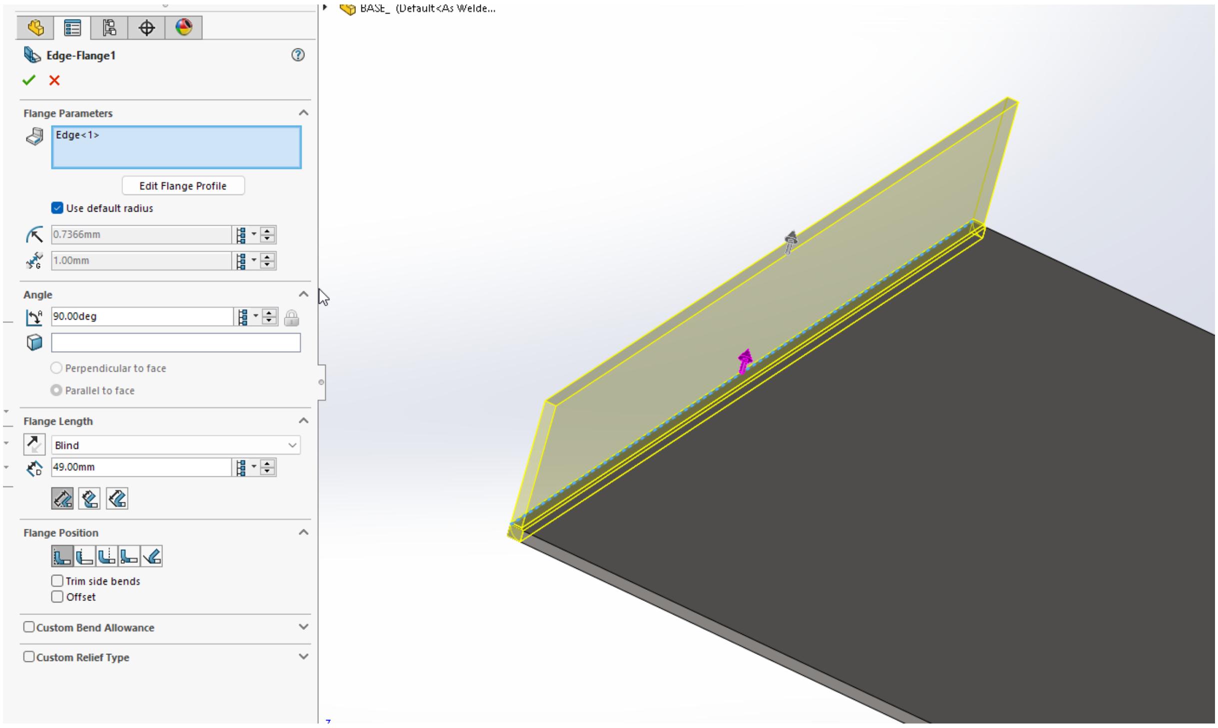

Figure 4.5 Creation of edge flange

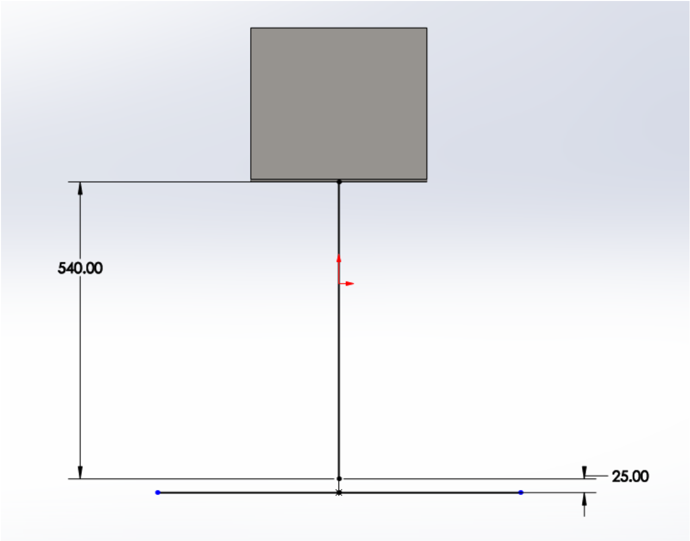

Figure 4.6 Sketch of base part for generation of weldments

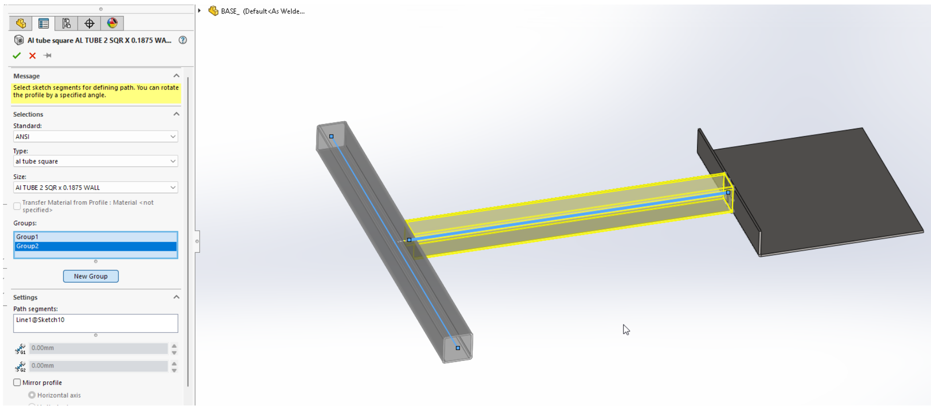

Figure 4.7 Extruding the tubular sections using Solidworks Weldments

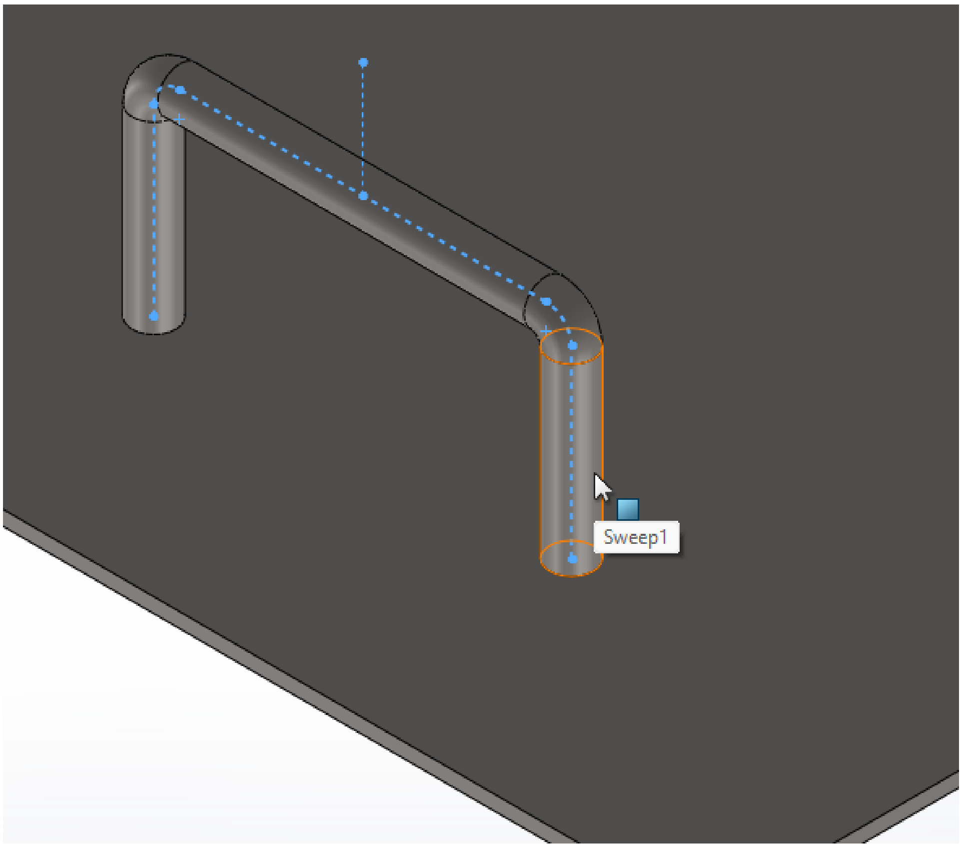

Figure 4.8 Sweep Boss Feature

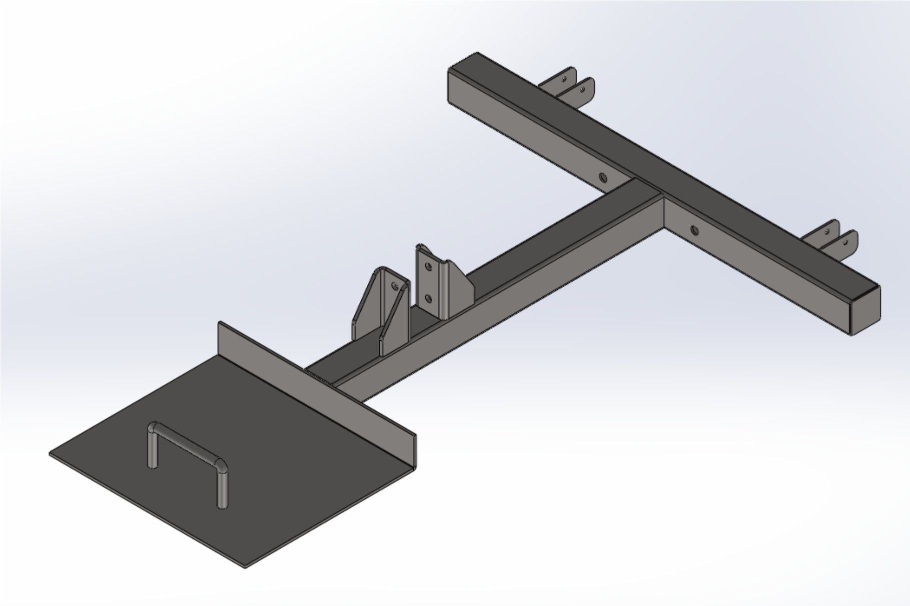

Figure 4.9 Final part isometric view

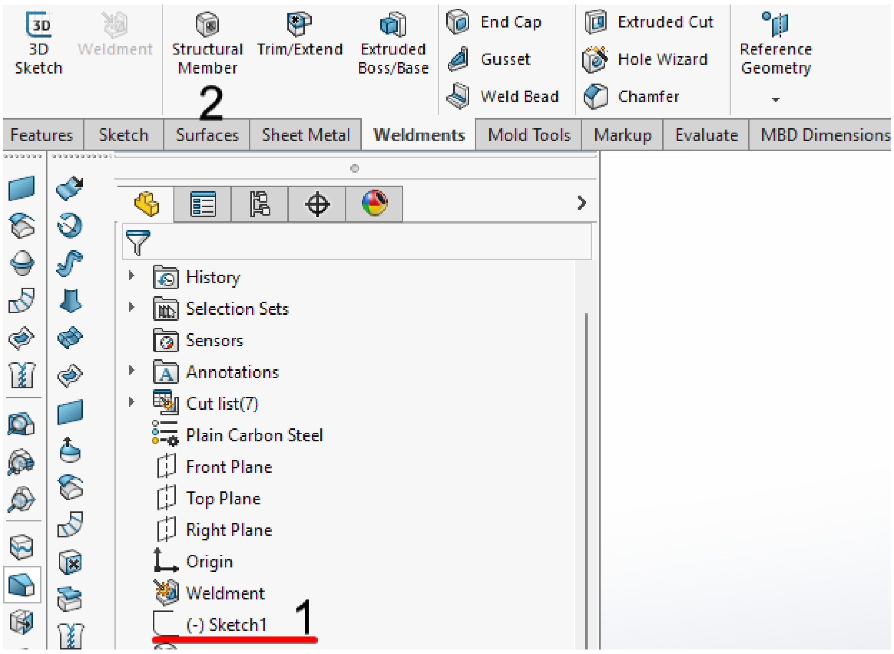

Figure 4.10 Weldments process

From the Figure 4.9. and Figure 4.10 we can indicate the steps to create the required profile of pipe, the steps are as follows:

1. Open SolidWorks and create a new sketch in the Weldments tab.

2. From the toolbar, select the Structural Member tool.

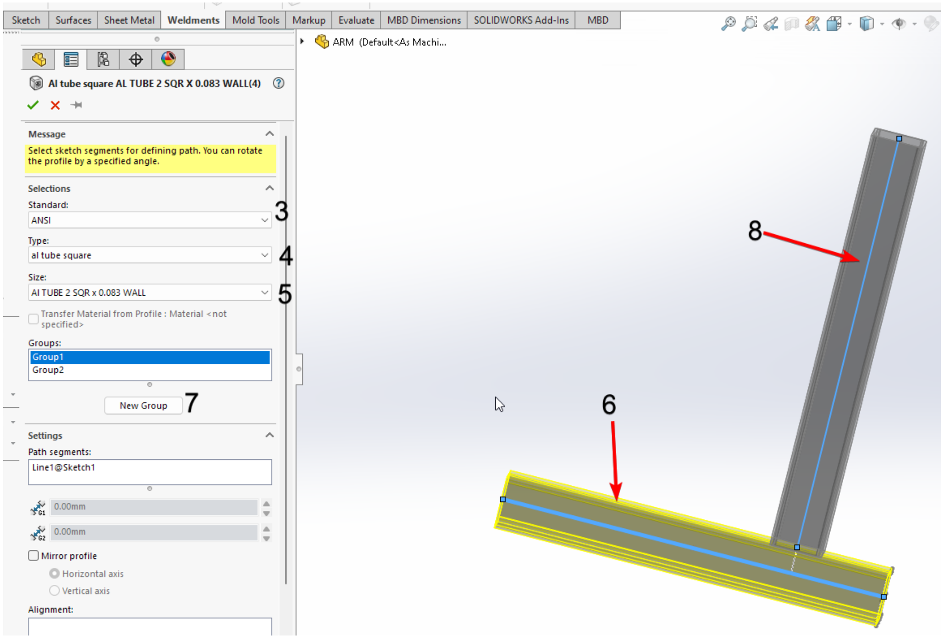

Figure 4.11 Weldments process

3. Open SolidWorks and create a new sketch in the Weldments tab.

4. From the toolbar, select the Structural Member tool.

5. In the Structural Member Properties dialog box, choose Pipe as the standard.

6. Select the desired type of profile for the pipe.

7. Enter the size of the pipe in the appropriate field.

8. In the sketch, draw the line for the first pipe using the Structural Member tool.

9. Create a new group for the second pipe by clicking on the New Group button in the Structural Member Properties dialog box.

10. Draw the line for the second pipe in the sketch using the Structural Member tool.

In Figure 4.12, the sketch for the slot is drawn, this sketch is then extruded as a cut using the extrude cut. The sketch plane selected is the wall of the pipe profile.

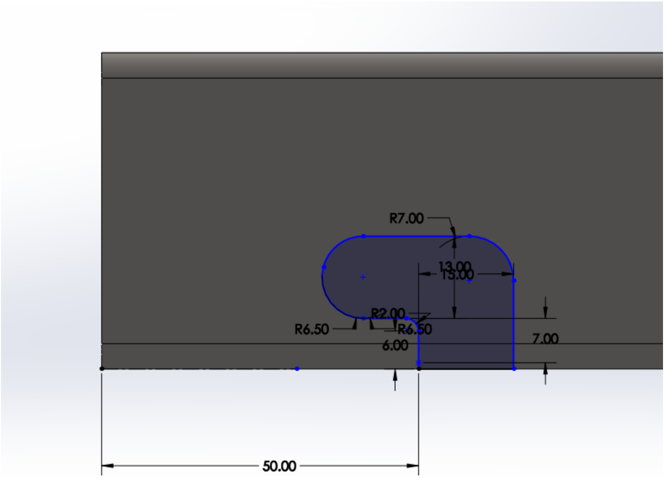

Figure 4.12 Sketch for the slot

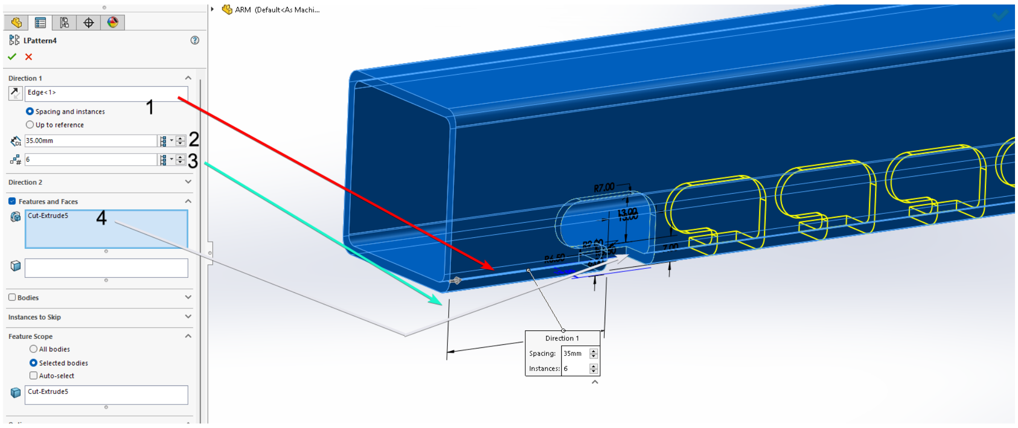

Figure 4.13 Solidworks Pattern command

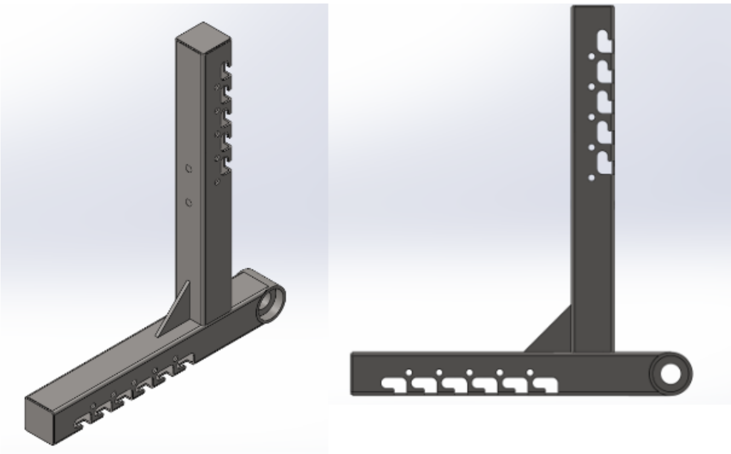

Figure 4.14 Final Part-Arm

From Figure 4.13. we can indicate the steps for making a pattern in solidworks which follows:

1. Select the direction of the pattern.
2. Input the distance between the features
3. Enter the number of patterns
4. select the feature to be patterned

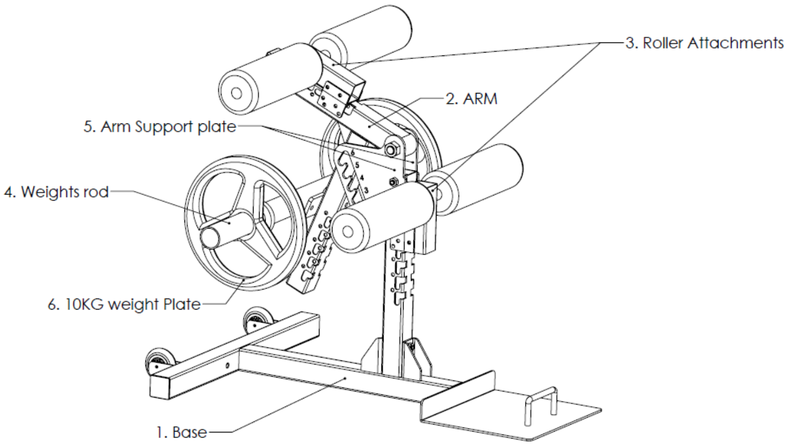

Figure 4.15 Final Model

The final design of the arm.sldprt is seen in Figure 4.15. These parts can be imported in ANSYS for static analysis.

The final model assembly is shown in the Figure 4.15 above, it includes

1. Base
2. Arm
3. Roller attachment
4. Weight rod
5. Arm support plate
6. Weight plates

5 FINITE ELEMENT METHOD AND ANSYS

5.1 Introduction to FEM

The limited component technique speaks to an augmentation of the grid strategies for the investigation of encircled structures to the examination of the continuum structures. The essential rationality of the strategy is to supplant the structure of the continuum having a boundless or unbounded number of questions at certain picked discrete focuses. The technique is to a great degree capable as it serves to precisely break down structures with complex geometrical properties and stacking conditions.

In the boundless technique, a structure or continuum is discretized and admired by utilizing a scientific model which is a get together of subdivisions or discrete components, known as limited components, that are thought to be interconnected just at the joints called hubs. Straightforward capacities, for example, polynomials are picked as far as obscure relocations at the hubs to inexact the variety of the real removals over each limited component. The outer stacking is likewise changed into equal powers connected at the hubs. Next, the conduct of every component freely and later as a get together of these components is gotten by relating their reaction to that of the hubs such that the accompanying essential conditions are fulfilled at every hub:

1. Equations of balance
2. The similarity of relocations
3. The material constitutive relationship

The conditions, which are obtained utilizing the above conditions, are as power dislodging relationships. At long last, the power uprooting conditions are tackled to acquire removals at the hubs, which are the essential questions in the limited component strategy.

The essential thought in the limited component technique is to discover the arrangement of an entangled issue by supplanting it by a less difficult one. Since a more straightforward one in finding the arrangement supplanted the genuine issue, we will have the capacity to discover just a rough arrangement as opposed to correct arrangement.

This is a numerical answer for acquiring answers for huge numbers of the issues experienced in building examinations. In this technique, the body or the structure might be isolated into little components of limited measurements called limited components. The first body or continuum is then considered as a gathering of these components associated at a limited number of joints called hubs.

5.2 Engineering Applications of Fem

Finite element analysis (FEA) is a powerful tool for analyzing and solving engineering problems. Here is a list of some common engineering applications of FEA:

5.2.1 Structural analysis

FEA is widely used to analyze the strength, stiffness, and stability of structural systems, such as beams, trusses, and frames. It can be used to predict how these systems will behave under different loading conditions, such as static or dynamic loads, and to optimize their design.

5.2.2 Thermal analysis

FEA can be used to predict the temperature distribution and heat transfer in a system, such as in electronic components or mechanical systems. This can help to optimize the design of these systems and avoid overheating or other thermal issues.

5.2.3 Fluid flow analysis

FEA can be used to analyze the flow of fluids, such as in pipes, tanks, and other containers. This can be used to predict pressure, velocity, and other flow characteristics, and to optimize the design of these systems.

5.2.4 Vibration analysis

FEA can be used to analyze the natural frequencies and modes of vibration of a system, such as in mechanical structures or machinery. This can help to predict the response of the system to dynamic loads and optimize its design to reduce vibrations.

Fatigue analysis: FEA can be used to analyze the life cycle and durability of a system under repeated loads, such as in aircraft structures or automotive components. This can help to optimize the design of these systems and extend their service life.

5.2.5 Nonlinear analysis

FEA can be used to analyze systems that exhibit nonlinear behavior, such as large deformations, contact, or material nonlinearity. This can help to predict the behavior of these systems under different loading conditions.

5.2.6 Optimization

FEA can be used to find the optimal design configuration of a system that meets certain performance criteria, such as minimizing weight or maximizing efficiency.

Multiphysics analysis: FEA can be used to analyze systems that involve multiple physical phenomena, such as coupled thermal-structural analysis or electro-magnetic-structural analysis.

Table 5.1 Applications of FEM

Application	Description
Structural analysis	Analysis of structural systems, such as beams, trusses, and frames, to determine their strength, stiffness, and stability
Thermal analysis	Analysis of heat transfer and temperature distribution in a system, such as in electronic components or mechanical systems
Fluid flow analysis	Analysis of fluid flow, such as in pipes, tanks, and other containers, to predict pressure, velocity, and other flow characteristics
Vibration analysis	Analysis of the natural frequencies and modes of vibration of a system, such as in mechanical structures or machinery
Fatigue analysis	Analysis of the life cycle and durability of a system under repeated loads, such as in aircraft structures or automotive components
Nonlinear analysis	Analysis of systems that exhibit nonlinear behavior, such as large deformations, contact, or material nonlinearity
Optimization	Analysis of a system to find the optimal design configuration that meets certain performance criteria, such as minimizing weight or maximizing efficiency

5.3 General Description of FEM

The well ordered technique for static issue can be expressed as takes after:

5.3.1 Discretization of Continuum

The initial phase in the limited component is to separate the structure of the arrangement area into subdivisions of components. The subdivision or discretization procedure of the continuum is basically an activity of designing judgment. These subdivisions are called components, and are associated with the adjoining of the components such that the first body is spoken to by it as nearly as could reasonably be expected. Henceforth, the general goal of such an admiration is to discretize the body into a limited number of components adequately with the goal that the straightforward removal models can sufficiently surmise the genuine arrangement.

5.3.2 Selection of Proper Interpolation Model

Since the dislodging (field variable) arrangement of the unpredictable structure under a particular load conditions can't be anticipated precisely, we accept some appropriate structure within a component to inexact the obscure arrangement. The expected arrangement must be from a computational perspective and it ought to fulfill certain joining necessities.

5.3.3 Derivative of Element Stiffness Matrices And Load Vectors

From the expected relocation, the firmness framework {K(e)} and load vector P(e) of the component "e" are to be isolated by utilizing either balance conditions or a reasonable variety rule.

5.3.4 Assemblage of Element Equation

Since the structure is made out of a few limited components, the individual component firmness frameworks and load vectors are to be collected in a variable way and the general balance conditions must be detailed as:

$$[K]\ \{d\} = [P]$$

Where *[K]* is called array firmness framework, {d} is called nodal relocation vector and P is called nodal vector for the total structure.

5.3.5 Solution of Systems Equations To Find Nodal Values of The Displacement

The general conditions must be changed, to represent the limit states of the issue, after the fuse of the limit conditions, the harmony conditions are tackled.

(A) Types of Elements

Frequently the kind of component to be utilized is apparent from the issue itself. For instance, if the issue includes the examination of the truss structure under a given arrangement of load conditions, the kind of component to be utilized is clearly "the bar or line components". Be that as it may, sometimes the sort of the components to be utilized for glorification may not be suitable and in such cases one needs to pick the kind of components judicially. In certain issues, the given body can't be spoken of as a collection of just a single kind of component. In such cases we may need to utilize at least two sorts of component glorification.

(B) Number of Elements

The quantity of components to be decided for romanticizing is identified with the exactness wanted, size of component and the quantity of degrees of flexibility included. In spite of the fact that an expansion in number of components by and large gives more precise outcomes, for any given issue, there will be a sure number of components achieving the point where no critical change will be found. In addition, since the utilization of a substantial number of components includes a vast number of degrees of flexibility, we will most likely be unable to store the subsequent lattices in the accessible PC memory.

(C) Size of Elements

The measure of components impacts the merging of the arrangement specifically and it must be picked with care. On the off chance that the span of components is little, the last arrangement is relied upon to be more exact. In any case, we need to recall that the utilization of components of litter size will likewise mean more confused time. Here and there, we may need to utilize the components of various sizes in a similar body. Another trademark identified with the measure of components, which influences the limited component arrangement is the "perspective proportion" of the components. The angle proportion is taken as the proportion of the component biggest measurement to the littlest measurement of the component. 'Components with an angle proportion of solidarity by and large yield better outcomes'.

(D) Convergence Requirements

Since the limited component strategy is a numerical method, we acquire an arrangement of inexact arrangements as the component estimate is diminished progressively. The arrangement will focalize to the correct arrangement if the insertion polynomial fulfills the accompanying prerequisites.

1. The uprooting capacity must be consistent within the component.
2. The dislodging capacity must be equipped for speaking to unbending body relocations of the component.
3. The uprooting capacity must be fit for speaking to strain states inside the component.

(E) Nodal Degrees of Freedom

The fundamental thought of FEM is to consider a body as made out of a few components, which are associated at particular hub focuses. The obscure arrangement or the field factors (like relocations, weights or temperatures) inside any limited component is thought to be given by a straightforward capacity as far as nodal estimations of the component. The nodal removal, pivots, important to determine totally the misshapening of the limited component is the degrees of opportunity of the component.

The nodal estimations of the arrangement, otherwise called nodal degrees of flexibility, are dealt with as questions in defining the arrangement of general conditions. The arrangement of the framework condition (like power harmony conditions) gives the estimation of the obscure nodal degrees of opportunity. Once the nodal degrees of flexibility are known, the arrangement inside any components will likewise be known to us. For having the outcomes as far as nodal degrees of flexibility the introduction work must be inferred as far as nodal degrees of opportunity.

5.4 Assembly of Element Equations

Once the component attributes, in particular, the component lattices and component vectors are found in a worldwide co-ordinate framework, the following stage is to develop the by and large or framework conditions.

The system of collecting the component lattices and vectors depends on the prerequisite of "Similarity" at the component hubs. This implies at the hubs where components are associated, the estimations of obscure degrees of flexibility of the factors are the same for every one of the components at the hubs.

5.5 Incorporation of The Boundary Conditions

In the wake of amassing the trademark grids *[K(e)]* and component trademark vectors $P(e)$ the general framework condition of the whole space of the body can be composed (for any balance issues) as,

$$[k]\{\varphi\} = \{p\}$$

These conditions can't be comprehended for *{φ}* since the network *[K]* will be particular and subsequently its converse does not exist. The physical importance of this, if there should arise an occurrence of strong mechanics issue, is that the stacked body or structure is allowed to experience boundless inflexible body movement unless some help limitations are forced to keep the body or structure in harmony under the heaps. Subsequently some limit or bolster conditions must be connected before fathoming for $\{\varphi\}$. In non-auxiliary issues we need to determine one or some of the time more than one nodal degree of flexibility. The quantity of degrees of opportunity is directed by the material science of the issue.

5.6 Advantages of Finite Element Analysis

1. Accuracy: FEA can provide highly accurate results when used correctly, particularly for complex systems that are difficult to analyze using other methods.

2. Versatility: FEA can be used to analyze a wide range of structures and systems, including those made of different materials and subjected to various loading conditions. It can also be used to analyze a wide range of phenomena, including linear and non-linear behavior, static and dynamic loading, and heat transfer.

3. Efficiency: FEA can be a more efficient way to analyze complex systems compared to traditional analytical methods. It can save time and resources by allowing the analysis to be performed quickly and easily on a computer.

4. Optimization: FEA can be used to optimize the design of structures and systems by identifying the optimal configuration of material and geometry. This can lead to cost savings and improved performance.

5. Visualization: FEA software allows for the visualization of the behavior of structures and systems, which can be helpful for understanding and communicating the results of the analysis.

5.7 Disadvantages of Finite Element Analysis

1. Complexity: FEA involves solving complex mathematical equations and requires a high level of expertise to use effectively. It may not be suitable for users with limited knowledge of mathematics or computer modeling.

2. Time and resource requirements: FEA can be time-consuming and resource-intensive, particularly for large and complex systems. It may require specialized software and hardware, as well as significant amounts of computing power and time to complete the analysis.

3. Modeling assumptions and limitations: FEA relies on certain assumptions about the behavior of materials and the geometry of the system being analyzed. These

assumptions may not always be accurate, which can lead to errors in the results. In addition, FEA may not be able to accurately represent certain types of behavior, such as non-linear or highly dynamic phenomena.

4. Sensitivity to input data: FEA results are sensitive to the accuracy and quality of the input data. If the input data is incorrect or incomplete, it can lead to significant errors in the results.

5. Cost: FEA software and hardware can be expensive, which may limit its accessibility to smaller organizations or individuals.

5.8 Finite Element Analysis

Limited component examination was first created for the utilization of aviation and atomic enterprises where the security of structure is basic. Today development in the utilization of strategy is specifically inferable from the quick advances in PC innovation. Thus business limited component bundles exist that are equipped for tackling the most advanced issues, not simply in auxiliary investigation, but rather for an extensive variety of wonders, for example, enduring state and dynamic temperature dispersions, liquid stream and assembling procedures, for example, infusion embellishment and metal framing. Limited component investigation is utilized as a part of new item outline, and existing item refinement. Adjusting a current item or structure is used to qualify the item or structure for another administration condition. If there should arise an occurrence of basic disappointment, Finite Element Analysis might be utilized to help in deciding the outline adjustments to meet the new conditions.

5.9 Types of Analysis

There are diverse sorts of examinations that are utilized as a part of industry: Structural, Modal, Harmonic, Transient and Spectrum.

Auxiliary Analysis comprises direct and non-straight models. Direct models are straightforward parameters and expect that material is not plastically distorted. Non-direct models consist of focusing on the material past its flexible capacities. The worries in the material at that point change with the measure of distortion.

Vibration investigation is utilized to test the material against arbitrary vibrations, stun and affect. Each of these episodes may follow up on the regular vibration recurrence of the material, which thus, may cause reverberation and resulting disappointment. So investigation is done on the material to anticipate the life of the material. Warmth Transfer Analysis models the warm conductivity or warm liquid progression of the material or structure. This may comprise an unfaltering state or transient exchange. Unfaltering state exchange alludes to consistent thermo properties in material that yield direct warmth dissemination.

The structure to be dissected is subdivided into work of limited estimated components of straightforward shape. Inside every component, the variety of removal is thought to be dictated by basic polynomial shape capacities and nodal relocations. Conditions for strain and stresses are produced as far as obscure nodal removals. From this, the conditions of harmony are collected in a lattice frame, which can be effectively modified and illuminated, on a PC. Subsequent to applying suitable limit conditions, the nodal removals are found by tackling the framework solidness condition. Once the nodal removals are known, component stresses and strains can be computed.

5.10 Introduction to Ansys Software

The motivation behind a limited component investigation is to demonstrate the conduct of a structure under an arrangement of burdens. To do as such, all impacting factors must be considered and decided if their impacts are impressive or immaterial on the last outcome. Numerous products are utilized for this reason. ANSYS, Pro-E, Uni illustrations, NISA, MSC, NASTRAN and so forth.

The ANSYS program is an independent broadly useful limited component program created and kept up by Swanson Analysis Systems Inc. The program contains numerous schedules, all interrelated and for fundamental reasons for accomplishing an answer for a building issue by Finite Element Method.

ANSYS gives an entire answer for outline issues. It comprises effective outline abilities like full parametric strong displaying, plan enhancement and auto fitting, which gives builds full control over their investigation.

The accompanying are the uncommon highlights of ANSYS programming:

1. It incorporates bilinear components.
2. Heat stream examination, liquid stream and component stream investigation should be possible.
3. Graphic bundle and broad preprocessing and post handling.

The accompanying demonstrates the short portrayal of steps followed in each stage:

5.11 Meshing

5.11.1 Manual Meshing

In the manual cross section the components are littler at the joint. This is known as work refinement, and it empowers the worry to be caught at the geometric brokenness. Manual lattice is a long and monotonous process for models with any level of geometric inconvenience, however with valuable devices developing in pre-forms, the undertaking is getting to be noticeably less demanding.

5.11.2 Meshing Controls

The default coinciding controls that the program uses may create a work that is satisfactory for the model we are investigating. For this situation, we require not to indicate any cross section controls. Be that as it may in the event that we do utilize coinciding controls we should set them before cross sectioning the strong model.

Lattice controls enable us to build up the component shape, fair size hub arrangement and component size to be utilized as a part of cross section the strong model, this progression is a standout amongst the most imperative of the whole examination for the choices we make at this phase in the model improvement will significantly influence the exactness and economy of the investigation.

5.11.3 Smart Sizing of Element

Keen component measuring (Smart estimating) is a cross section that makes beginning component sizes with the expectation of complimentary lattice operations.

Shrewd measuring gives the user a superior shot of making sensibly molded components amid programmed work era.

5.11.4 Free And Mapped Mesh

A free work is one that has no confinements regarding component shapes, and no particular example connected to it. Contrasted with a free work, a mapped work is limited as far as the component shape it contains and the example of the work. A mapped work contains just quadrilateral (zone) or just hexahedron (volume) components. On the off chance that this sort of work is wanted, the client must form the geometry as an arrangement of genuinely normal volumes as well as zones that can acknowledge a mapped work.

5.12 Pre-Processor

The pre-processor organize in ANSYS bundle includes the accompanying:

1. Specify the title, which is the name of the issue.
2. Set the kind of the examination to be utilized, i.e., basic, warm, liquid, or electro-attractive, and so on.,
3. Create the model – The model is attracted to 1D, 2D, or 3D space in the suitable units (m, mm, in, and so on). The model might be made in pre-processor or it can be foreign made from another CAD drafting bundle through a nonpartisan record organization like IGES, STEP, ACIS, Para strong, DFX, ETC.,). Similar units ought to be connected every which way, generally results will be hard to translate, or in outrageous cases the outcome won't show up botches made amid stacking and controlling of the model
4. Define the component sort, this might be 1D, 2D or 3D, and determine the examination sort being done.
5. Apply work – Mesh era is the way toward separating the investigation continuum into a number of discrete parts or limited components. The better the work, the

better the outcome, however the more extended the examination time. Along these lines, the bargain amongst precision and arrangement speed is generally made.

6. Assign the properties – Material properties (Young's Modulus, Poisson's proportion, thickness, and if appropriate coefficient of extension, rubbing, warm conductivity, damping impact, particular warmth, and so on.,) must be characterized.

5.13 Solution

1. Apply the heaps. Some sort of load is really connected to the examination demonstration. The stacking might be as a point load, weight or an uprooting in an anxiety investigation, a temperature or warmth motion in a warm examination and a liquid weight or speed in a liquid investigation. The heaps might be connected to a point, an edge, a surface or even to a total body.

2. Applying the limit conditions. Subsequent to applying burden to the model with a specific end goal to stop it quickening boundlessly through the PC for all intents and purposes either no less than one limit condition must be connected

A FE solver can be intelligently isolated into three fundamental parts, the pre-solver, the scientific motor and the post-solver. The pre-solver peruses the model made by the pre-processor and figures the numerical portrayal of the model and calls the scientific motor, which ascertains the outcomes. The outcome came back to the solver and the post-solver is utilized to ascertain the strains, stresses, and so forth., for every hub inside the part or continuum

5.14 Post-Processor

In this module, the aftereffects of the investigation are perused and deciphered. All post-processor incorporate the computation of anxiety in the majority of the X, Y, or Z headings, or in fact toward the path at a point to facilitate tomahawks. The guideline anxiety may likewise be plotted.

5.15 Analysis

Basic examination is presumably the most widely recognized use of the FEM. The term auxiliary suggests not just considerate designing structures, for example, scaffolds and structures, yet in addition maritime, aeronautical, and mechanical segments, for example, pistons, machine parts and apparatuses. The essential questions (nodal level of flexibility) computed in a basic investigation are relocations of different qualities, for example, strains, stresses and response powers are gotten from the nodal removals.

5.16 Modal Analysis

Definition: We utilize Modal Analysis to decide the vibration qualities (Natural frequencies and mode shapes) of a structure of a machine part while it is being outlined. It likewise can be a beginning stage for another, more point by point, Dynamic Analysis, for example, a transient dynamic, a consonant reaction examination, or a range investigation.

Utilizations for Modal Analysis: The Natural frequencies and mode shapes are essential parameters in the outline of a structure for Dynamic stacking conditions. They are likewise required in the event that you need to do a range examination or a mode superposition symphonious or transient investigation.

We can do modular examination on a pre-focus on structure, for example, a turning turbine edge. Another helpful element is modular cyclic symmetry, which enables you to survey the mode states of a consistently symmetry structure by displaying only a part of it.

Modular Analysis in the ANSYS group of items is a straight examination. Any nonlinearity, for example, pliancy and contact (hole) components, are overlooked regardless of the possibility that they are characterized. You can look over a few mode extraction strategies: subspace, Block Lanczos, Power Dynamics, diminished, unsymmetrical, and damped. The damped technique enables you to incorporate damping in the structure. Insights about mode extraction strategies are canvassed later in this area.

5.17 Structural Static Analysis

Definition: A static investigation ascertains the impacts of relentless stacking conditions on a structure, while disregarding idleness and damping impacts, for example, those caused by time-shifting burdens. A static investigation can, nonetheless, incorporate relentless dormancy loads, (for example, gravity and rotational speed), and time-changing burdens that can be approximated as static proportionate burdens, (for example, the static identical breeze and seismic loads ordinarily characterized in many construction regulations).

Loads in a Static Analysis: Static examination is utilized to decide the relocations, stresses, strains and powers in structures or segments caused by loads that don't initiate huge dormancy and damping impacts. Consistent stacking and reaction conditions are expected; that is, the heaps and the structure's reaction are accepted to fluctuate gradually as for time. The sorts of stacking that can be connected in a static investigation include:

1. Externally connected powers and weights
2. Steady-state inertial powers, (for example, gravity or discerning speed)
3. Imposed (non-zero) removals
4. Temperatures (for warm strain)
5. Fluencies (for atomic swelling)

A static investigation computes the impacts of consistent stacking conditions on a structure, while disregarding latency and damping impacts, for example, those caused by time-changing burdens. A static investigation can, in any case, incorporate relentless inactivity loads, (for example, gravity and rotational speed), and time shifting burdens that can be approximated as static proportionate burdens, (for example, static comparable breeze and seismic loads usually characterized in many construction regulations.

Loads in a Static Analysis: - Static investigation is utilized to decide the relocations, stresses, strains, and powers in structures or segments caused by loads that do exclude critical dormancy and damping impacts. Consistent stacking and reaction conditions are expected; that is, the heaps and the structure's reaction are accepted to differ gradually as for time. The sorts of stacking that can be connected in a static investigation.

5.18 Overview of Steps in A Static Analysis -

A static analysis is a type of analysis that evaluates the behavior and performance of a system or structure under static (i.e., non-dynamic) loading conditions. Here is an overview of the steps typically involved in a static analysis:

1. Modeling: The first step in a static analysis is to create a finite element model of the system or structure being analyzed. This involves defining the geometry of the model, selecting appropriate element types and sizes, and defining the material properties and boundary conditions.

2. Meshing: Once the model has been defined, the next step is to generate a finite element mesh, which divides the model into a set of smaller elements that can be analyzed individually. The mesh should be designed to accurately capture the geometry and behavior of the model, while minimizing the number of elements and computational cost.

3. Solving: Once the mesh has been generated, the next step is to solve the finite element equations that describe the behavior of the model under the applied loads and boundary conditions. This typically involves assembling the global stiffness matrix and solving for the unknown nodal displacements and element stresses and strains.

4. Post-processing: After the analysis has been solved, the results can be post-processed to extract useful information about the behavior and performance of the model. This may include calculating quantities such as nodal displacements, element stresses and strains, and global reaction forces and moments.

6 ANALYSIS USING ANSYS

Two analysis are done in this project they are

1. STRUCTURAL ANALYSIS
2. FATIGUE ANALYSIS

6.1 Structural Analysis

Analysis was done for MILD CARBON STEEL with different wall thicknesses of material:

1. 50x50mm 2.0mm Thickness
2. 50x50mm 2.6mm Thickness
3. 50x50mm 3.0mm Thickness

6.2 A Project Schematic

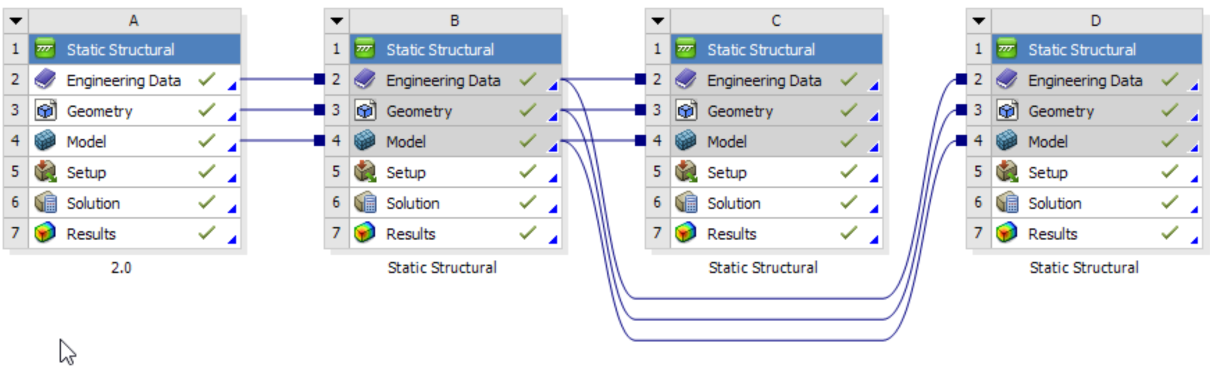

Figure 6.1. Project Schematic

The total analysis was done for each individual part with different material wall thicknesses at five different loads 60Kg, 80Kg, 120Kg, 180Kg and 220 Kg respectively.

6.3 Base part

This part is the bottom part which supports all the parts above. This part carried most weight but it is also subjected to loading in perpendicular direction to the support gussets.

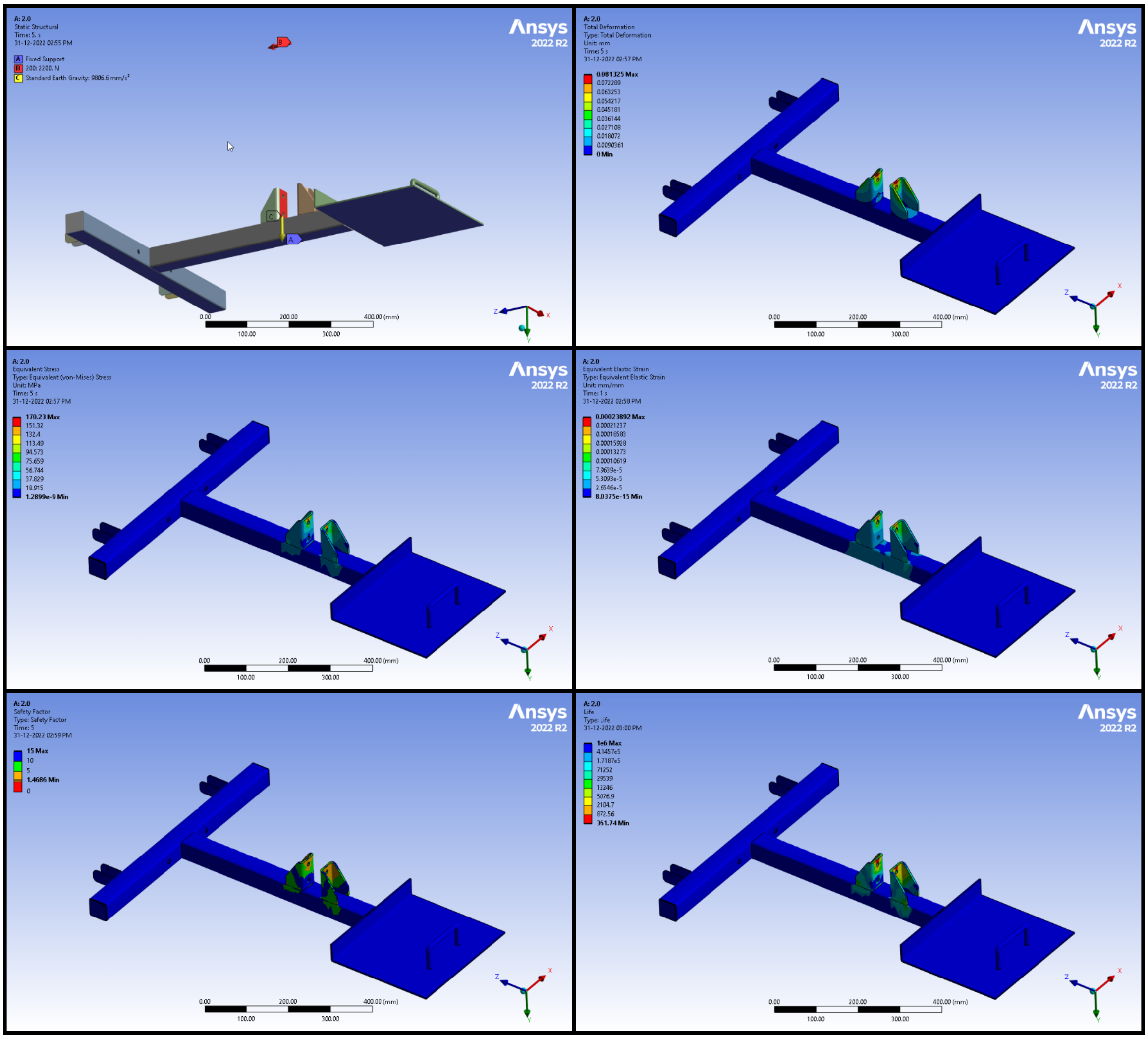

Figure 6.2 Base ANSYS results

A remove load is being applied which varies from 600N to 2200N, this process was repeated with different tube wall diameters, from 2.0mm to 3.0mm.

6.4 Arm

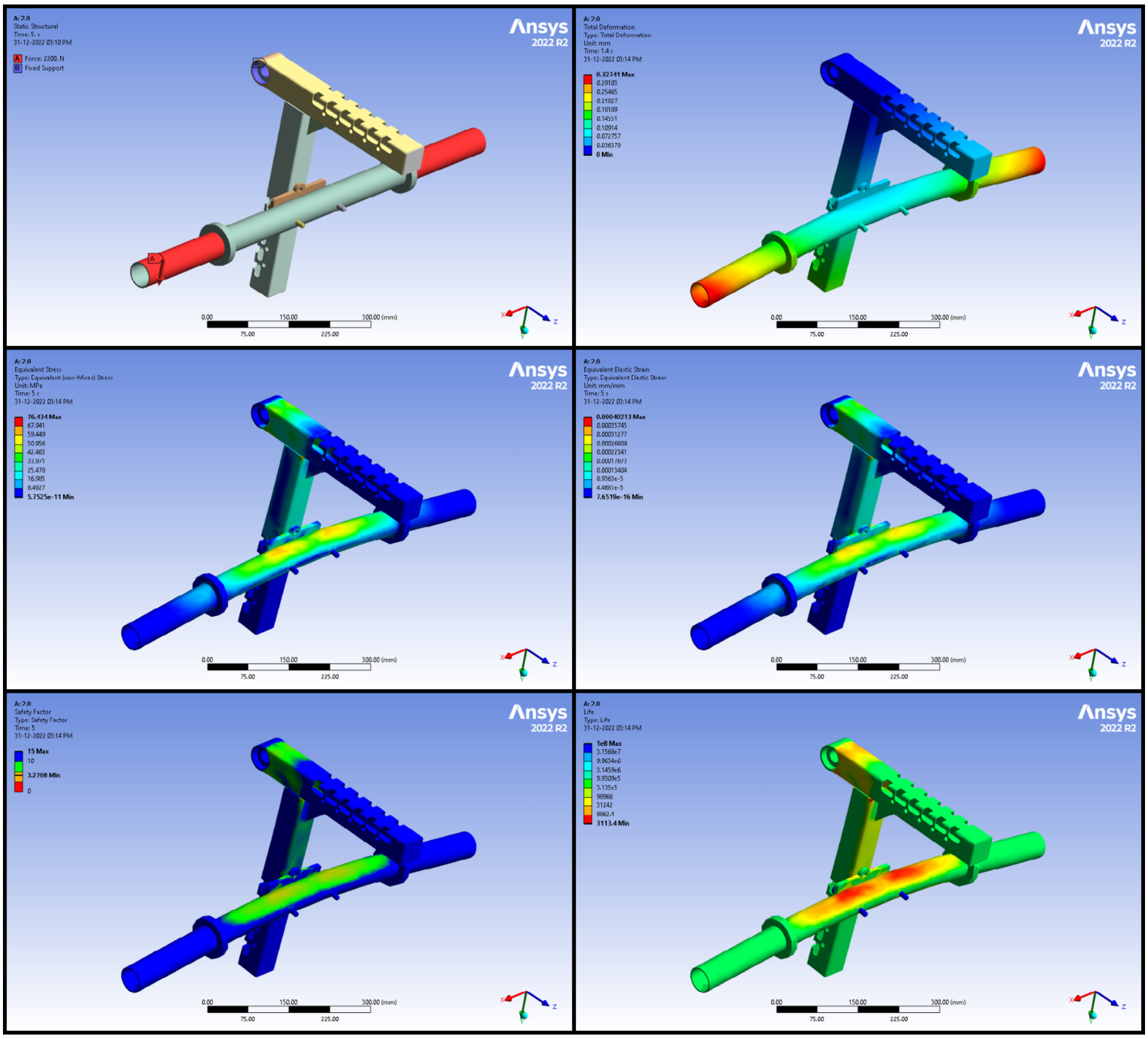

Figure 6.3 Arm ANSYS Results

The first image in Figure 6.3 shows the boundary conditions applied to the analysis, including any fixed or support points as well as any loading conditions. The second image displays the deformation of the structure under load, with the most deformed areas shown in red and the least deformed shown in blue. The third image presents the stress experienced by the structure, with high stress points shown in red and low stress points shown in blue. The fourth image displays the strain on the structure, with areas of highest strain shown in red and lowest in blue. The fifth image illustrates the factor of safety for the structure, with values above 1 indicating a safe design and values below 1 indicating a potentially unsafe design. The final image displays the fatigue life of the structure, with those areas predicted to fail sooner shown in red and those with longer predicted life shown in blue.

6.5 Arm Support Plate

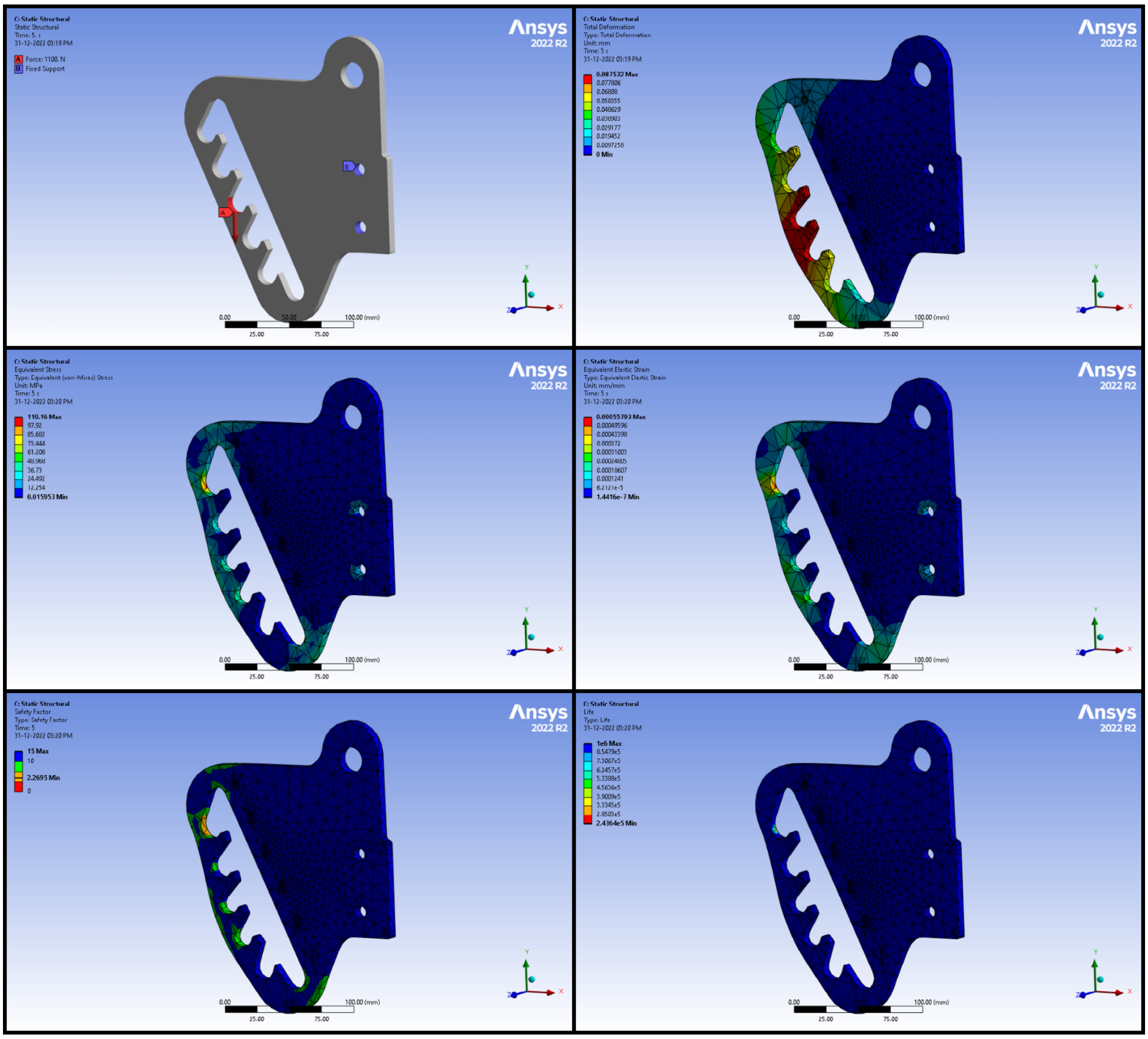

Figure 6.4 Arm Support Plate ANSYS Results

The first image Figure 6.4 shows the boundary conditions applied to the analysis of the Arm Support Plate, including any fixed or support points as well as any loading conditions. The second image displays the deformation of the Arm Support Plate under load, with the most deformed areas shown in red and the least deformed shown in blue. The third image presents the stress experienced by the Arm Support Plate, with high stress points shown in red and low stress points shown in blue. The fourth image displays the strain on the Arm Support Plate, with areas of highest strain shown in red and lowest in blue. The fifth image illustrates the factor of safety for the Arm Support Plate, with values above 1 indicating a safe design and values below 1 indicating a potentially unsafe design. The final image displays the fatigue life of the Arm Support Plate, with those areas predicted to fail sooner shown in red and those with longer predicted life shown in blue.

6.6 Vertical Arm

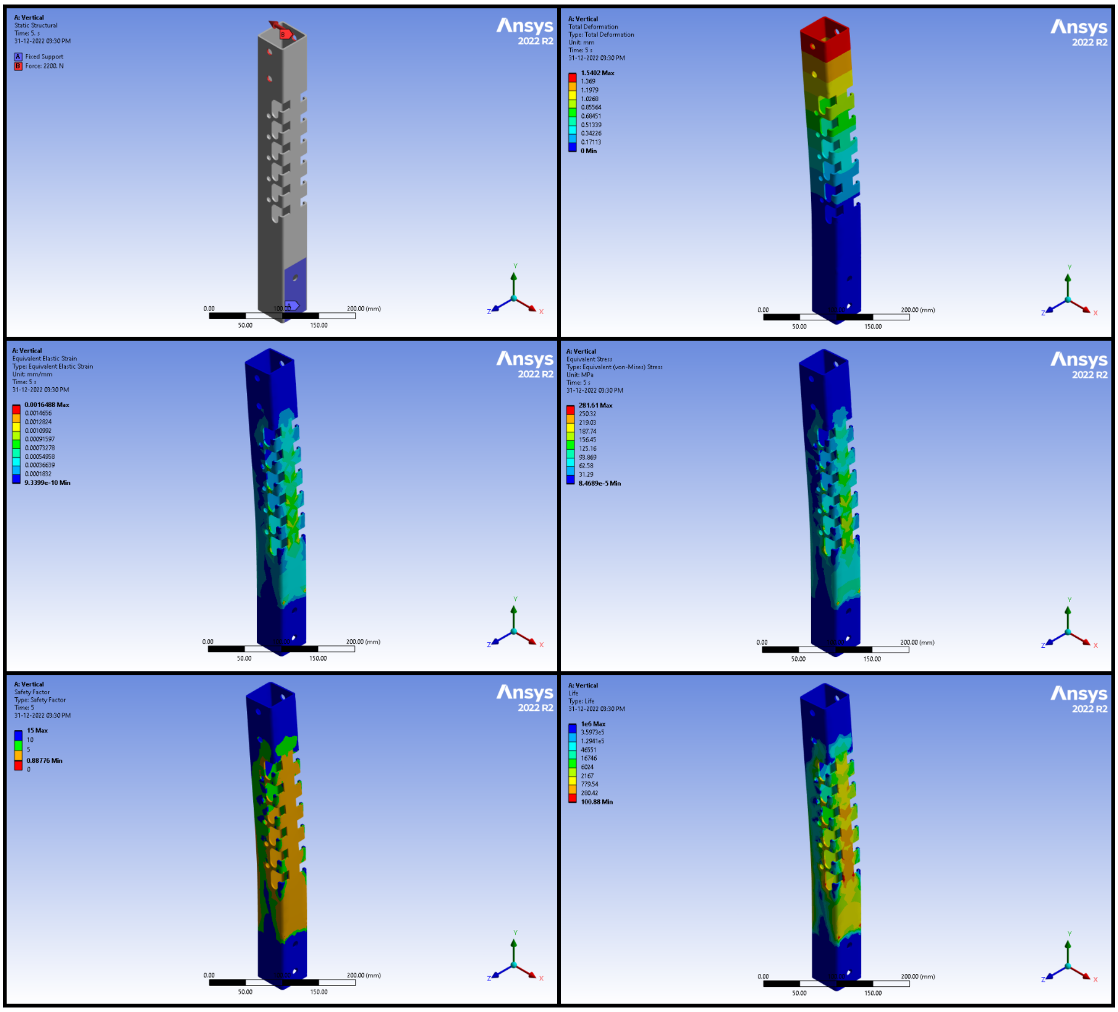

Figure 6.5 Vertical tube ANSYS Results

In Figure 6.5, the boundary conditions applied to the analysis of the cantilever vertical arm tube are depicted. These boundary conditions include any fixed or support points as well as any applied loading conditions. The second image illustrates the deformation of the cantilever vertical arm tube under load, with the most deformed areas shown in red and the least deformed shown in blue. The stress experienced by the cantilever vertical arm tube is displayed in the third image, with high stress points shown in red and low stress points shown in blue. The fourth image presents the strain on the cantilever vertical arm tube, with areas of highest strain shown in red and lowest in blue. The factor of safety for the cantilever vertical arm tube is shown in the fifth image, with values above 1 indicating a structurally sound design and values below 1 indicating a potentially unstable design. The fatigue life of the cantilever vertical arm tube is displayed in the final image, with those areas predicted to fail sooner shown in red and those with longer predicted life shown in blue.

6.7 Roller

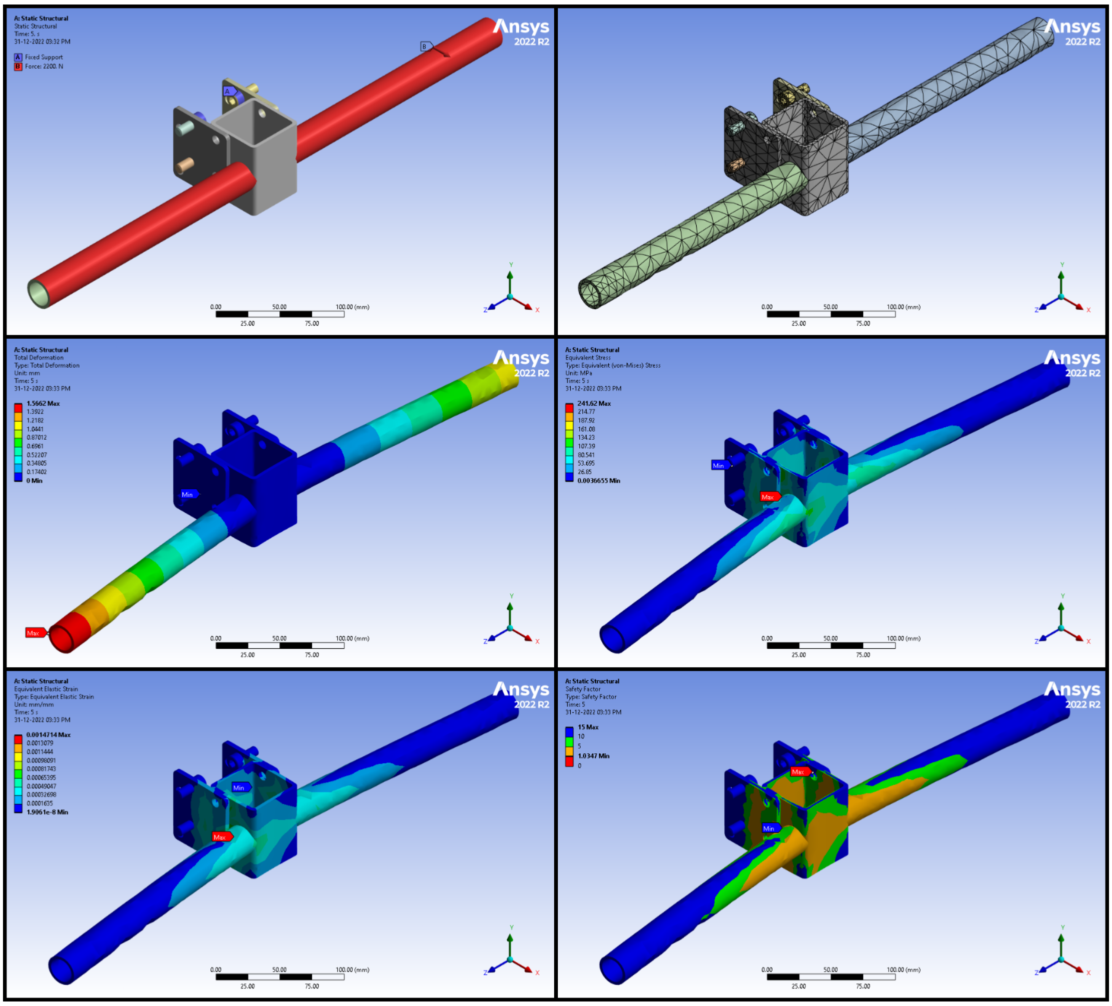

Figure 6.6. Roller Attachment ANSYS Results

Figure 6.6 presents the boundary conditions, deformation, stress, strain, factor of safety, and fatigue life of the roller attachment. The boundary conditions depicted include any fixed or support points as well as any applied loading conditions. The deformation, stress, and strain of the roller attachment under load are shown, with high values depicted in red and low values shown in blue. The factor of safety for the roller attachment is presented, with values above 1 indicating a structurally sound design and values below 1 indicating a potentially unstable design. The fatigue life of the roller attachment is displayed, with those areas predicted to fail sooner shown in red and those with longer predicted life shown in blue.

7 RESULTS AND DISCUSSIONS

7.1 Base

Deformation is a measure of how much an object changes shape under a load or stress. It is typically represented by a graph showing how much the object has deformed over a range of applied stresses.

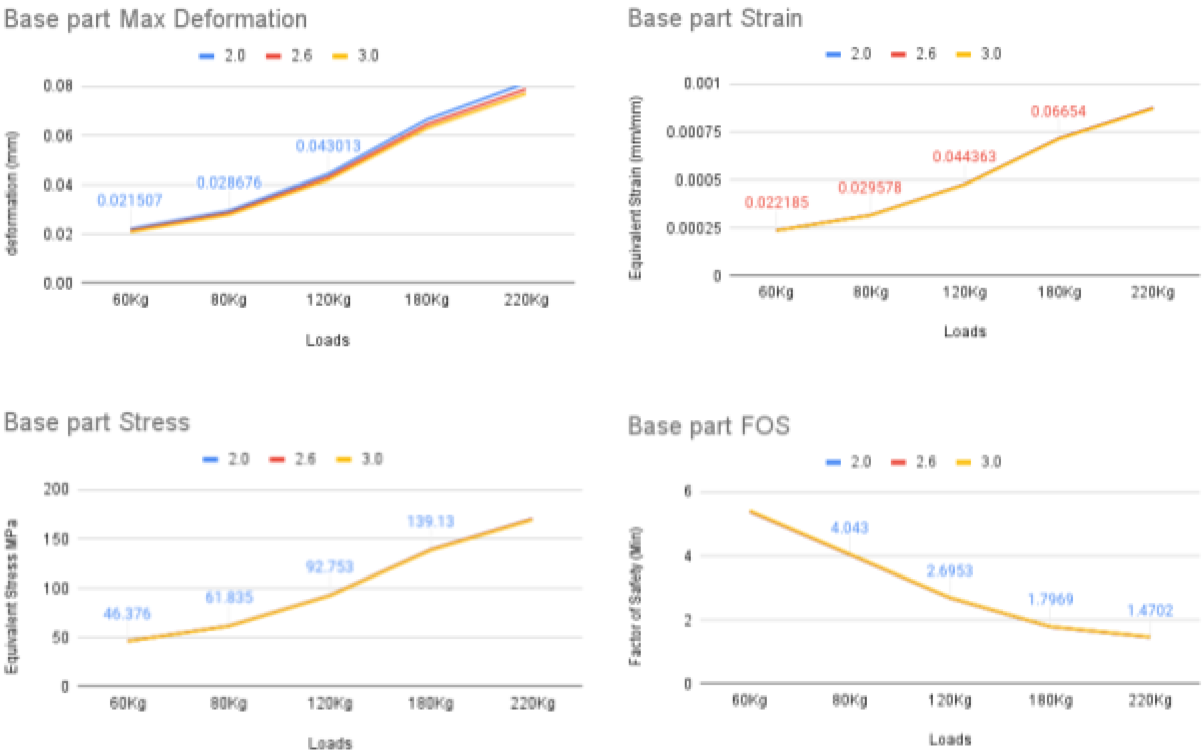

Figure 7.1 Base part result comparisons

In the above charts, it can be seen that increasing the thickness of the material only changes the pattern of the graphs marginally. This suggests that the material's thickness has a relatively small effect on its deformation, stress, strain, and factor of safety when subjected to a range of applied loads or stresses.

7.2 ARM

The first graph shows deformation, which is the change in shape or size of an object due to an applied force. The x-axis represents the applied force and the y-axis represents the resulting deformation.

Figure 7.2 Arm part result comparisons

The second graph shows stress, which is the force applied to an object per unit area. The x-axis represents the applied force and the y-axis represents the resulting stress.

The third graph shows strain, which is the measure of deformation of an object due to an applied force. It is calculated as the change in length of the object divided by its original length. The x-axis represents the applied force and the y-axis represents the resulting strain.

The fourth graph shows the factor of safety, which is a measure of the margin of safety in a structure or component. It is calculated as the ratio of the maximum load that an object can withstand before failing, to the actual load applied to it. The x-axis represents the applied force and the y-axis represents the resulting factor of safety.

As shown in the graphs, increasing the thickness of the materials results in a decrease in stress and an increase in the factor of safety. This is because thicker materials are able to withstand higher loads before failing, resulting in a higher margin of safety.

7.3 Vertical Tube

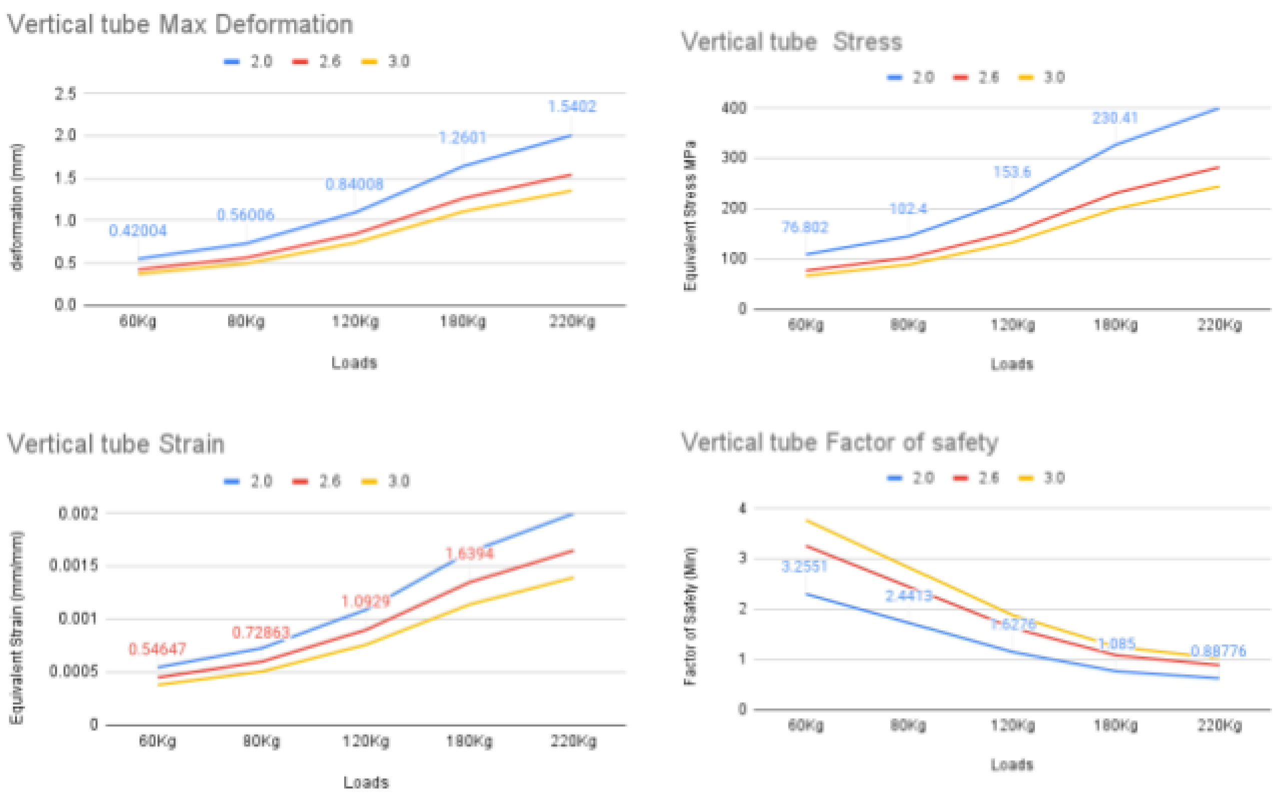

Figure 7.3 Vertical Tube part result comparisons

In Figure 7.3.1, which shows deformation, we can see that as the thickness of the material increases, the deformation decreases. This is because thicker materials are able to withstand higher forces without deforming as much as thinner materials.

7.4 Arm Support Plate

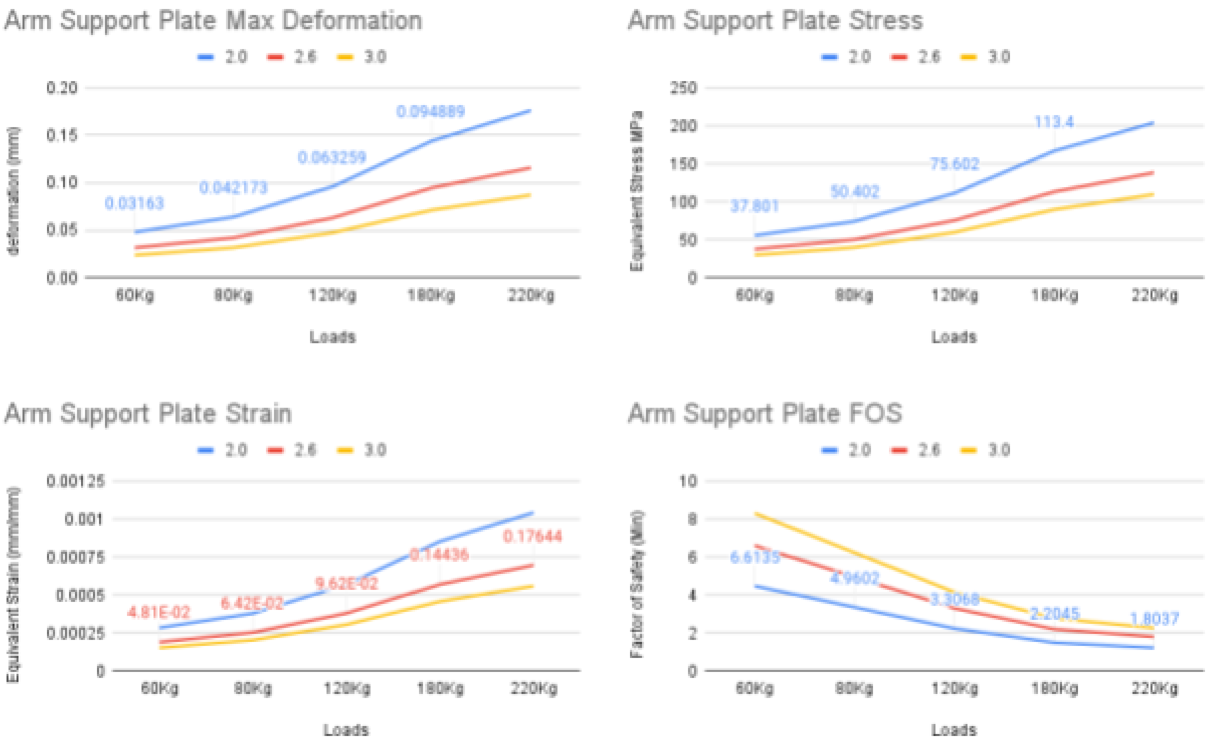

Figure 7.4 Arm Support plate result comparisons

In Figure 7.4.1, which shows stress, we can see that as the thickness of the material increases, the stress decreases. This is because the applied force is distributed over a larger area in thicker materials, resulting in lower stress.

7.5 Roller Attachment

In Figure 7.5.1, which shows strain, we can see that as the thickness of the material increases, the strain decreases. This is because thicker materials are able to withstand higher forces without stretching as much as thinner materials.

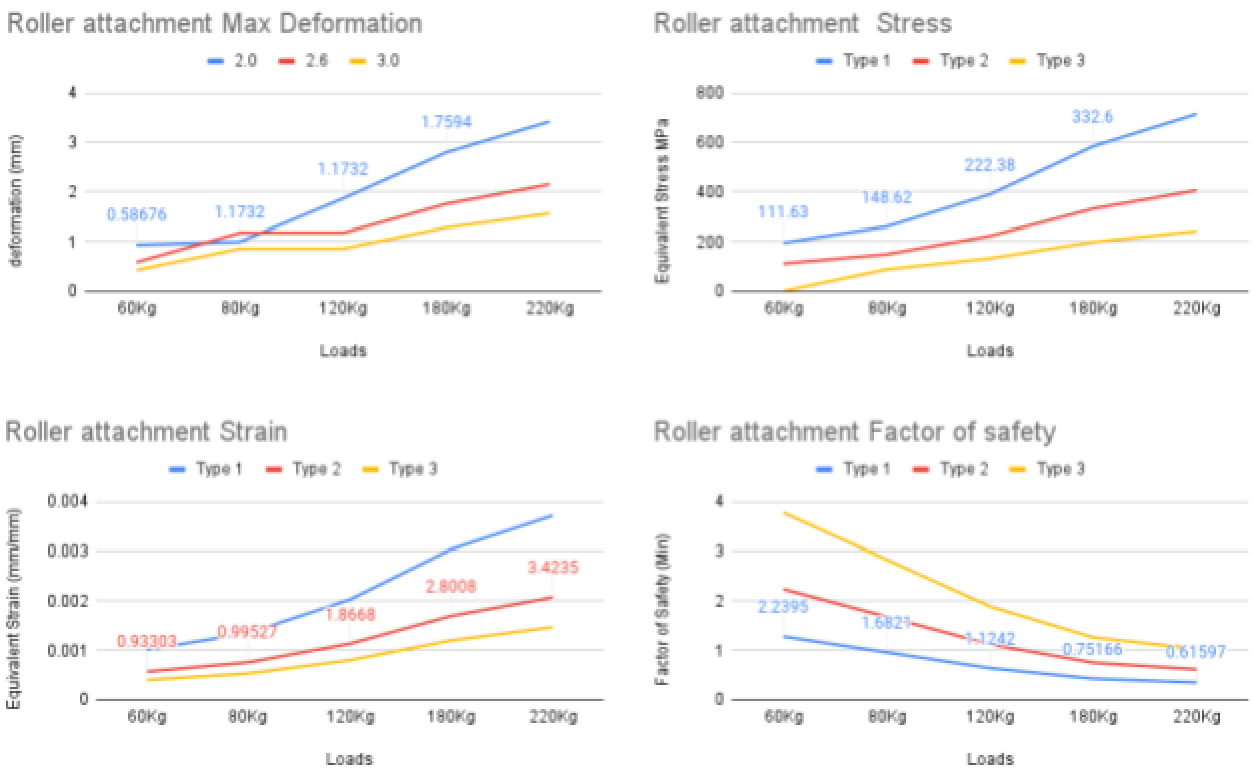

Figure 7.5 Roller Attachment result comparisons

The fourth graph, which shows the factor of safety, would also likely show an increase in the factor of safety as the thickness of the material increases. The factor of safety is a measure of the margin of safety in a structure or component, and is calculated as the ratio of the maximum load that an object can withstand before failing, to the actual load applied to it. Thicker materials are able to withstand higher loads before failing, resulting in a higher margin of safety.

Overall, it is clear that increasing the thickness of materials has a positive effect on deformation, stress, strain, and the factor of safety. This is why it is important to use materials with high thickness in applications where high loads or forces are expected

CONCLUSION

The results of the design analysis showed that the base of the gym equipment does not deform at different material thicknesses, indicating that it is robust and effective. However, it is possible to optimize the weight of the base by reducing the material thickness without compromising its structural integrity.

The arm and vertical parts of the equipment showed signs of deformation and stress, indicating that they may be susceptible to failure under heavy loads. In order to address this issue, it may be necessary to modify the design of these parts or use more durable materials that can withstand the applied stresses. The arm support was identified as a critical component, and a thickness of 6mm for the plate material is recommended to ensure adequate strength and stability.

The roller attachment was found to be insufficient for handling heavy loads above 120kg, suggesting that it should be modified or reinforced in order to support higher weight capacities. In summary, this design analysis report provided valuable insights into the performance of the gym equipment and identified areas for improvement to enhance its durability and functionality.

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