FABRICATION OF STAIR-CASE CLIMBING TROLLEY USING 3D PRINTER AND LOAD ANALYSIS ON ITS COMPONENTS

A PROJECT REPORT SUBMITED IN PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR THE AWARD OF THE DEGREE OF

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the Project Report Work entitled **"FABRICATION OF STAIR-CASE CLIMBING TROLLEY USING 3D PRINTER AND LOAD ANALYSIS ON ITS COMPONENTS"** has been carried out by NITIN SANGANA (314126520110), P. HYMANJALI (314126520115), RUMANA (314126520138), P. HARSHANANDAN (314126520123) of Mechanical Engineering, **ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES,** Visakhapatnam during the Year 2017-2018 in partial fulfilment of the requirements for the award of the Degree of Bachelor Of Mechanical Engineering by ANDHRA UNIVERSITY, VISAKHAPATNAM.

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ABSTRACT

The project aims to bring forward a means to transport heavy objects over stairs. The need of such a system is obvious from the day-to-day requirements of our society. Devices such as hand trucks are used to relieve the stress of lifting while on flat ground; however, these devices usually fail when it becomes necessary to negotiate a short flight of stairs. In the light of this, the project attempts to design a stair climbing hand cart which can carry heavy objects up the stairs with less effort compared to carrying them manually. It also endeavours to study the commercial viability and importance of such a product.

Several designs were conceived that would allow a non-industrial hand truck to travel over stairs, curbs, or uneven terrain while putting minimal strain on the user. One strategy, a three-wheel rotating system, was selected for development and several solid models were created and a prototype was constructed. The finished design was tested with a payload of approximately 100 kg, and it was determined that the hand truck design is a viable option for a stair-climbing consumer product.

CHAPTER – 1

INTRODUCTION

1. INTRODUCTION

1.1.1 Rapid Prototyping (RP):

The term rapid prototyping refers to the class of technologies that can automatically construct physical models from computer aided design (CAD) data. The main advantage of the system is that almost any shape can be produced. Time and money savings vary from 50-90% compared to conventional systems. Rapid prototyping techniques are often referred to solid free-from fabrications; computer automated manufacturing or layer manufacturing. The computer model is sliced into thin layers and the part is fabricated by adding layers onto of each layer. Rapid prototyping is a group of techniques used to quickly fabricate a scale model of physical part or assembly using three-dimensional computer aided design data. Construction of a part or assembly is actually done using 3D printing or "additive layer manufacturing" technology.

The first methods of rapid prototyping became available in the 1980's and were used to produce models and prototype parts. Today they are used for a wide range of applications and used to manufacture production-quality parts in relatively small numbers if desired without the typical unfavourable short-run economics. This economy has encouraged online service bureaus. Historical surveys of RP technology start with discussions of simulacra production techniques used in 19^{th} century sculptors. The ability to reproduce designs from a dataset has given rise to issues of rights, as it is now possible to interpolate volumetric data from one dimensional image.

1.1.1.1 Current Techniques and Materials:

A wide range of technologies and materials can be used for rapid prototyping. Commercial techniques are available to produce objects from numerous plastics, metals, and wood-like paper.

Among those some techniques are

*Stereo lithography

*Selective laser sintering

*Fused deposition modelling or fused filament fabrication

*Three dimensional printing

*Laminated objects manufacturing

*Multi jet modelling

*Laser engineered net shaping

1.1.2 Basic Steps Involved In RP:

Basically there are five steps in prototyping technology for development of the prototypes they are given below:

*3D CAD model creation of the parts

*CAD data in a specific file format (STL) is processed and oriented in an optimal build position

*The data is then sent to the RP machine were it is numerically sliced into thin layers

*The RP machine then fabricates each 2D cross-section and bonds it to the previous layer

*A complete prototype is built by stacking layer upon layer until the prototype is completed

*Cleaning and finishing the model. The costs can be reduced because rapid prototyping processes are fully automated and therefore need the skill of individual craftsmen for no more than finishing the part.

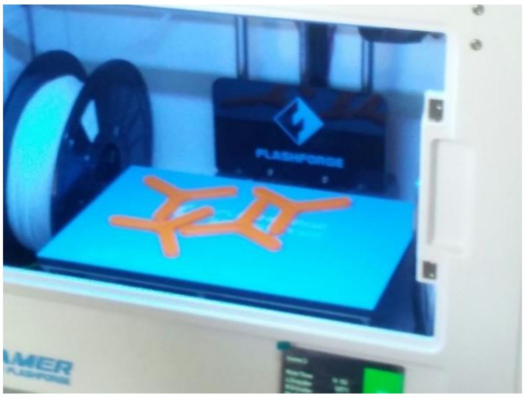


Fig. 1.2.2.1 Rapid Prototyping of Brackets

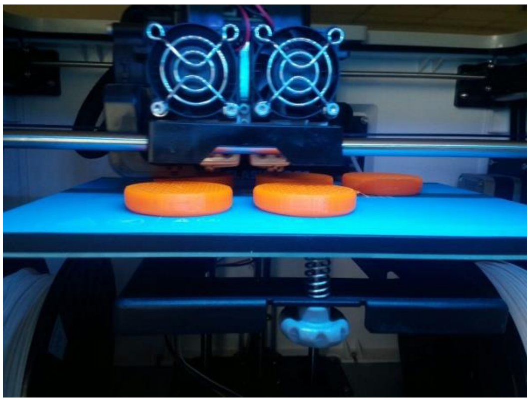


Fig. 1.2.2.2 Rapid Prototyping of Wheels

1.1.3 Applications:

RP technology has potential to reduce time from conception to market up to 10-50percent. It has abilities of enhancing and improving product development while at the same time reducing costs due to major breakthrough in manufacturing. Although poor surface finish limited strength and accuracy are the limitations of RP models, it can deposit a part of any degree of complexity theoretically therefore, RP technologies are successfully used by various industries like aerospace, automotive, jewellery, coin making, tableware, saddletrees, biomedical etc. It is used to fabricate concept models, functional models, patterns for investment and vacuum casting, medical models, models for engineering analysis.

CHAPTER – 2

LITERATURE REVIEW

1. LITERATURE REVIEW

The selection of a staircase climbing trolley is based on the available conditions of their use in field. The best way to fabricate it, is selected on the basis of their performance by carrying out various testing and experimentation on the same. In order to fabricate it, we chose the feasible way of 3D printing to take ahead the manufacturing of the prototype using suitable data from the papers below, which are taken into consideration.

Thierry Rayna, Ludmila Striukova: There is a growing consensus that 3D printing technologies will be one of the next major technological revolutions. While a lot of work has already been carried out has to what these technologies will bring in terms of product and process innovation, little has been done on their impact on business models and business model innovation. Yet, history has shown that technological revolution without adequate business model evolution is a pitfall for many businesses. In the case of 3D printing the matter is further complicated by the fact that adoption of these technologies has occurred in four successive phases (rapid prototyping, rapid tooling, digital manufacturing, and home fabrication) that correspond to a different level of involvement of 3D printing in the production process. This article investigates the effect of each phase on the key business model components. With the impact of rapid prototyping and rapid tooling is found to be limited in extent, direct manufacturing and even more so, home fabrication has the potential to be highly disruptive. While much more value can be created, capturing value can become extremely challenging. Hence, finding a suitable business model is critical. To this respect, this article shows that 3D printing technologies have the potential to change the way business model innovation is carried out, by enabling adaptive business models and by bringing the 'rapid prototyping' paradigm to business model innovation itself.

Mohammad Iqbal, Emir Hidayat Ismail, Ibraahiim Jalil, JunizaMd Saad and Mastura Samsudin: This paper describes the mechanical design and development of tri-star wheel system for surveillance mobile trolley. The trolley will be used to enter potential dangerous disaster site in search of human survivor and to collect some related information for rescue team. Surveillance mobile trolley need to be able to overcome natural and virtual obstacles such as stairs which are the most known obstacles in the collapse buildings. The mechanical design is provided for three main parts of the trolley: the tri-star wheel assembly, the main body of the trolley and the connection shaft between the body sections. Several alternative designs were developed and Pugh's method was used to select the best design. Movement performance is predicted through manual and software simulation by using Solid Work 2009. Base on the result of the simulation study, the design were then improved and the prototype were developed. The studied showed that the tri-star wheel system performs successfully. The climbing task to the standard stair was smoothly provided without any serious problem.

CHAPTER -3
3D PRINTING

3. 3-D PRINTING

3.1 WHAT IS 3-D PRINTING?

3D printing refers to any manufacturing process which additively builds or forms 3D parts in layers from CAD data. The technology is significant because it offers direct manufacturing, meaning a design goes directly from you to physical product through a computer and printer.

3D printing starts with a digital file derived from computer aided design (CAD) software. Once a design is completed, it must then be exported as a standard tessellation language (STL) file, meaning the file is translated into triangulated surfaces and vertices. The STL file then has to be sliced into hundreds – sometimes thousands – of 2-D layers. A 3D printer then reads the 2-D layers as building blocks which it layers one atop the other, thus forming a three dimensional object. All design files, regardless of the 3D printing technology, are sliced into layers before printing. Layer thickness – the size of each individual layer of the sliced design – is determined partly by technology, partly by material, and partly by desired resolution and your project timeline; thicker layers equates to faster builds, thinner layers equate to finer resolution, less visible layer lines and therefore less intensive post-processing work . After a part is sliced, it is oriented for build.

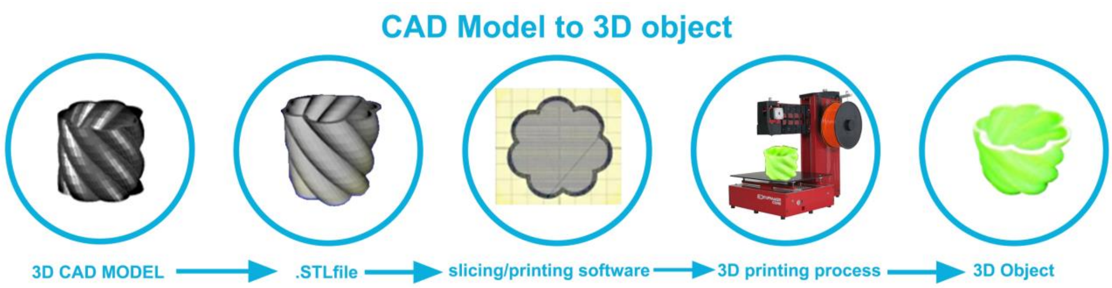


FIG 3.1 CAD MODEL TO 3D PROJECT VIEW

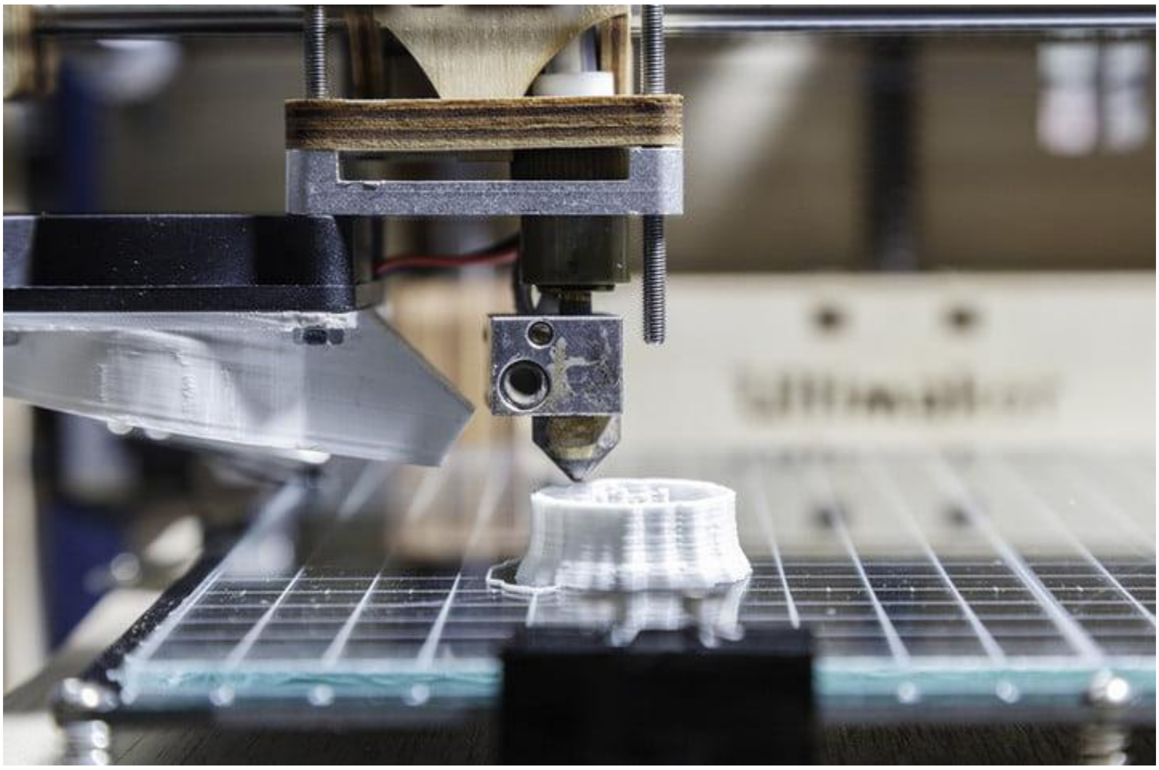


FIG 3.1.2 3D PRINTING SLICING

3.2 WHEN AND WHO CREATED 3D PRINTER?

The earliest 3D printing technologies first became visible in the late 1980’s, at which time they were called Rapid Prototyping (RP) technologies. This is because the processes were originally conceived as a fast and more cost-effective method for creating prototypes for product development within industry. As an interesting aside, the very first patent application for RP technology was filed by a Dr Kodama, in Japan, in May 1980. Unfortunately for Dr Kodama, the full patent specification was subsequently not filed before the one year deadline after the application, which is particularly disastrous considering that he was a patent lawyer! In real terms, however, the origins of 3D printing can be traced back to 1986, when the first patent was issued for stereo lithography apparatus (SLA). This patent belonged to one Charles (Chuck) Hull, who first invented his SLA machine in 1983. Hull went on to co-find 3D Systems Corporation — one of the largest and most prolific organizations operating in the 3D printing sector today.

3D Systems' first commercial RP system, the SLA-1, was introduced in 1987 and following rigorous testing the first of this system was sold in 1988. As is fairly typical with new technology, while SLA can claim to be the first past the starting post, it was not the only RP technology in development at this time, for, in 1987, Carl Deckard, who was working at the University of Texas, filed a patent in the US for the Selective Laser Sintering (SLS) RP process. This patent was issued in 1989 and SLS was later licensed to DTM Inc, which was later acquired by 3D Systems. 1989 was also the year that Scott Crump, a co-founder of Stratasys Inc. filed a patent for Fused Deposition Modelling (FDM) — the proprietary technology that is still held by the company today, but is also the process used by many of the entry-level machines, based on the open source RepRap model, that are prolific today. The FDM patent was issued to Stratasys in 1992. In Europe, 1989 also saw the formation of EOS GmbH in Germany, founded by Hans Langer. After a dalliance with SL processes, EOS' R&D focus was placed heavily on the laser sintering (LS) process, which has continued to go from strength to strength. Today, the EOS systems are recognized around the world for their quality output for industrial prototyping and production applications of 3D printing. EOS sold its first 'Stereos' system in 1990. The company's direct metal laser sintering (DMLS) process resulted from an initial project with a division of Electrolux Finland, which was later acquired by EOS.

Other 3D printing technologies and processes were also emerging during these years, namely Ballistic Particle Manufacturing (BPM) originally patented by William Masters, Laminated Object Manufacturing (LOM) originally patented by Michael Feygin, Solid Ground Curing (SGC) originally patented by Itzchak Pomerantz et al and 'three dimensional printing' (3DP) originally patented by Emanuel Sachs et al. And so the early nineties witnessed a growing number of competing companies in the RP market but only three of the originals remain today — 3D Systems, EOS and Stratasys.

Through out the 1990's and early 2000's a host of new technologies continued to be introduced, still focused wholly on industrial applications and while they were still largely processes for prototyping applications, R&D was also being conducted by the more advanced technology providers for specific tooling, casting and direct manufacturing applications. This saw the emergence of new terminology, namely Rapid Tooling (RT), Rapid Casting and Rapid Manufacturing (RM) respectively.

In terms of commercial operations, Sanders Prototype (later Solidscape) and ZCorporation were set up in 1996, Arcam was established in 1997, Objet Geometries launched in 1998, MCP Technologies (an established vacuum casting OEM) introduced the SLM technology in 2000, EnvisionTec was founded in 2002, ExOne was established in 2005 as a spin-off from the Extrude Hone Corporation and Sciaky Inc was pioneering its own additive process based on its proprietary electron beam welding technology. These companies all served to swell the ranks of Western companies operating across a global market. The terminology had also evolved with a proliferation of manufacturing applications and the accepted umbrella term for all of the processes was Additive Manufacturing (AM). Notably, there were many parallel developments taking place in the Eastern hemisphere. However, these technologies, while significant in themselves and enjoying some local success, did not really impact the global market at that time. During the mid nineties, the sector started to show signs of distinct diversification with two specific areas of emphasis that are much more clearly defined today. First, there was the high end of 3D printing, still very expensive systems, which were geared towards part production for high value, highly engineered, complex parts. This is still ongoing — and growing — but the results are only now really starting to become visible in production applications across the aerospace, automotive, medical and fine jewellery sectors, as years of R&D and qualification are now paying off. A great deal still remains behind closed doors and/or under non-disclosure agreements (NDA). At the other end of the spectrum, some of the 3D printing system manufacturers were developing and advancing 'concept modellers', as they were called at the time. Specifically, these were 3D printers that kept the focus on improving concept development and functional prototyping, that were being developed specifically as office- and user-friendly, cost-effective systems. However, these systems were all still very much for industrial applications.

Looking back, this was really the calm before the storm.

At the lower end of the market — the 3D printers that today are seen as being in the mid range — a price war emerged together with incremental improvements in printing accuracy, speed and materials.

In 2007, the market saw the first system under $10,000 from 3D Systems, but this never quite hit the mark that it was supposed to. This was partly due to the system itself, but also other market influences. The Holy Grail at that time was to get a 3D printer under $5000 — this was seen by many industry insiders, users and commentators as the key to opening up 3D printing technology to a much wider audience. For much of that year, the arrival of the highly-anticipated Desktop Factory — which many predicted would be the fulfilment of that Holy Grail — was heralded as the one to watch. It came to nothing as the organization faltered in the run up to production. Desktop Factory and its leader, Cathy Lewis, were acquired, along with the IP, by 3D Systems in 2008 and all but vanished. As it turned out though, 2007 was actually the year that did mark the turning point for accessible 3D printing technology — even though few realized it at the time — as the RepRap phenomenon took root. Dr Bowyer conceived the RepRap concept of an open source, self-replicating 3D printer as early as 2004, and the seed was germinated in the following years with some heavy slog from his team at Bath, most notably Vik Oliver and Rhys Jones, who developed the concept through to working prototypes of a 3D printer using the deposition process. 2007 was the year the shoots started to show through and this embryonic, open source 3D printing movement started to gain visibility. But it wasn't until January 2009 that the first commercially available 3D printer – in kit form and based on the RepRap concept – was offered for sale. This was the BfB RapMan 3D printer, closely followed by Makerbot Industries. In April the same year, the founders of which were heavily involved in the development of RepRap, until they departed from the Open Source philosophy following extensive investment. Since 2009, a host of similar deposition printers have emerged with marginal unique selling points (USPs) and they continue to do so. The interesting dichotomy here is that, while the RepRap phenomenon has given rise to a whole new sector of commercial, entry-level 3D printers, the ethos of the RepRap community is all about Open Source developments for 3D printing and keeping commercialization at bay.2012 was the year that alternative 3D printing processes were introduced at the entry level of the market. The B9Creator (utilising DLP technology) came first in June, followed by the Form 1 (utilising stereo lithography) in December. Both were launched via the funding site Kickstarter — and both enjoyed huge success. As a result of the market divergence, significant advances at the industrial level with capabilities and applications, dramatic increase in awareness and uptake across a growing maker movement, 2012 was also the year that many different mainstream media channels picked up on the technology. 2013 was a year of significant growth and consolidation. One of the most notable moves was the acquisition of Makerbot by Stratasys. Heralded as the 2nd, 3rd and, sometimes even, 4th Industrial Revolution by some, what cannot be denied is the impact that 3D printing is having on the industrial sector and the huge potential that 3D printing is demonstrating for the future of consumers. What shape that potential will take is still unfolding before us.

3.3 ORIENTATION:

Orientation refers to how and which direction a part is placed on the 3D printing build factor for 3D printing, and can affect material finish and accuracy of 3D print platform. For example, a part may be oriented at an angle, or lying flat/

standing vertical. Similar to CNC machining, orientation factors into the outcome of surfaces and details on a 3D printed part. Because 3D printing builds one 2-D layer at a time, the individual lines appear as ribbed surfaces on parts. Downward facing surfaces usually reveal more layer lines. Certain build orientations are better for curved or square features while delicate features require special consideration. Technologies with higher instances of warp (or material deformation) must account for large flat surfaces during build orientation. It is critical to consider these factors because how a part is oriented determines where supports are added – or needed – within the build.

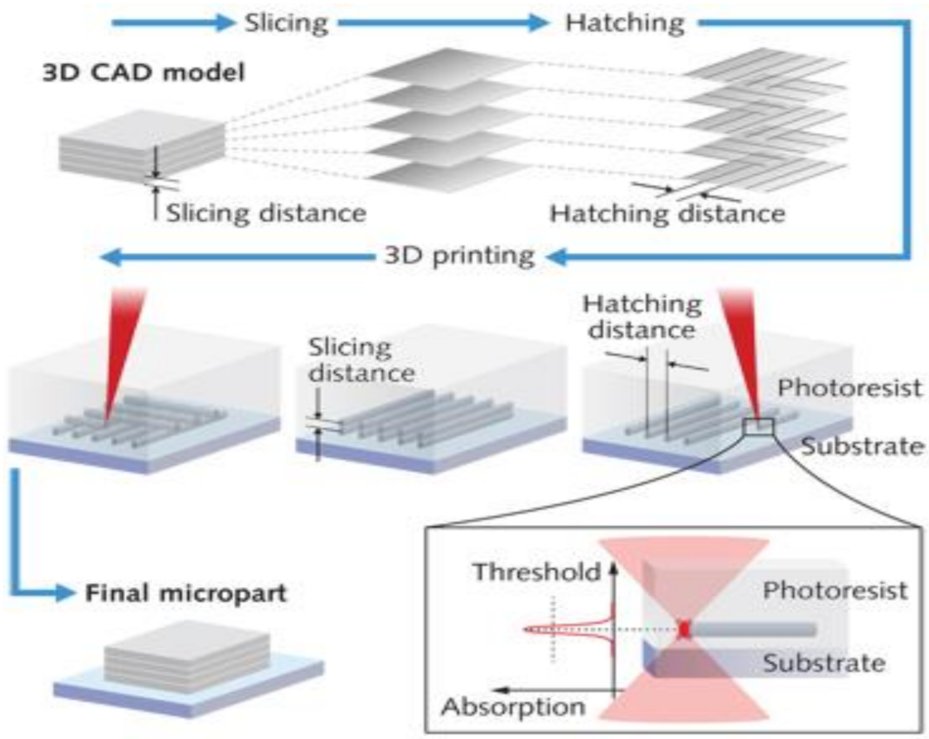


FIG 3.3.1 ORIENTATION OF 3D PRINTING

3.4 HOW DOES 3-D PRINTING WORK?

There are 3 main steps in 3D printing:

1.FIRST STEP: is the preparation just before printing, when you design a 3D file of the object you want to print. This 3D file can be created using CAD software, with a 3D scanner or simply downloaded from an online marketplace. Once you have checked that your 3D file is ready to be printed, you can proceed to the second step.

2. SECOND STEP: is the actual printing process. First, you need to choose which material will best achieve the specific properties required for your object. The variety material will best achieve the specific properties required for your object. The variety of materials used in 3D printing is very broad. It includes plastics, ceramics, resins, metals, sand, textiles, biomaterials, glass, food and even lunar dust! Most of these materials also allow for plenty of finishing options that enable you to achieve the precise design result you had in mind, and some others, like glass for example, are still being developed as 3D printing material and are not easily accessible yet.

3. THIRD STEP: is the finishing process. This step requires specific skills and materials. When the object is first printed, often it cannot be directly used or delivered until it has been sanded, lacquered or painted to complete it as intended.

3.5 DIFFERENT TECHNOLOGIES BASED ON MATERIAL:

The material chosen for the project will determine which printing methods are most suitable. Among these, the most commonly used techniques for each group of materials are described next.

USING PLASTIC AND ALMUNIDE:

1. FUSED DEPOSITION MODELLING TECHNOLOGY: is at the very entry of the market as it mainly used by individuals. It is probably the most popular printing method due to the number of printers available on the market. FDM is an affordable 3D printing process compared to other 3D printing technologies. This process works by material being melted and extruded through a nozzle to 3D print a cross section of an object each layer at a time. The bed lowers for each new layer and this process repeats until the object is completed. Layer thickness determines the quality of the 3D print. Some FDM 3D printers have two or more print heads to print in multiple colours and use support for Overhanging areas of a complex 3D parts.

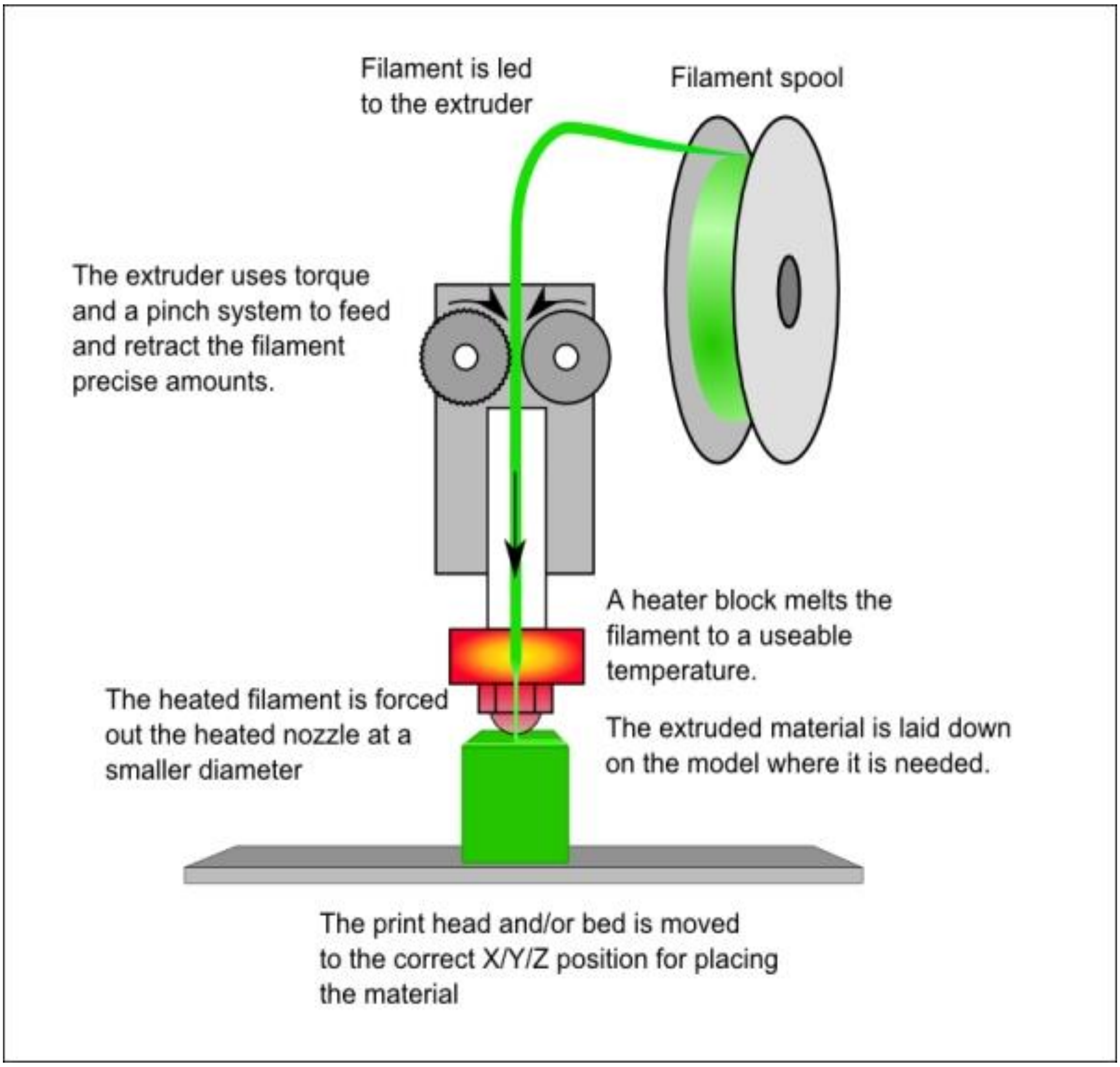


FIG 3.5.1 FDM PRINTER

FDM printers use a thermoplastic filament, which is heated to its melting point and then extruded, layer by layer, to create a three-dimensional object. FDM follows a defined automated process. It builds parts layer-by-layer from bottom up by heating and extruding thermoplastic filament. The process follows three steps:

WORKING OF FDM:

1. **PRE PROCESSING**: This step involves importing design file, picking options

and creating slices (layers). Sections are calculated using the pre-processing software. The part design is sliced into many layers. The software then generates tool paths which drives the extrusion of thermoplastic.

2. PRODUCTION: Two materials one to make the part and other to support it enters the extrusion head. Thermoplastic is heated to a semi-liquid state by 3D printer. It is then deposited in ultra-fine beads along the extrusion path. Removable material is deposited during support which acts as scaffolding.

3. POST PROCESSING: The part is ready to use once the user breaks away support material or dissolve it in detergent and water.

BENEFITS OF FDM:

1. Durable parts with high stability: Supported production-grade thermoplastics are mechanically and environmentally stable as they endure exposure to heat, chemicals, humid or dry environments and mechanical stress.
2. Complex geometries and cavities: Such things were difficult to build on traditional manufacturing methods. Now, soluble support materials can produce complex geometries and cavities.
3. Clean, simple and office-friendly technology
4. Faster Lead Times

APPLICATIONS OF FDM:

1. Prototypes for form, fit and functional testing: FDM components can be used to check fitments in assemblies. Sometimes it can be used for performance tests as well as for engineering assignments. Functional prototype allows you to detect the flaws before it becomes a costly affair. It reduces time to market and enhances product performance.

2. Finished goods: Aerospace companies, medical device makers and limited-production automakers can use FDM to produce finished goods as it reduces time and cost and allows you to make design revisions whenever necessary.

3. Manufacturing tools: Use FDM printers for making jigs, fixtures, gauges, patterns, molds and dies instead of spending time on machining, fabrication, molding or casting as they reduce time and cost for manufacturing tools.

Why it's Significant: FDM uses the same materials aerospace, medical and industrial sectors have relied on from injection molding with the ability to build complex geometries and the lower material consumption associated with 3D printing. Because FDM builds layer by layer, features and multiple components can be combined into one design, minimizing assembly. Undercuts, interior features, attachment fittings are seamlessly incorporated into one part. FDM has become invaluable to sectors requiring lightweight, strong and affordable plastic parts – without the need for hard tooling or machining

2. SLS Technology: Laser sintering is a 3D printing technique consisting of the fabrication of an object by melting successive layers of powder together in order to form an object. The process most notably facilitates in the creation of complex and interlocking forms. It is available for Plastic and Alumide.

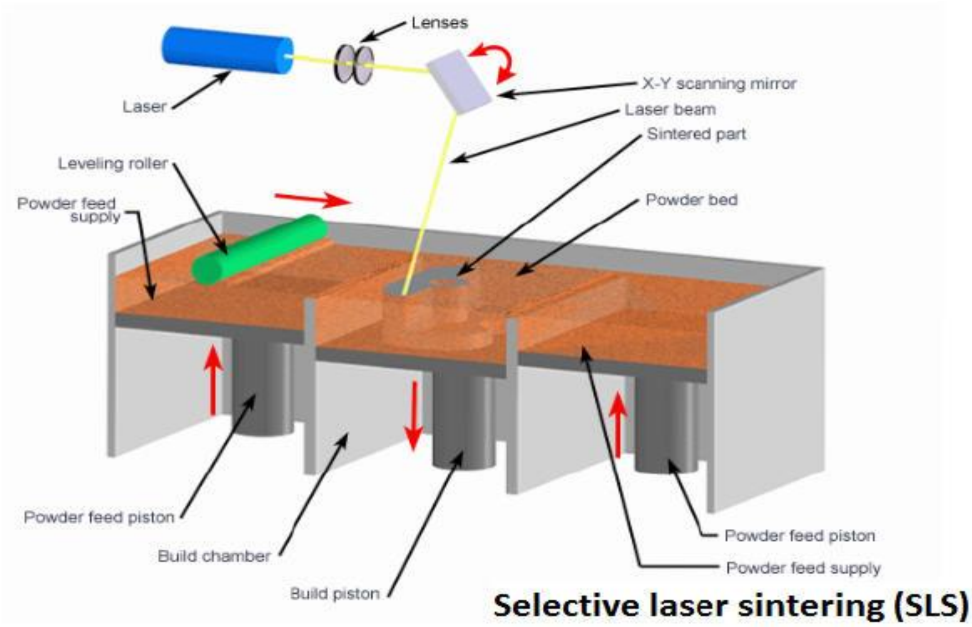


FIG 3.5.2 SLS PRINTER

3. Digital Light Processing (DLP): a projector is used to cure photopolymer resin. This is very similar to the SLA method except that instead of using a UV laser to cure the photopolymer resin, a safelight (light bulb) is used. Objects are created similarly to SLA with the object being either pulled out of the resin, which creates space for the uncured resin at the bottom of the container thus forming the next layer of the object, or down into the tank with the next layer being cured at top.

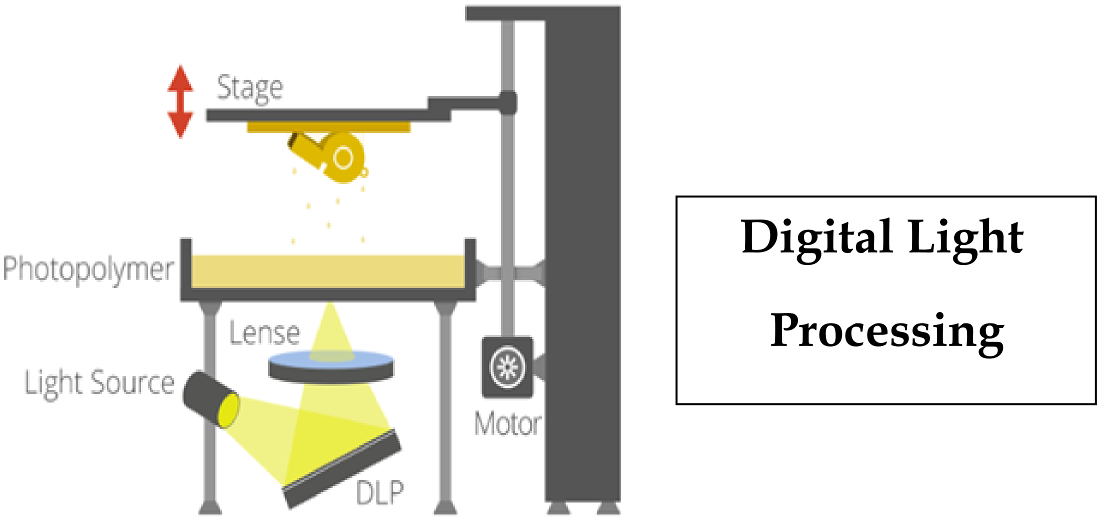


FIG 3.5.3 DLP PRINTER

4. Electron Beam Melting (EBM): uses an electron beam as the power source instead of a laser to 3D print metal. An electron beam melts metal powder layer by layer within a high vacuum and can achieve full melting of the metal powder. This method can produce high-density metal parts thus retaining the material's properties.

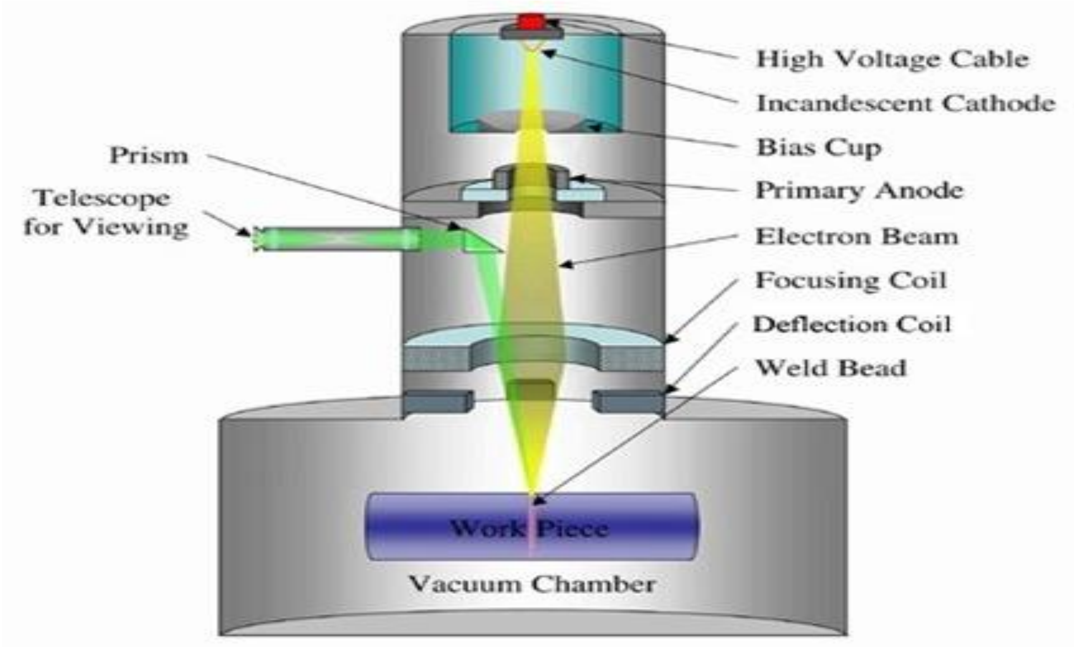


FIG 3.5.4 EBM PRINTER

5. Selective Deposition Lamination: is a 3D printing process using paper. This process is similar to Laminated Object Manufacturing (LOM) rapid prototyping method. The process involves layers of adhesive coated paper (or plastic or metal laminates) that are successively glued together with a heated roller and cut to shape with a laser cutter layer by layer. A roller with the material moves each new sheet of material over the last and repeats the process until the object is completed.

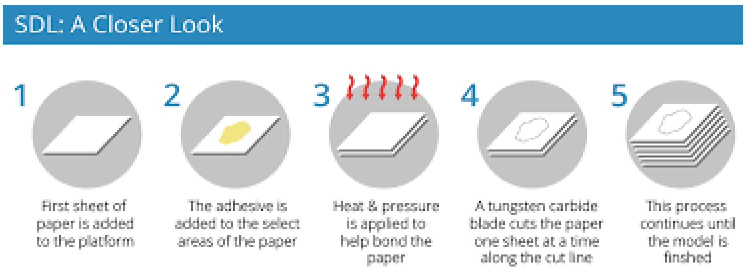


FIG 3.5.5.1 SDL CLOSE OUTLOOK

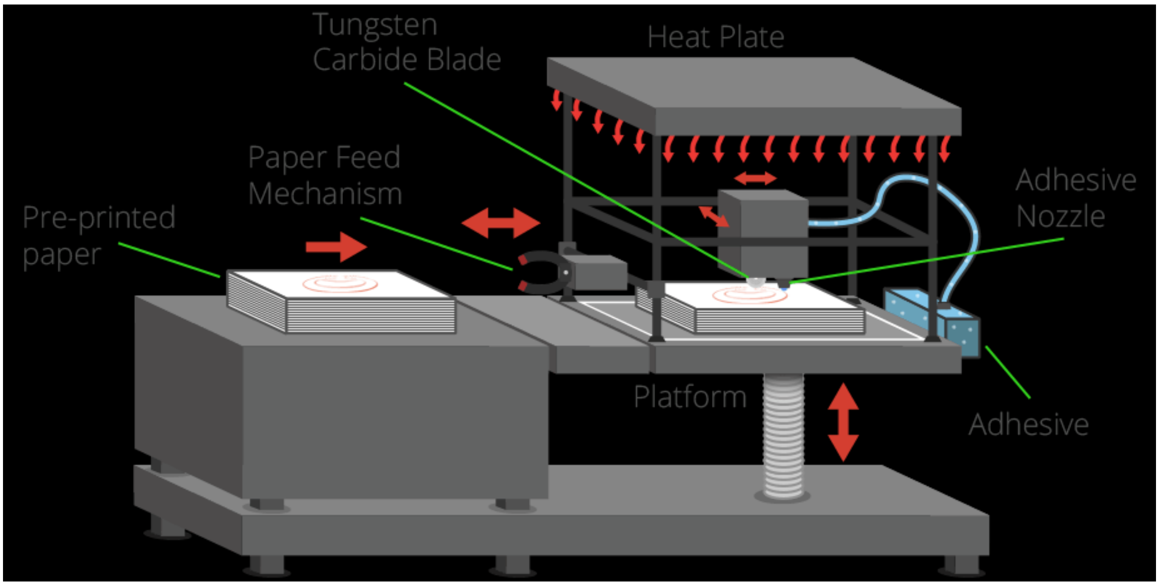


FIG 3.5.5.2 SDL PRINTER

6.Triple-jetting technology (PolyJet): used in Stratasys Objet500 Connex3, is the most advanced method of PolyJet 3D printing. This technology performs precise printing with three materials and thus makes three-colour mixing possible. To know more about this technology, you can refer to PolyJet & Multijet.

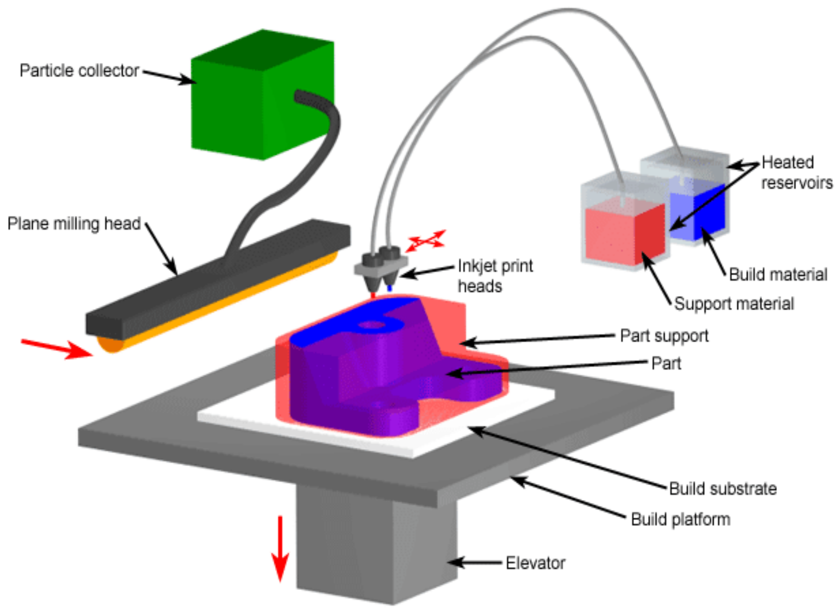


FIG 3.5.6 TRIPLE JET PRINTER

3.6 PRO'S AND CON'S OF 3D PRINTING:

Advantages:

- Customization – A major advantage in 3d printing. With just a raw material, a blueprint and a 3d printer, one can print any design no matter how complex it might be.
- Constant Prototyping and Increased Productivity – It enables quick production with a high number of prototypes or a small-scale version of the real object in less time than using conventional methods. This helps designers to improve their prototypes, for any design flaws that may affect the quality of the product.
- Affordability – The initial cost for setting up a 3d printing facility is definitely high; however, it is much cheaper compared to labor costs and manufacturing costs while using the conventional way. Adding to it, is the fact that the cost of producing or manufacturing products using 3d printing technology is equal for small-scale and mass manufacturing.
- Storage – Traditional manufacturing produces additional products that you probably know you will eventually need thus storage problems arise. However, 3d printing technology, products can be "printed" when needed thus excess products are eliminated and no storage cost is required.
- Employment Opportunities – The widespread use of 3d printing technology will definitely increase the demand for engineers who are needed to design and build these printers. Technicians who are skilled at troubleshooting and maintenance and Designers to design blueprints for products and more jobs will be created.
- Health Care – With the advancement of technology, a customizable human body parts and organs can now be manufactured this technology is termed as Bio-printing. Although right now this is still experimental, the potential is huge. This breakthrough will not only address the shortage of organ donors, but also organ rejection since the organs that are built will consist of the patient's unique characters and DNA

Disadvantages:

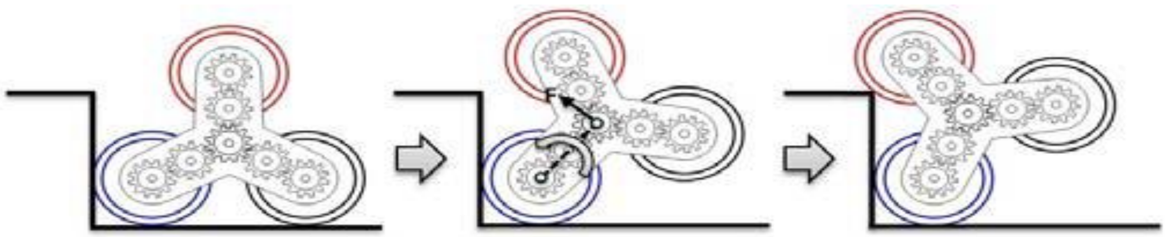
- Decrease in Manufacturing Jobs – The decrease in manufacturing jobs will greatly affect the economy of countries that rely on a large number of low skill jobs.
- Limited Size – The size of objects created with 3d printers is currently limited however, in the near future; large items such as architectural structures can be created using 3d printing.
- Limited Raw Materials – Traditional manufacturing of products has an enormous range of raw materials that can be used. Presently 3d printers can work up to approximately 100 different raw materials and creating products that uses more raw materials are still under development.
- Violation of Copyrights – The biggest disadvantage of 3d printing is Counterfeiting. Anyone who gets a hold of a blueprint will be able to counterfeit products easily. It will become more common and tracing the source of the counterfeited items will be nearly impossible. Many copyright holders will have a hard time protecting their rights and businesses producing unique products will suffer.
- Production of Dangerous Items – With 3d printers, plastic knives, guns and any other hazardous objects can be created. It makes easier for terrorists and criminals bring a weapon without being detected.

CHAPTER – 4
TRI-STAR
WHEEL DESIGN

4. TRI-STAR WHEEL DESIGN

The Tri-Star wheel was designed in 1967 by Robert and John Forsyth of the Lockheed Aircraft Corporation. They were first developed as a module of the Lockheed Terrastar, a commercially unsuccessful amphibious military vehicle. A tri-star wheel functions as an ordinary wheel on flat ground, but has the ability to climb automatically when an impediment to rolling is encountered. This wheel design consists of three tires, each mounted to a separate shaft. These shafts are located at the vertices of an equilateral triangle. The three shafts are geared to a fourth, central shaft (to which a motor may be attached). When geared in this quasi-planetary fashion, these triangular sets of wheels can negotiate many types

FIG 4.1.1 TRI-STAR WHEEL MECHANISM



of terrain, including sand and mud; they can also allow a vehicle to climb over small obstructions such as rocks, holes, and stairs. The wheel assembly may be gear-driven, with two wheels in rolling contact with the ground. The third wheel idles at the top until the lower front wheel hits an obstruction. The obstruction prevents the lower front wheel from moving forward but does not affect the motion of the driving axle. This causes the top wheel to roll forward into position as the new front wheel. This wheel usually lands on top of the obstruction and allows the rest of the assembly to vault over the obstruction. The tri-star wheel design allows relatively smooth ascension of stairs. The assembly functions in a similar fashion to a large wheel with several chunks missing. The compliance of the tri-star is greater than that of an irregular wheel, however, because of the gearing of the tri-star. In most cases, the gearing allows the mechanism to interact only with the horizontal and vertical stair surfaces, avoiding the points and wrapping around each stair. Its weight and cost make the full tri-star system overkill for a simple consumer-grade product; however, tri-star wheels might still be a realistic option if lighter, simpler wheels were to be designed.

4.1 MECHANICAL DESIGN AND DEVELOPMENT OF TRI-STAR WHEEL SYSTEM FOR STAIR CLIMBING TROLLEY:

4.1.1 Introduction:

This project aims to design a stairs climbing trolley using tri star wheel driving system. By using the Solid Works 2013 Education Version software, all the design part been dimensioned using the theoretical formula. The part materials and strength of the materials were predicted by using this software. The mathematical modelling and calculation concept of the tri star wheel have been applied and come up with a successful result. This project deals with the development of a stair climbing trolley with Tri star wheels. The main technical topics have been discuss in this project are; mathematical modelling, mechanical design and fabrication of the trolley. The trolley uses Tri star wheels, which are driven both at the peripheral drive wheels and the centre Tri star, therefore enabling the trolley to climb stairs by rotating the Tri star assembly and to move using the powered peripheral wheels

4.1.2 Project Description:

Nowadays, there are many types of trolley designed which are used to climb a stairs. This project focused on the tri star wheel trolley design. The focuses are more on the tri star wheel design and the gearing drive system. The project was designed and research on the force, gears and some applications (not required programming and electronics section

The mechanical design has been divided into three sections, firstly a design for the tri star wheel assembly, secondly, the main body of the trolley and then, the design of the connection shaft between the body sections. In each of the sections, design features are identified and discussed followed by a mathematical analysis where applicable e.g. analysis of the applied forces requiring resolution and the gearing required within each section. During a design for the tri star wheel in the first phase of the project, the characteristics of the holder were justified. This is the most important parts because the tri star holder determines whether the trolley is able to climb the stairs. The type of driving system used to drive the trolley was also justified in this stage. The main body was designed by considering its purpose as a carrier. Types of material are one of the important things that need to be considered in this project. The autonomous, mechanical design and structure of the trolley are directly restricted for the matter to reduce cost, weight, and improve ergonomics. The tri star is a novel wheel design originally by Lockheedin 1967 in which three wheels are arranged in an upright triangle with two on the ground and one above them, as shown in Figure 1. If either of the wheels in contact with the ground gets stuck, the whole system rotates over the obstruction. A Tri-Star wheel consists of a three spoke-wheel, with 3 leaf wheels on the end of the each spoke, all powered. This means, at rest, each Tri-Star wheel is likely to have two leaf wheels in contact with the ground. On the flat ground, the leaf wheels will simply turn, and give simple and relatively efficient grip.

4.1.3 Project Design

Four main principles - rolling, walking, crawling and jumping - have been identified for full or partial solid state contact. However, additional locomotion principles without solid state contact could be of interest in special environment. Most of the mobile trolleys for planetary exploration will move most of their time on nearly flat surfaces, where rolling motion has its highest efficiency and performance. However, some primitive climbing abilities are required in many cases. Therefore hybrid approaches, where for example rolling motion is combined with stepping, are of high interest. Tri-Star wheel concept has been chosen for specific trolley requirement as project target. The list of target specifications which required in in design guideline are as follow:

-The maximum mass that the trolley can withstand is 100kg.

- The trolley must be able to climb a stairs (4 cm x 5cm) .

4.1.4 Design Selection:

Several reviews have been made to the design in order to choose the best alternative design by using Pugh's method. Base on the Pugh's table, the selection went to the first design for driving system (same gear size) and also the first design for tri star holder (same degree). The reason the characteristics has been selected for the first design is because of the mounting ability, simplicity of construction, size (weight and dimension), cost, speed and power consumption.

Firstly, belting system is decided as the main driving system. For a long term period, the belting will deteriorate and becoming inconvenience. After several discussions, it would be better if the gearing system changes to the tri star wheel driving system. After the characteristics of the project are selected, rough sketching will be provided using the Solid work software and also planned to do the final design and simulations using the Solid work software after the mathematical analysis are completed. In order to create a final/real design, some mathematical models are applied to get the best condition of the characteristics of each part.

4.2 Tri-Star Wheel Design :

Deriving the Tri-Star wheel parameters depends on the position of Tri-Star wheel on stairs. It depends on two parameters, the distance between the edge of wheel on lower stair and the face of the next stair(L1), and the distance between the edge of wheel on topper stair and the face of next stair (L2), as shown in Figure .

By comparing these parameters, three states may occur, as follow:

1. L1 < L2
2. L1 >L2
3. L1 = L2

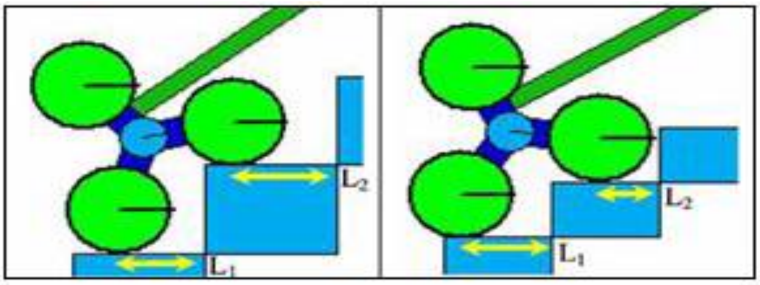


FIG 4.1.2 BASED ON PARAMETERS, DESIGN VARIATION

Based on these states, the third states (L1 = L2) will be used as the reference of project to design the Tri-Star wheel. In this case, the L1 and L2 don't change and remain constant while climbing stairs. Therefore the case (1) and case (2) are not suitable since the trolley will encounter the problems while climbing stairs, but the case (3) is suitable for climbing trolley smoothly. It should be noted that the value of L1 and L2 for derivation of the parameters maybe any values but equal. L1 and L2 are assumed equal to the radius of angular wheel (L1=L2=r).

In the design of Tri-Star wheel, five parameters are important which are the height of the stairs (a), width of stairs (b), radius of regular wheel (r), radius of Tri-Star wheel, the distance between the centre of Tri-Star wheel and the centre of its wheel (R) and the thickness of holders that fix the wheel on its place on Tri-Star wheel (2t), as shown in Figure.

According to the project requirements, the value of (a) and (b) are determined as

a = 4 , b = 5 ;

$$R = \sqrt{\frac{(a^2 + b^2)}{3}}$$

$$R = \sqrt{\frac{16 + 25}{3}}$$

R = 3.696 ≈3.7cm =37mm

The minimum value of the radius of regular wheel (r_{min}) to prevent the collision of the holders to the stairs is derived as follows :

$$r_{min} = \frac{6Rt + a\left(3b - \sqrt{3}a\right)}{\left(3 - \sqrt{3}\,\right)a + \left(3 + \sqrt{3}\,\right)b}$$

$$r_{min} = \frac{6(3.696)(0.5) + 4(15 - \sqrt{12}}{\left(3 - \sqrt{3}\right)4 + \left(3 + \sqrt{3}\,\right)5}$$

$$r_{min} = \frac{57.228}{28.731}$$

$$r_{min} = 19.918mm$$

The maximum value radius of the radius regular wheels (r_{max}) to prevent the collision of the wheels together is :

$$r_{max} = \sqrt{\frac{a^2 + b^2}{2}}$$

$$r_{max} = \sqrt{\frac{16 + 25}{2}}$$

$$r_{max} = 45.2mm$$

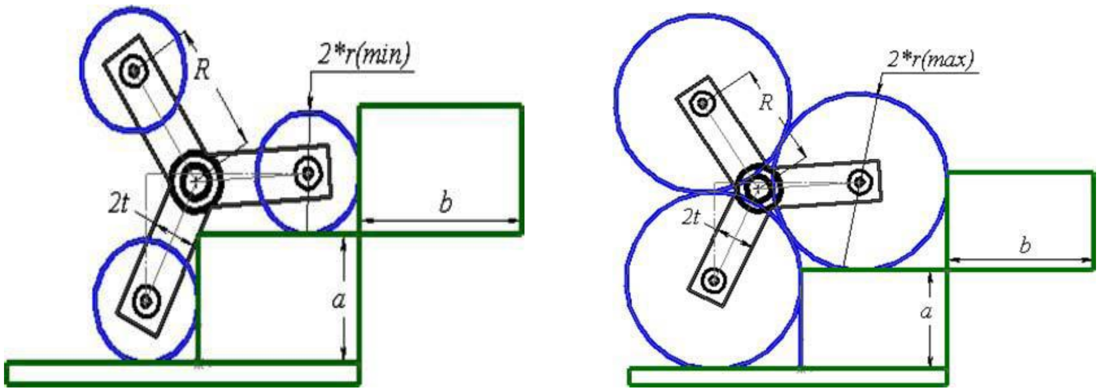


FIG 4.1.3 DESIGNING WHEEL TO AVOID COLLISION (IN TERMS OF RADIUS)

The maximum value of the thickness of holders ($t_{1\,max}$) to avoid the collision between the holders and stairs is derived by :

$$t_{1\,max} = \frac{ar\left(3 - \sqrt{3}\right) + br\left(3 + \sqrt{3}\right) + a\left(\sqrt{3}a - \sqrt{3}b\right)}{6R}$$

$$t_{1\,max} = \frac{(4 * 1)(1.267) + 5(4.732) + (6.92 - 8.66)}{22.2}$$

$$t_{1\,max} = 9.8mm$$

Furthermore, knowing the amounts of r and R, we can derive the maximum height of stairs that the robot can pass through it, as follows :

$$a_{max} = \sqrt{a^2 + b^2 - r^2}$$

$$a_{max} = \sqrt{16 + 25 - 1}$$

$$a_{max} = 63.245mm$$

For traversing the stairs with maximum height derived above, the half thickness of the holder must be in the following range:

$$t_{2\,max} = \frac{r(r + \sqrt{3(a^2 + b^2 - r^2)})}{2\sqrt{a^2 + b^2}}$$

$$t_{2\,max} = \frac{1(1 + \sqrt{3(16 + 25 - 1)})}{2\sqrt{16 + 25}}$$

$$t_{2\,max} = \frac{11.9544}{12.649}$$

$$t_{2\,max} = 9.45mm$$

Regarding to the limit that have been derived for t and the point that $t_{2\,max}$is less than $t_{1\,max}$, and to fulfilled both condition of not colliding of the holder with the stairs and traversing stairs with the maximum height derived before, it is only necessary that the t to be in $t_{2\,max}$.

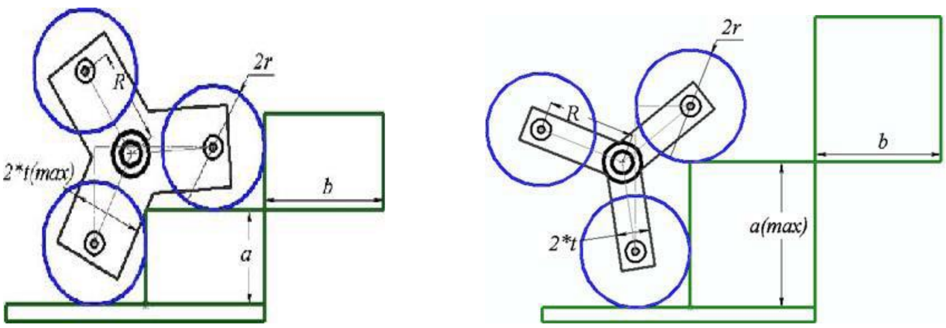


FIG 4.1.4 DESIGNING WHEEL TO AVOID COLLISION (IN TERMS OF THICKNESS)

CHAPTER – 5

PROTOTYPING

5. PROTOTYPING

Modelling can be done in various methods such as wireframe modelling, surface modelling, solid modelling, etc. the easiest way is chosen for modelling. Here we have chosen solid modelling method of creating a solid. There are many packages for modelling, out of which Solidworks has been selected for its ease of availability and as it is user friendly.

5.1 SOLIDWORKS:

Solid Works is a solid modeler, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel. It is published by Dassault Systems. Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

5.2 PART MODELLING:

The parts of staircase climbing trolley are first modeled in Solidworks software in order to fabricate the setup.

The parts of the staircase climbing trolley are as follows:

1) L Body: This comprises of two plates attached to each other with two ribs. FIG 5.1 BASE PLATE
2) Bracket or Tri-star Frame.
3) Wheels.

1) L body:

A) Base plate:

Step 1: Take a new part drawing in Solidworks. Select a plane (ex. Top plane) and press sketch. Draw a rectangle with length of 100mm and breadth of 95mm.

Step 2: Go to features menu and press extruded boss feature and extrude it to a distance of 5mm.

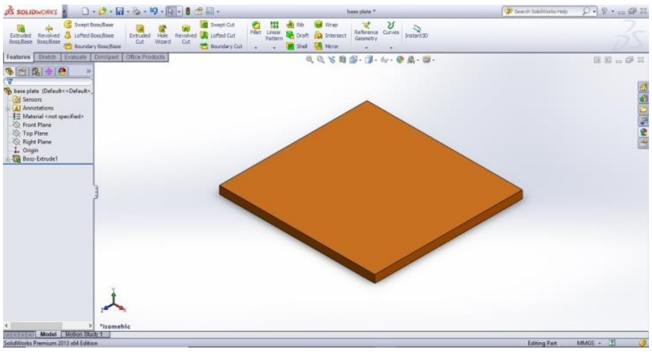


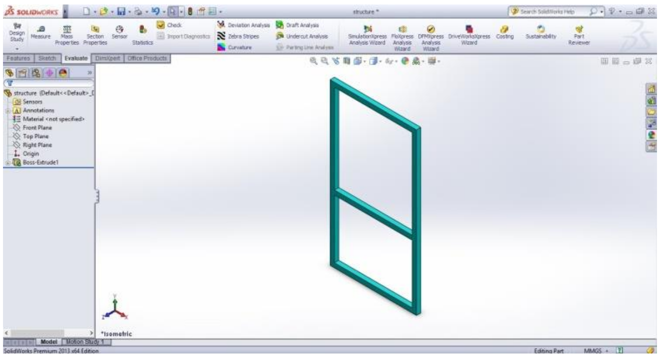
FIG 5.1 BASE PLATE

Step 3: Save the part drawing as a .STL file.

B) Structure:

Step 1: Take a new part drawing in Solidworks. Select a plane (Front plane) and click on sketch. Draw a rectangle with length of 100mm and breadth of 185mm.

Step 2: Go to features menu and press extrude feature and extrude it to a distance of 5mm.

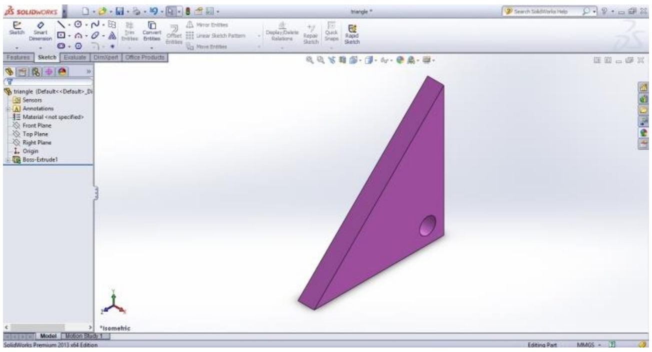


Step 3: Now select one of the face of the plate and sketch two rectangles on that face of the plate, so that borders of inner rectangles are at a distance of 5mm from the outer surface. One rectangle is of length 90mm and breadth 102.5mm and other rectangle whose length is 90mm and breadth is 67.5mm.

Step4: Trim unnecessary portions and use extruded cut feature to create the required shape. Save the part drawing as .STL file.

c) Ribs:

Step 1: Take a new part drawing in Solidworks. Select a plane (Right plane) and click on sketch. Draw two lines from origin perpendicular



to each other. Using smart dimensions, give dimensions to the lines (40mm). Then close the figure to get a triangle. Use extruded boss feature and extrude it to 5mm distance.

Step2: Draw a circle of radius 5mm with its centre at a distance of 7.07mm from the origin at angle of 45 degrees. Using extrude cut feature, remove the circular portion for inserting axle.

Step3: Save the part drawing as .STL file.

The whole part when assembled looks: (L BODY)

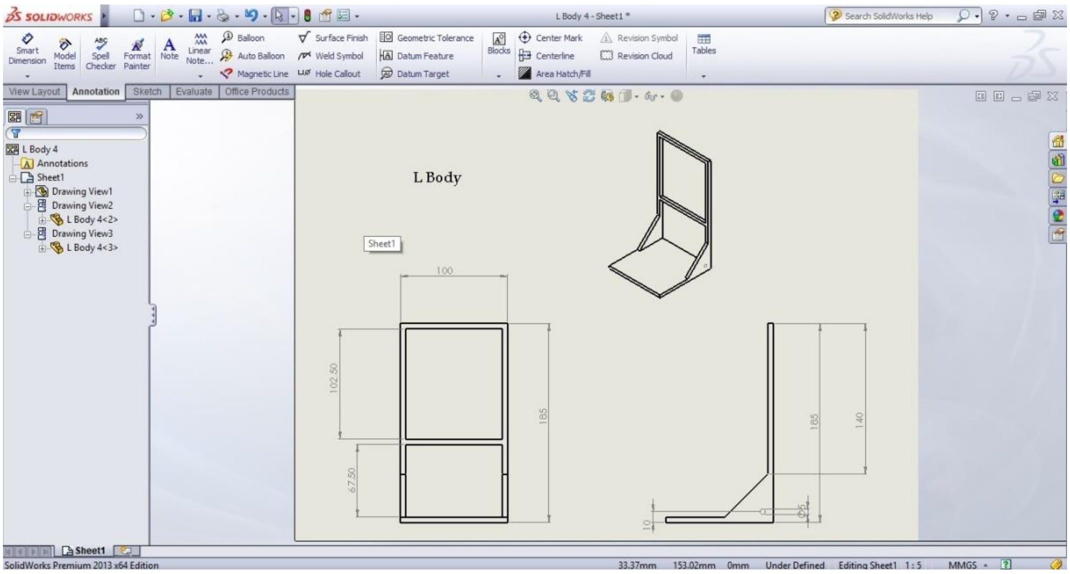


FIG 5.4 L BODY

2) Tri-star frame:

Step 1: Take a new part drawing in Solidworks. Select a plane (Right plane) and click on sketch. First draw two circles, one of diameter 5mm and other 10mm being concentric to each other. Then again draw two more concentric circles of diameter 3mm and 10mm respectively at some distance perpendicularly.

Step2: Draw a line in such a way that it passes through the centre's of the circles. Using smart dimension, give its dimension as 37mm.

Step 3: Then go to circular sketch pattern and arrange 3 circular patterns of the drawing in 360 degrees to get the tri star frame shape. Trim unnecessary portions of the sketch.

Step4: Go to features menu and select extruded boss and extrude it to a distance of 4mm.

Step 5: Save the part drawing as .STL file.

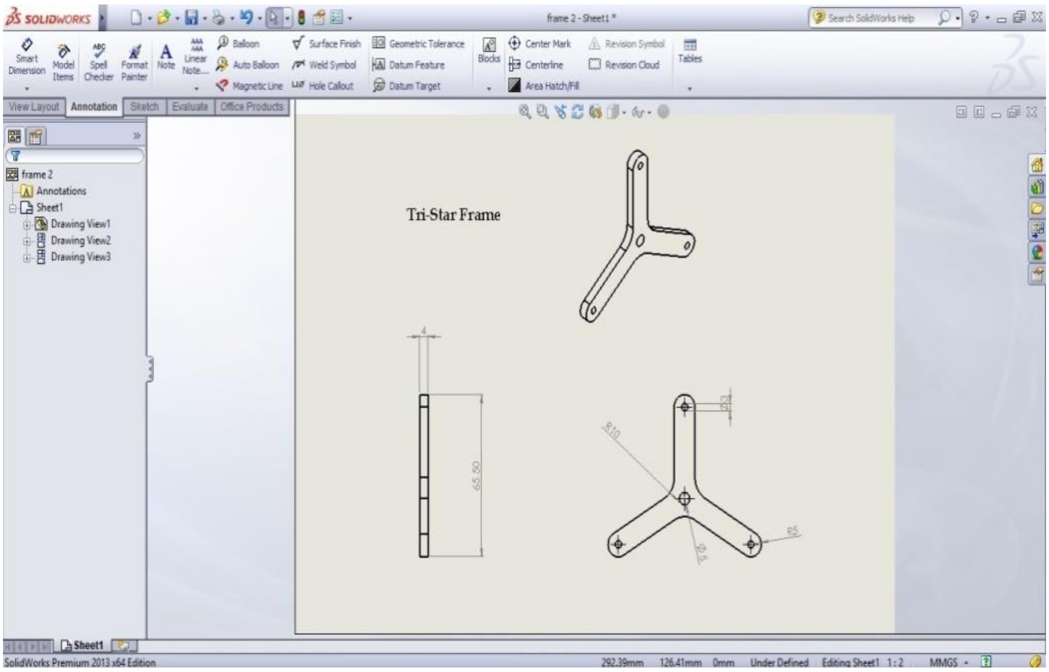


FIG 5.5 TRI STAR FRAME

3) Wheels:

Step1: Take a new part drawing in Solidworks. Select a plane (Right plane) and click on sketch. Draw two concentric circles about origin with diameters of 3mm and 45mm respectively. (Use smart dimensions for dimensioning).

Step 2: Exit from the sketch and go to features menu, use extruded boss feature, and extrude it to a distance of 10mm.

Step3: Save the part drawing as a .STL file.

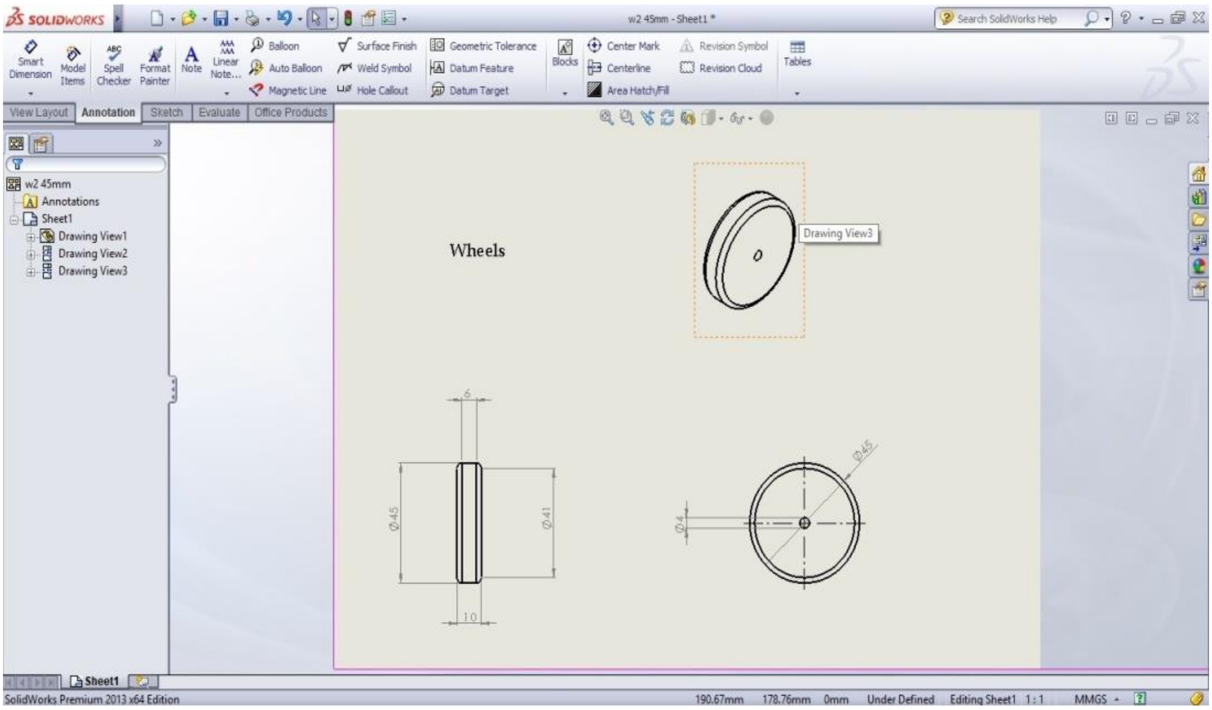


FIG 5.6 WHEELS

5.3 ASSEMBLY MODELLING:

The assembly of the parts is done with proper constraints in the following manner:
Step1: Import the base part first (i.e.L body) and fixing it.
Step2: Import all the other parts (Tri-star frame and wheels) and assemble them with various constraints to planes and features like mate, insert, etc.

Step3: Save the file with desired file name.

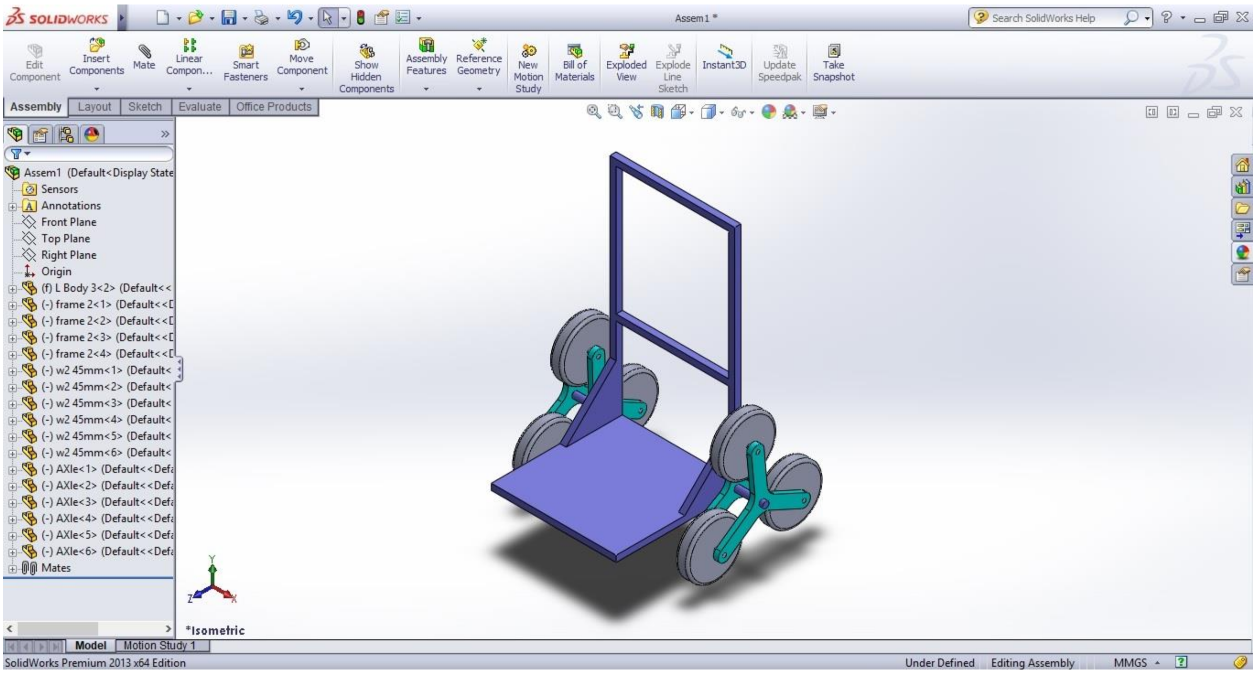


FIG 5.7 ASSEMBLY MODELLING

CHAPTER-6

ANALYSIS

6. ANALYSIS

6.1 ANALYSIS INTRODUCTION:

The modelling of the actual model has been carried out by the designs made in Solidworks and imported into Ansys Workbench 15.0.

The dimensions carried out in it have been calculated manually with the empirical theoretical formulae based on the strength of materials.

The final results have been then considered into the design by taking into considerations the availability of standard specifications of the components.

Besides we took in the two materials to carry out the analysis on the most commonly used types of M.S namely ASTM A 36 and AISI 1018. Their respective strengths and young's modulus have been taken into consideration to carry out the calculations determining their approximate dimensions required to build the prototype.

In this project two main components have to be designed:

1. AXLE
2. TRI-STAR FRAME

6.2 AXLE:

As in the title itself it is said that, this design work is carrying to make a structure which can with stand 100 kgs or 981 N load.

Here, we have considered two type of materials:

ASTM A 36		AISI 1018	
Density	7.85 g/cc	Density	7.87 g/cc
Young's Modulus	200 GPa	Young's Modulus	205 GPa
Poisson Ratio	0.26	Poisson Ratio	0.29
Yield Strength	250 MPa	Yield Strength	370 MPa
Ultimate Strength	500 MPa	Ultimate Strength	440 MPa

FIG 6.1 COMPARISON BETWEEN ASTMA36 AND AISI 1018

Now, finding of shaft/axle diameter:

We know the Bending Equation is: E/R = M/I = F/Y

Clearly,

Young's Modulus/Radius of Curvature = E/R

Bending Moment/Moment of Inertia = M/I

Bending Stress/Distance of Outer fiber from center =F/Y

Here,

Load, P = 100 kgs or 981 N

Length of Axle = 800 mm

After Manual calculation:

Reaction at A = 490.5 N

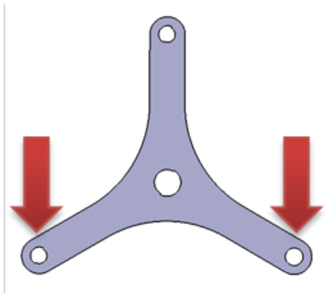
Reaction at B = 490.5 N

Max. Moment, M = 196200 N-mm

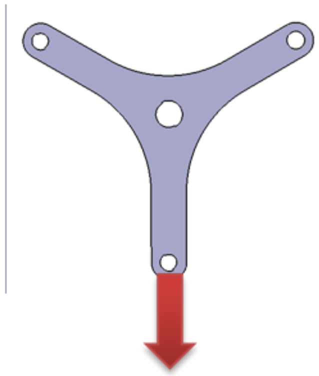
6.3 TRISTAR FRAME:

As in the title itself it is said that, this design work is carrying to make a structure which can with stand 100 kgs or 981 N load.

This frame is modeled and analyzed in ANSYS WORKBENCH 16, where we found the stress generated and compared with the yield stress of selected material, if the analyzed value is less than the yield strength, and then the design is safe.



(FIG 6.2.1.1 WHEN ON FLAT SURFACE)



(FIG 6.2.1.2 ON STAIRS)

For that, we took two case in this frame design:

1. When the frame is moving on flat surface
2. When the frame is moving on stairs

In case one, two-arms of the Tri-Star frame are downwards and the load will be shared by both of them. Pressure acts in the middle that too bottom portion.

For this we need to find pressure:

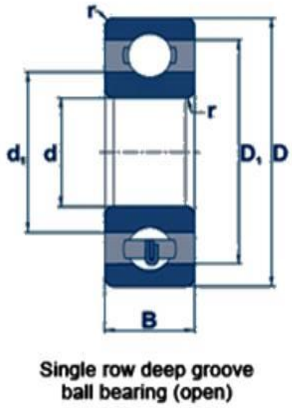
Pressure, pr = Force/Area = P/ (pi*r*thickness)

Here, thickness is considered as 12 mm (According to Bearings availability, will discuss later)

Pr = 981/ (pi*(28/2)*12) = 1.1073 N/mm^2 or Pa

[HERE, ONLY ONE MATERIAL IS CONSIDERED & SO DIAMETER WON'T CHANGE]

[EVEN THOUGH THE ENTIRE LOAD GETS DIVIDED TWO FOUR WHEELS, WE CONSIDERED IT AS 981 N INTENTIONALLY TO TEST THE STRENGTH OF THE FRAME]



Through Selected parameters, this Single Row Deep Groove Ball Bearing will fit in the Tri-Star frame:

Outside Diameter = 47 mm

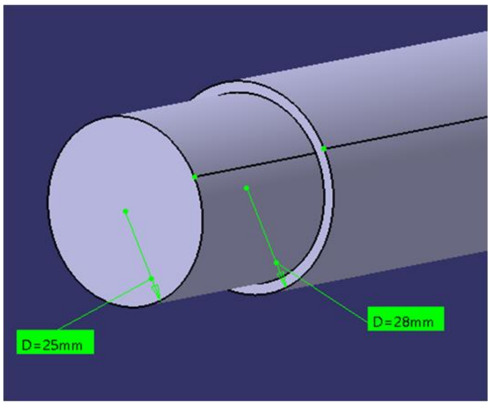
Inside Diameter = 25 mm

Width of Bearing = 12 mm

Static Load Rating = 5850 N

Dynamic Load Rating = 10100 N

FIG 6.2.2 SINGLE ROW DEEP GROOVE BALL BEARING



If we remember this,

Standard sizes available in market are (in mm) – 20, 22, 25, 28, 30, 32 etc.

So, for availability purpose for ASTM A36 material, d = 28 mm (considered)

And for availability purpose for AISI 1018 material, d = 25 mm (considered)

For ASTM A 36, we have chosen 28 mm Axle, because it has to fit in the bearing, the ends of the axle are trimmed to 25mm, as shown here:

6.4 ANALYSIS ON AXLE USING ANSYS:

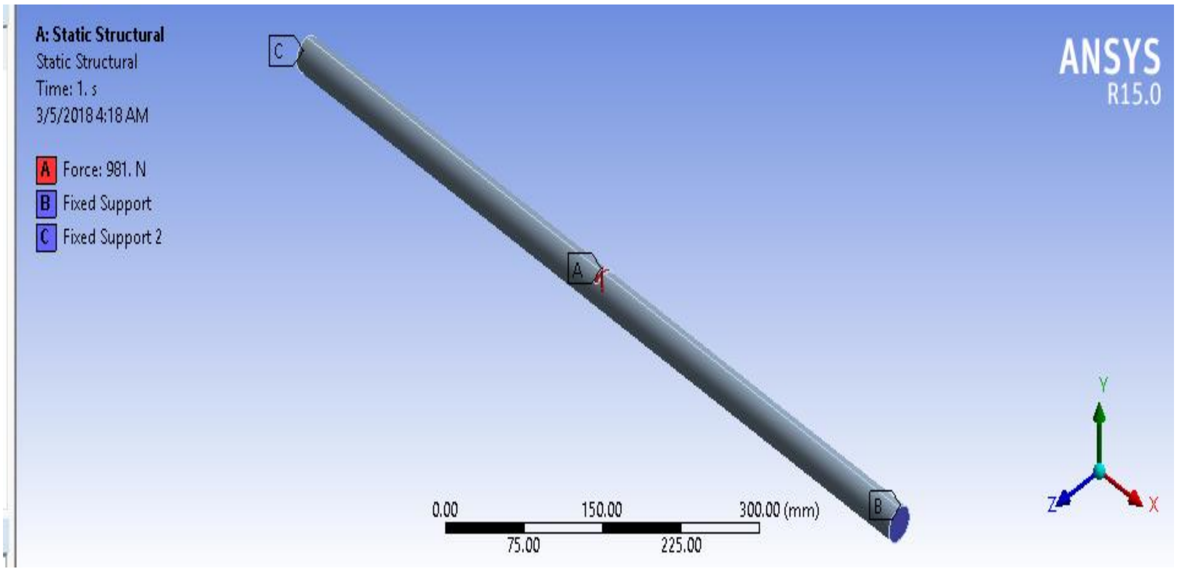


FIG 6.3 GEOMETRY OF THE AXLE AND ITS CONSTRAINTS

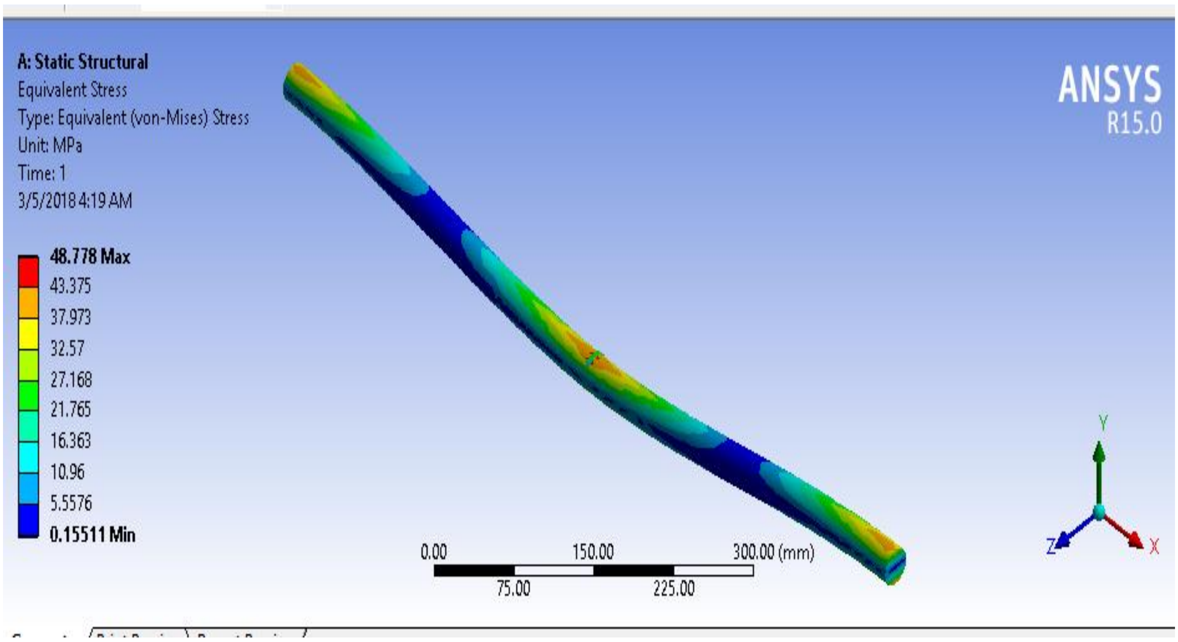


FIG 6.3.1 EQUIVALENT STRESS DISTRIBUTION ON AXLE

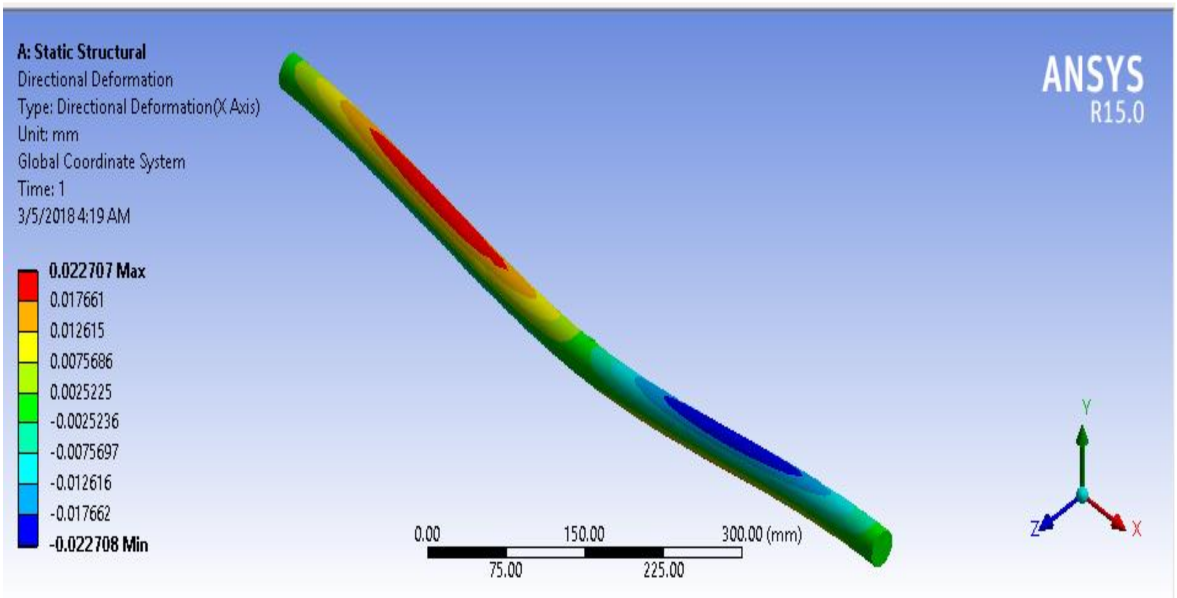
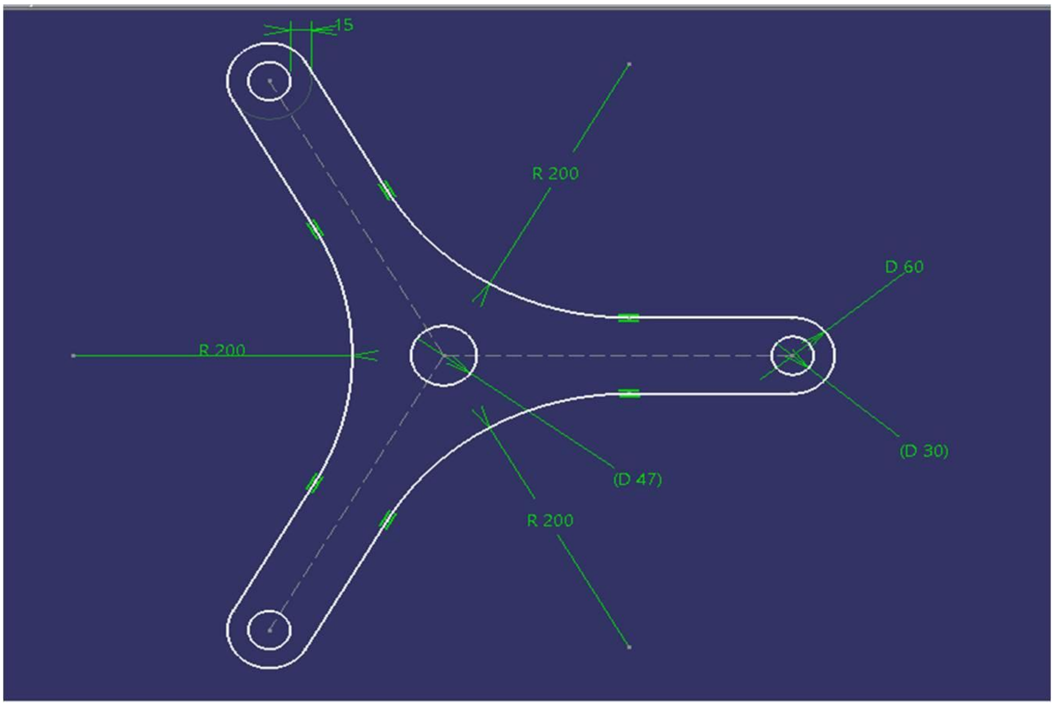


FIG 6.3.2 DIRECT DEFORMATION ON AXLE

6.5 TRI STAR FRAME GEOMETRY:



6.6 TRI STAR FRAME ANALYSIS ON FLAT SURFACE:

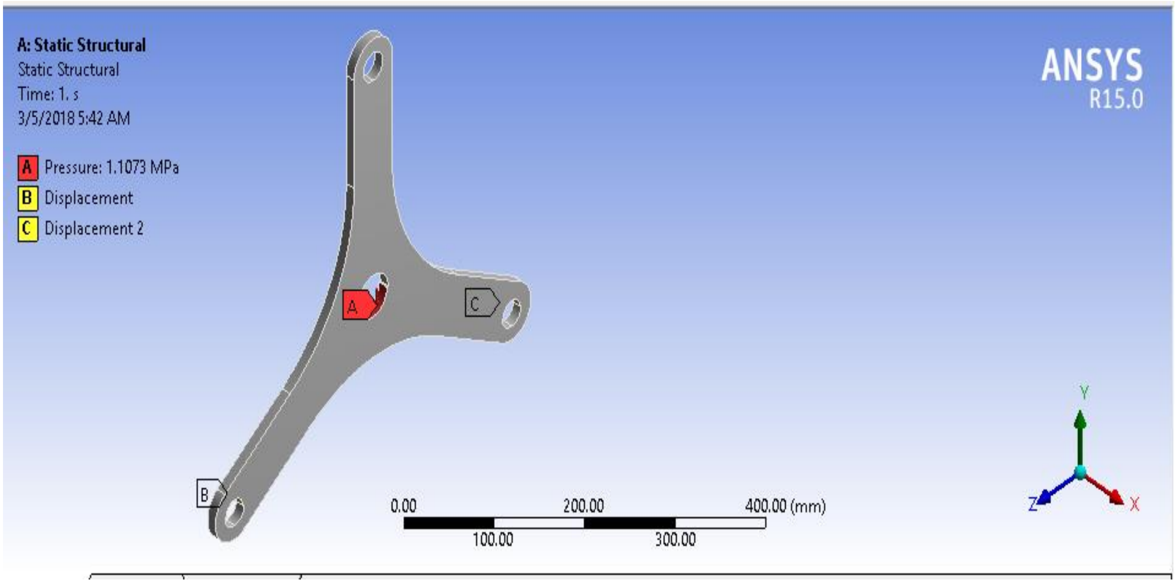


FIG 6.4.1 GEOMETRY AND CONSTRAINTS OF TRI STAR FRAME MOVING ON FLAT SURFACE

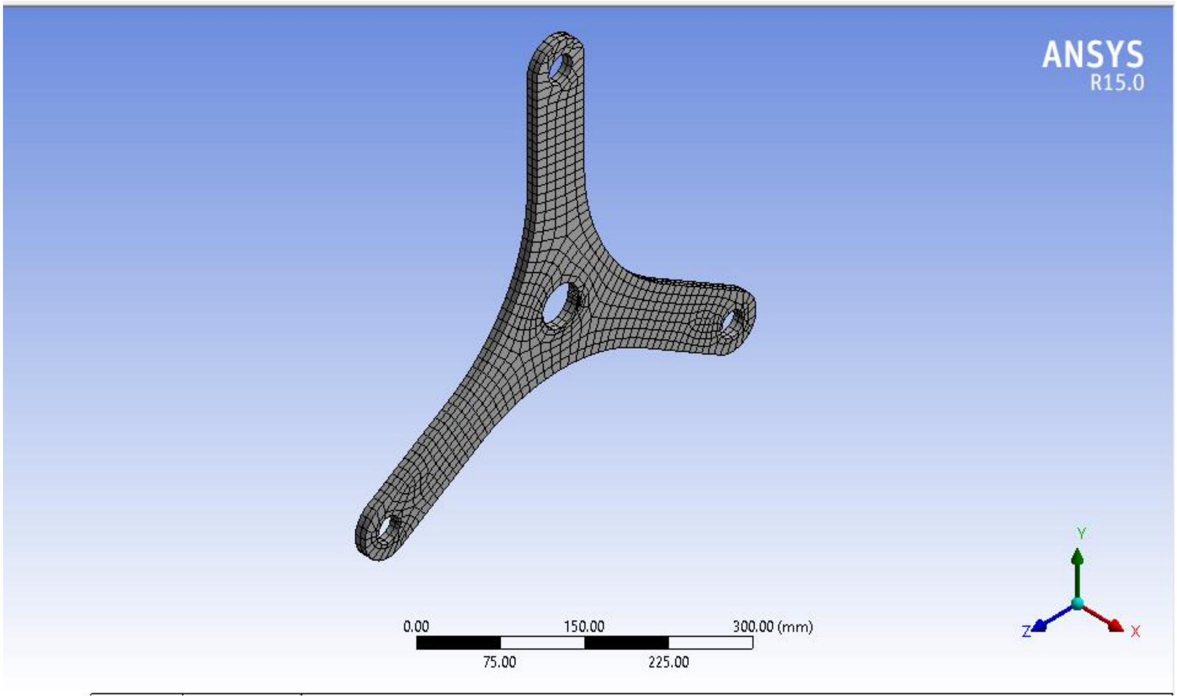


FIG 6.4.2 MESHING OF TRI STAR FRAME

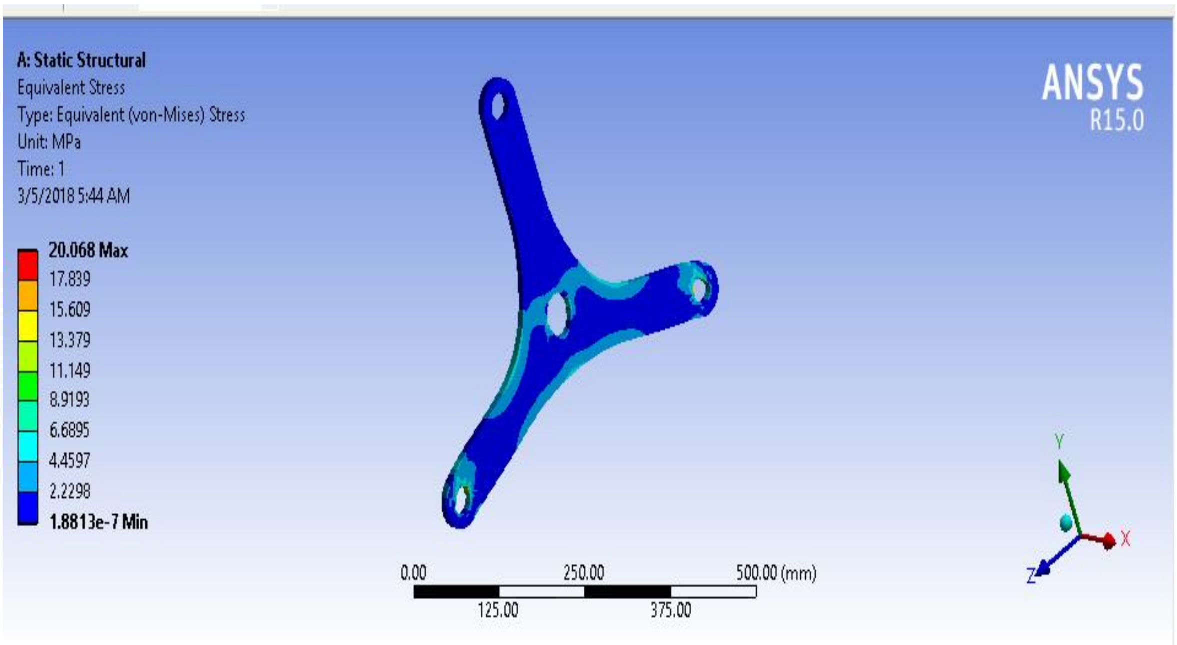


FIG 6.4.3 EQUIVALENT STRESS DISTRIBUTION ON TRI STAR FRAME

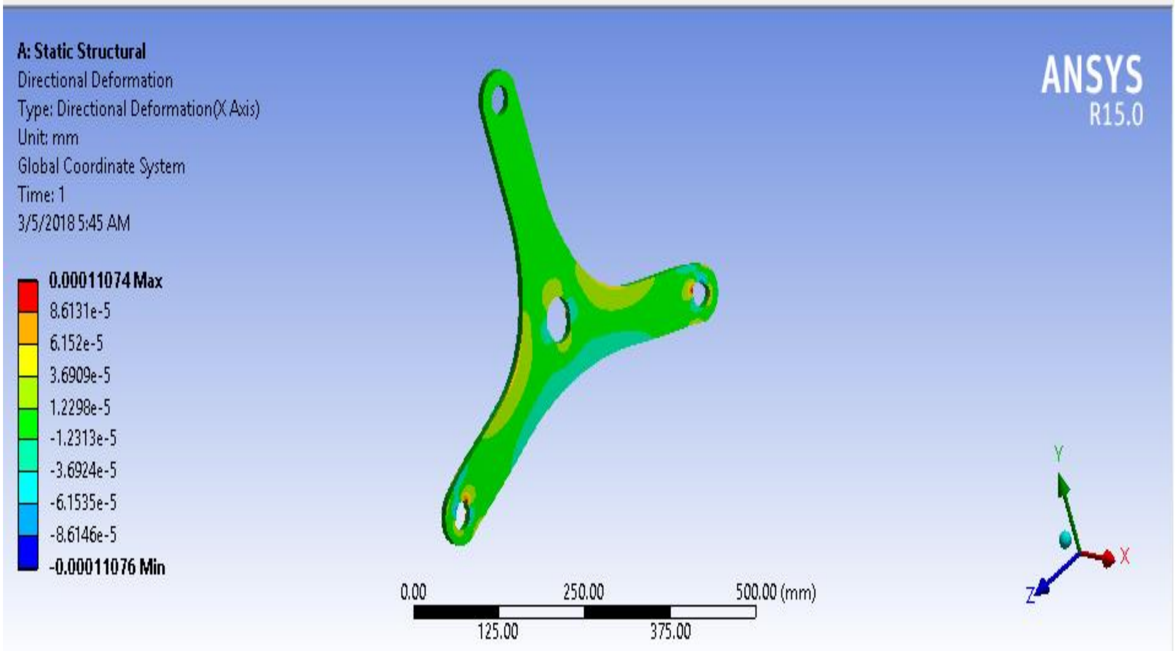


FIG 6.4.4 DIRECTIONAL DEFORMATION ON TRI STAR FRAME

6.7 TRI STAR FRAME ANALYSIS WHILE MOVING ON STAIRS:

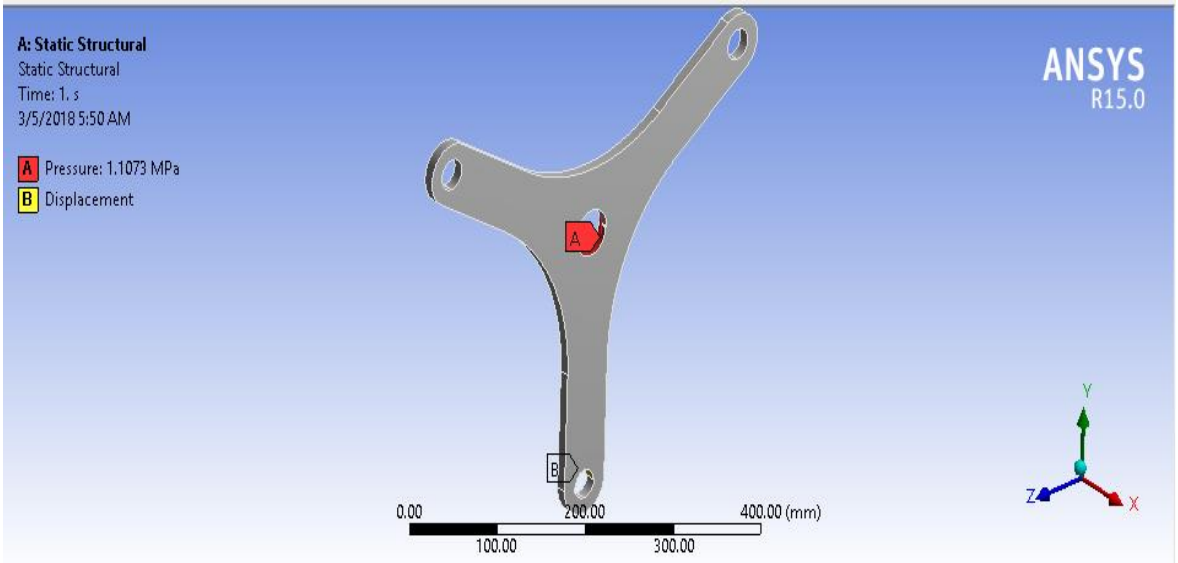


FIG 6.5.1 GEOMETRY AND CONSTRAINTS OF TRI STAR FRAME MOVING ON STAIRS

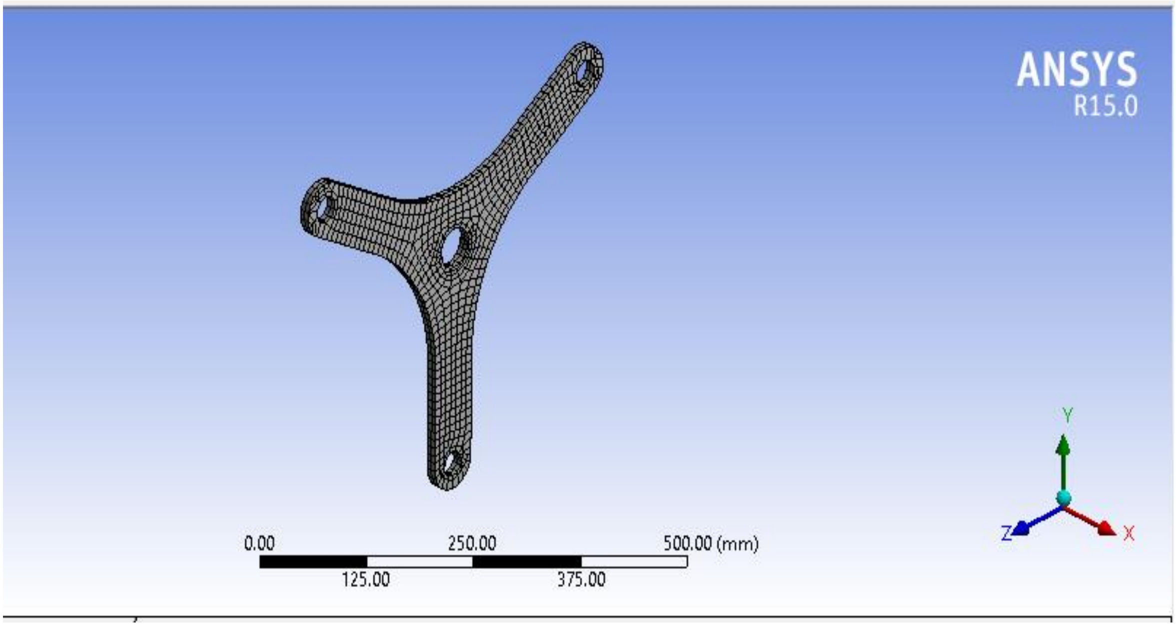


FIG 6.5.2 MESHING OF TRI STAR FRAME ON STAIRS

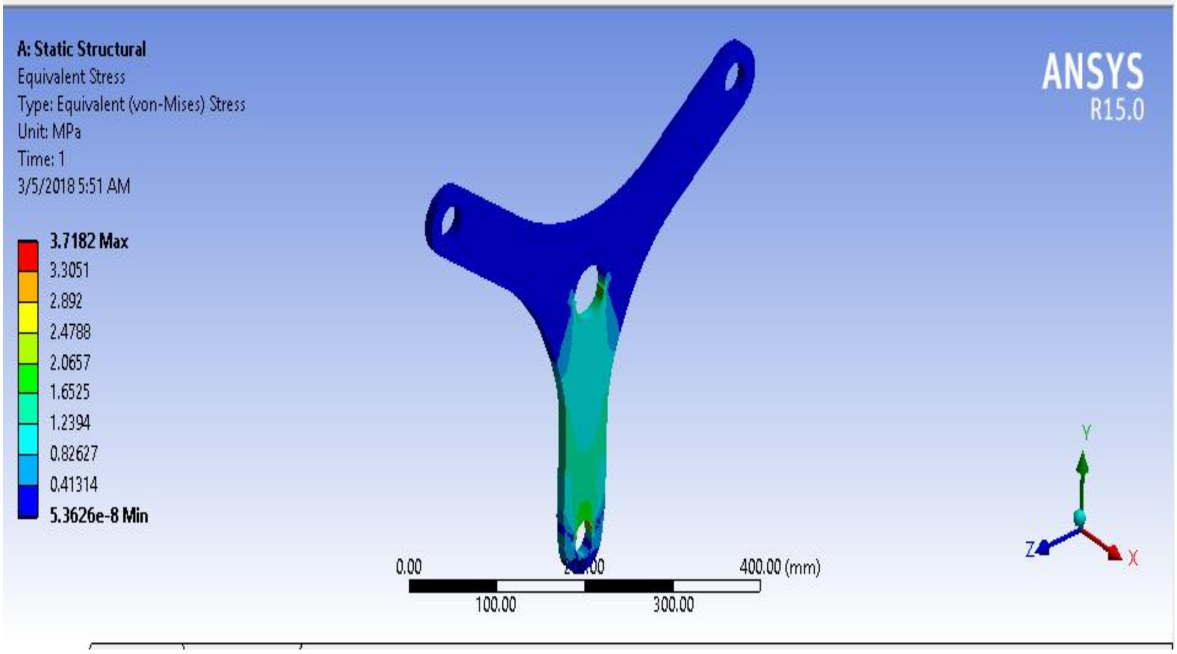


FIG 6.5.3 EQUIVALENT STRESS DISTRIBUTION ON TRI STAR FRAME (MOVING ON STAIRS)

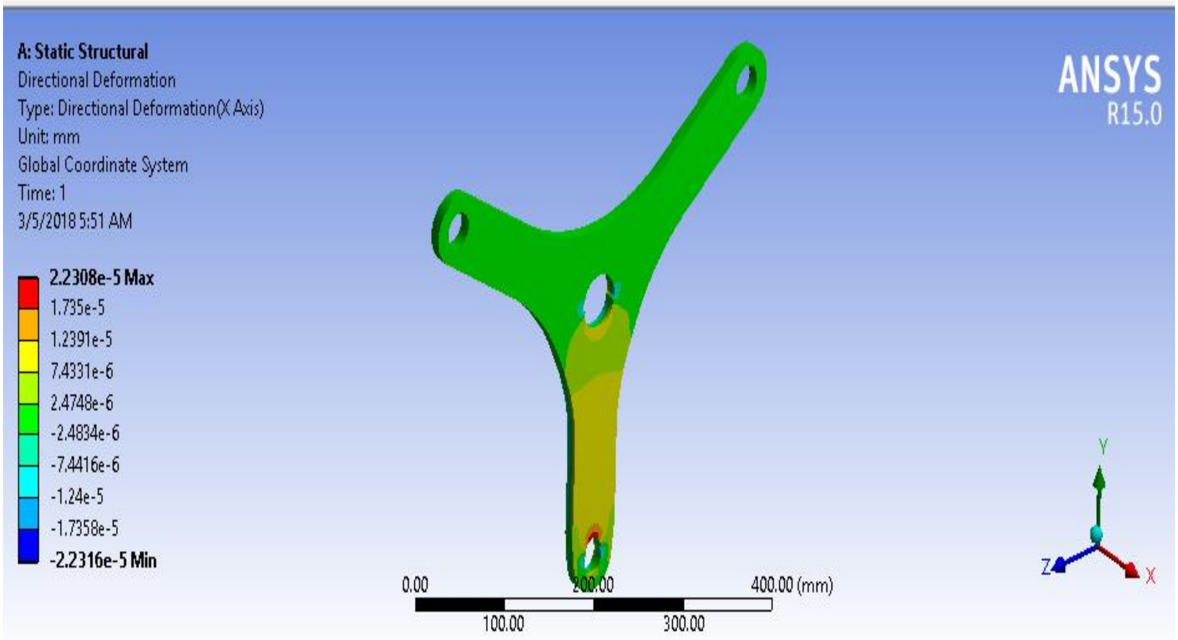


FIG 6.5.4 DIRECTIONAL DEFORMATION ON TRI STAR FRAME (MOVING ON STAIRS)

CHAPTER-7

FABRICATION OF STAIRCASE CLIMBING TROLLEY

7. FABRICATION OF STAIRCASE CLIMBING TROLLEY

The staircase climbing trolley parts are converted into .STL files for rapid prototyping. There are many rapid prototyping methods available in the market. The cost effective one is the fused filament fabrication (FFF). The machine used for the fabrication is Flash-Forge Dreamer dual extruder.

7.1 FUSED FILAMENT FABRICATION:

FFF (fused filament fabrication) is an additive manufacturing technology. A fused filament fabrication tool deposits a filament of a material (such as plastic, wax or metal) on top or alongside the same material, making a joint (by heat or adhesion). The rapid prototype machine used here is the Flash Forge Dreamer Dual Extruder, any FFF based RP machine contains these common parts, materials and terms as below.

7.2 Flash Forge Dreamer Dual Extruder Details:

- **Extruder:** The extruder on a FDM printer is the part that extrudes the plastic filament in a liquid form and deposits it on a printing platform by adding successive layers. The printing head is made of many distinct parts including a motor to drive the plastic filament and a nozzle (or extruder) to extrude the plastic. To regulate the plastic cooling process, some printers are enclosed. This helps maintain a uniform temperature in the manufacturing chamber, ensuring greater consistency in the print result.
- **Nozzle:** The actual hole where melted FFF material is extruded is the nozzle. Typical nozzle sizes are in the 0.5mm to 0.25mm range, although larger nozzles are sometimes used to fill in (infill) the interior of a model more quickly, and smaller nozzles are sometimes used for more detail. The smaller your nozzle, the more pressure is needed to extrude the material, the slower your print speed will be, and the more likely it is to get plugged.

- **Thermocouple:** A temperature sensor typically used on both the hot end (nozzle) of the printer and a heated print bed so that the electronics can maintain a consistent temperature.
- **Stepper/ Step motor**: The Stepper or step motor is a very precise motor that moves the extruder along its coordinates.
- **Print Bed/Printer bed**: The print bed is where you finished the project / product will end up. Normally the size of a 3D printers Print bed and the maximum range of motion for the length(Y- axis), width(X-axis) and height(z-axis) of the printer is a pretty good indication to the size of the largest object you can print with that printer at one time. The size of the Print bed is commonly referred to as the print volume. The print Bed moves up and down along the z-axis to adjust the height of the object being printed while the extruder moves along the x and y- axes.
- **Guide way**/Guide rods: It is the track rod that allows the Extruder of your 3D printer to move along its axes. The vertical /z-axis rod is usually indistinguishable from part of the frame.
- **LCD Screen:** An LCD screen is/can be added to many 3D printers which allow your printer to provide you information, such as the current Extruder temperature, without the use/need of a computer.
- **Fused Deposition Modelling (FDM) :** A trademarked term used by the Stratasys corporation, equivalent to FFF which describe the process of manufacturing an object by melting a filament of material and laying down molten material which immediately solidifies (fusing to previous layers) under programmatic control. Objects built up layer by layer.
- **Slicer:** Perimeter defines minimum number of vertical shells (i.e. walls) a print will have. Unless the model requires single width walls it is generally recommended to have a minimum of two perimeters as this gives some insurance that if a section of the perimeter is not printed correctly then the second perimeter will help cover it.
- **Infill:** Fill density is defined on a scale of between 0 and 1, where 1 is 100 % and 0.4 would be 40%. For the majority of cases it makes no sense to 100% fill the

model with plastic, this would be a waste of material and a take a long time. Instead, most models can be filled with less material which is then sandwiched between layers filled at 100%.

- **Support:** Because printed objects or built at one layer at a time having an overhung is problematic, as plastic would need to be printed unsupported in open air. Support material is material that is not part of the finished object, but it is printed under “overhangs “so that the plastic for the object being printed will have something to rest upon.
  Dual Extruder or sometimes multi Extruder printers can use a different (presumable, easier to remove or dissolvable) material in separate Extruder.
- **Skirt:** Extra material printed around the base of an object, typically to prime the Extruder and test the levelling and distance to the print bed. If the skirt is not adhering to the print bed properly, the print can be aborted in the z-axis height or print bed heater can be adjusted. In advance operations, skirts can also be made more than one layer thick, which can be useful to shield an object from drafts while it is been printed.
- **Brim:** Extra material printed touching the base of an object on the first layer to increase the surface area of the bottom layer, to promote adhesion to the print bed. Typically used for small objects or tall objects. After the printing is completed the brim is filed.
- **Raft:** A bed of printed material that is several layers thick is printed on the print bed under the object.
  The raft can act like a brim (increasing the surface area of the object to the print bed) as well as compensating for minor levelling problems of the print bed, but must be removed from the object after printing.

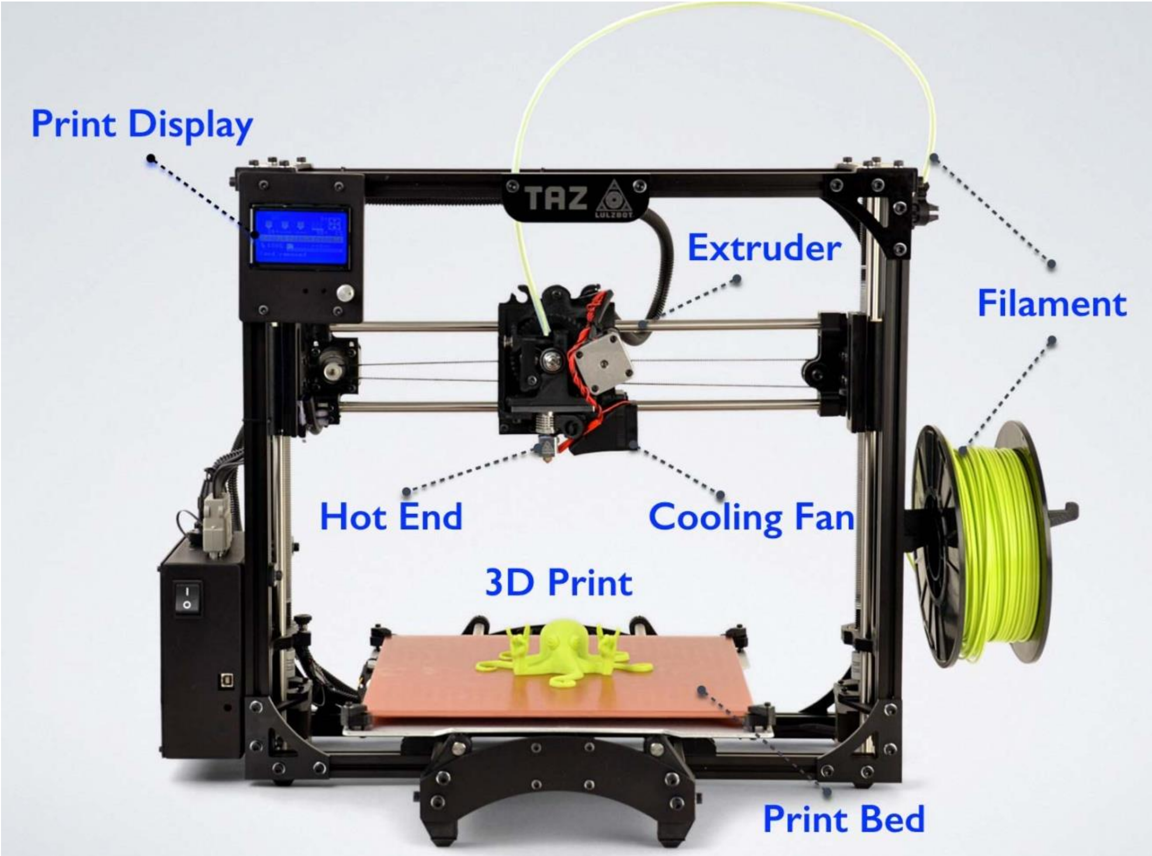


FIG 7.1 FDM EQUIPMENT

7.3 Materials for RP:

7.3.1 ABS:

ABS as a polymer can take many forms and can be engineered to have many properties. In general, it is a strong plastic with mild flexibility (compare to PLA). Natural ABS before colorants have been added is soft milky beige. The flexibility of ABS makes creating inter locking pieces or pin connected pieces easier to work with. It is easily sanded and machined.

Notably ABS is soluble in acetone allowing one to weld parts together with a drop or two, or smooth and create high gloss by brushing or dipping full pieces in acetone.

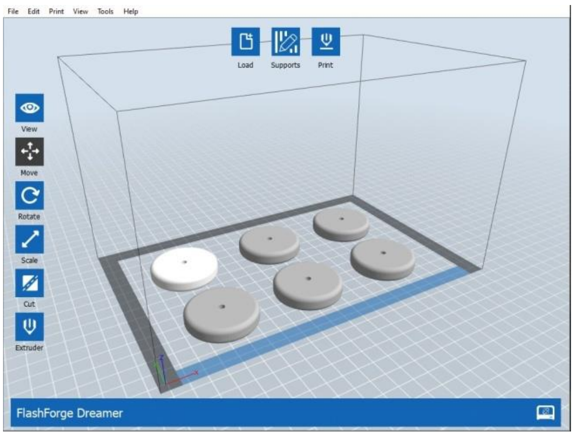
Compared to PLA, it is much easier to recycle ABS. Its strength, flexibility, machinability, and higher temperature resistance make it often a preferred plastic by engineers those with mechanical users in mind.

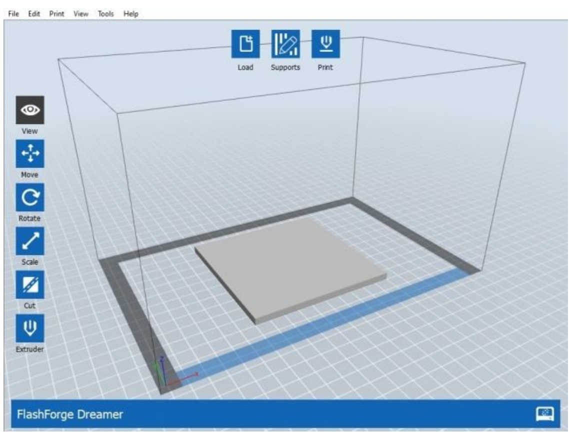
7.3.2 PLA:

Created from processing any number of plant products including corn, potatoes or sugar –beets , PLA is considered a more earth friendly plastic compared to petroleum based ABS. Used primarily in food packaging and containers, PLA can be composted at commercial composed facilities . It won't bio degrade in your backyard or home composed pile however. It is naturally transparent and can be coloured to various degrees of translucency and opacity.

Also strong, and more rigid than ABS, it is occasionally more difficult to work with in complicated inter locking assemblies and pin joints. Printed objects will general have glossier look and feel than ABS. With a little work, PLA can also be sanded and machined.

The lower melting temperature of PLA makes it unsuitable for many applications even parts spending the day in a hot car can droop and deform.





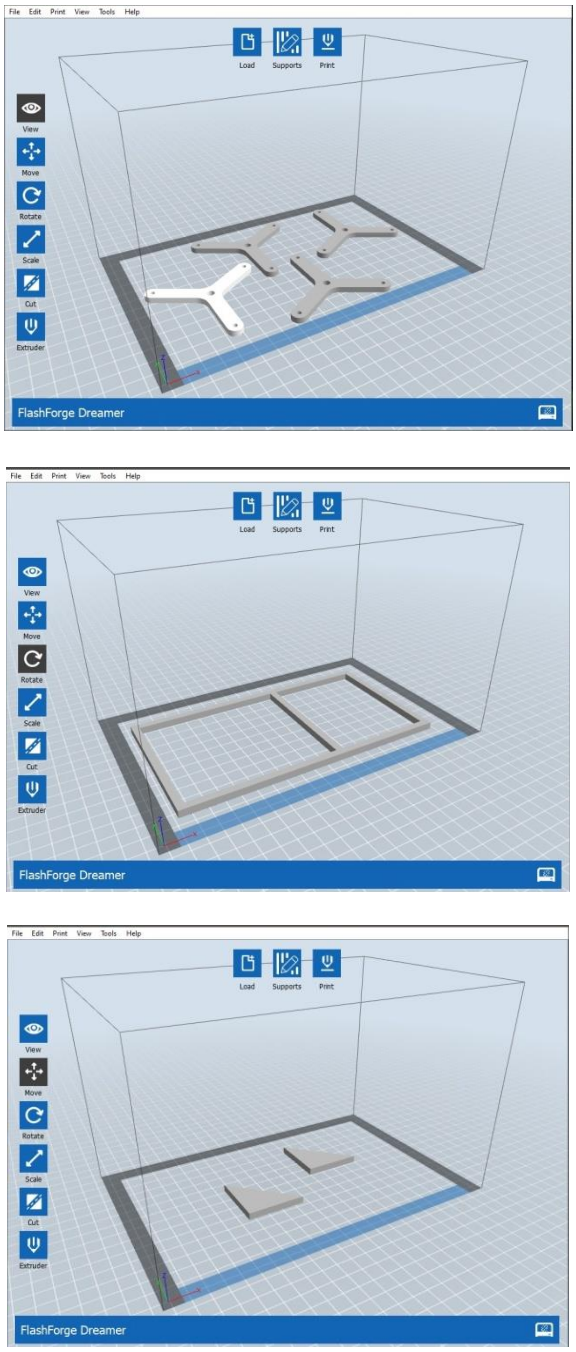


FIG 7.2 SLICING ON WHEELS, BASEPLATE, BRACKETS, STRUCTURE AND RIBS

CHAPTER- 8

RESULTS

8. RESULTS

The results of the time taken to fabricate the components are given below:

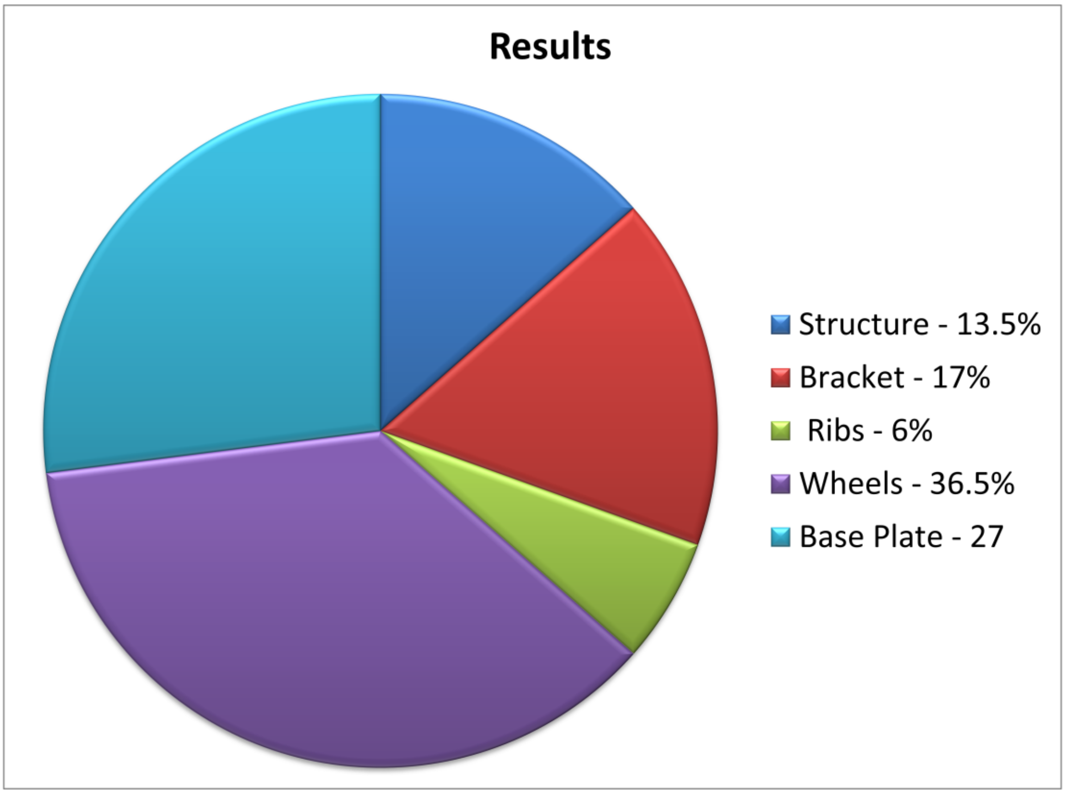


FIG 8.1 PIE DIAGRAM

REPRESENTATION OF TIME TAKEN FOR FABRICATION

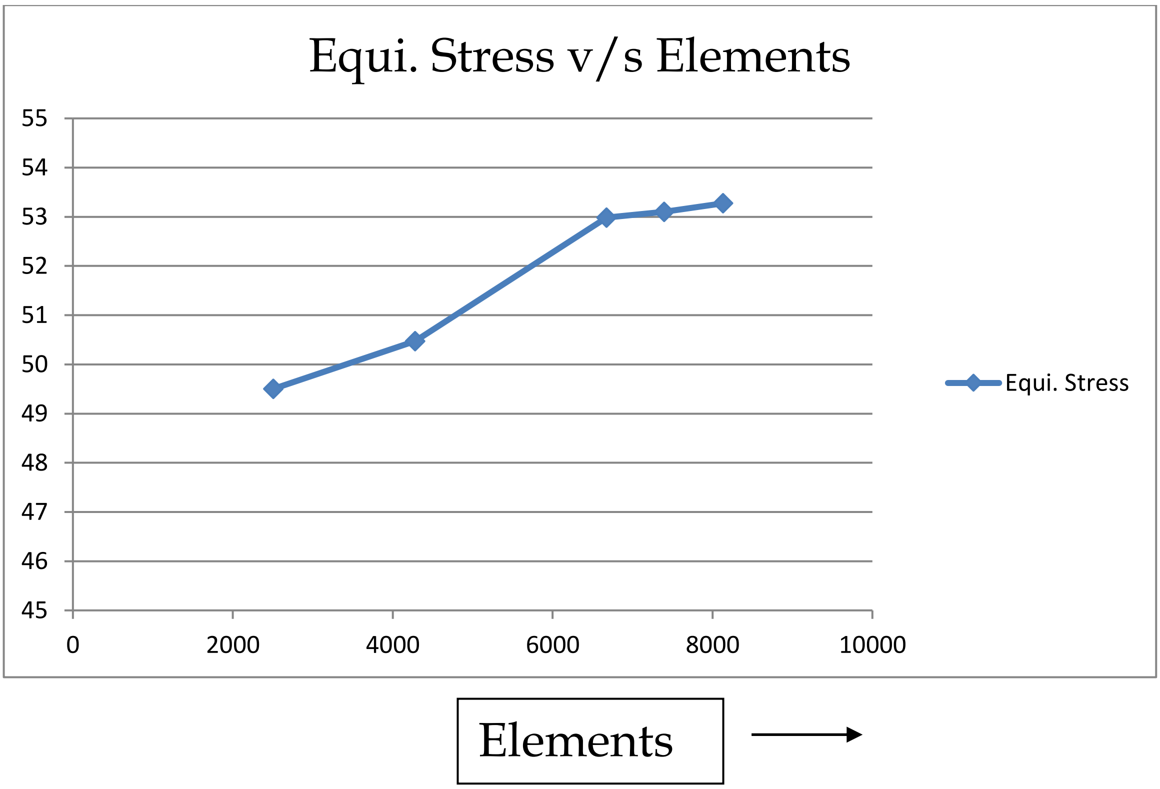
The above pie chart shows the time taken by the 3D printer to print the components individually, which was then summarised up to the percentage of total time required for the printing to complete.

We've taken up the convergence of the elements with respect to the relevancies to check out the closeness in the acquired stress values to prove the safe loading of the load carrying components. The individual results for the same have been shown below.

ON AXLE

TABLE 8.1

Relevance	Elements	Equi. Stress
10	2507	49.503
40	4283	50.474
68	6678	52.985
83	7398	53.104
97	8134	53.274



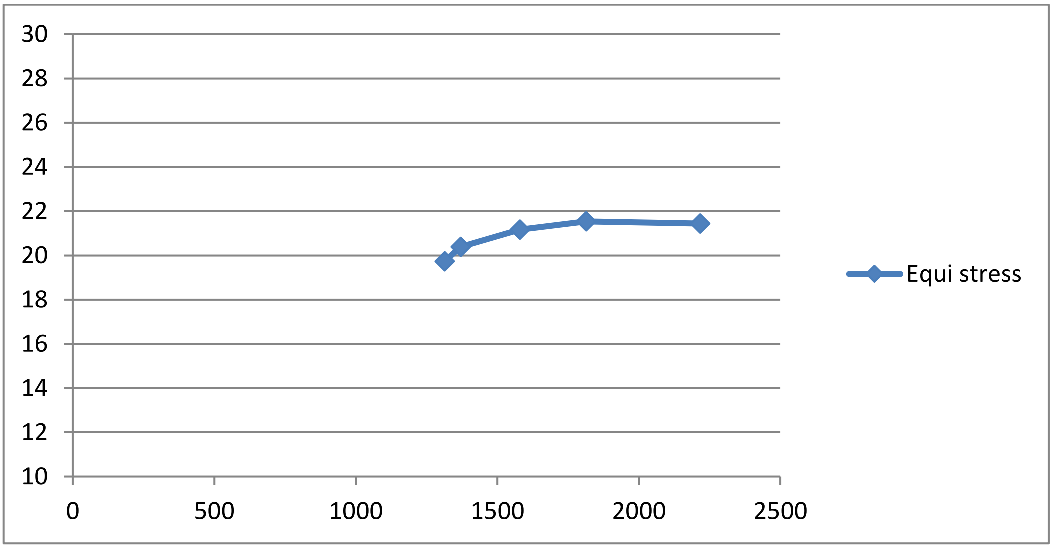
GRAPH 8.1

ON FLAT SURFACE

TABLE 8.2

Relevance	Elements	Equi. Stress
10	1314	19.731
22	1370	20.384
45	1580	21.161
60	1814	21.535
80	2216	21.443

Equi. Stress v/s Elements



Elements →

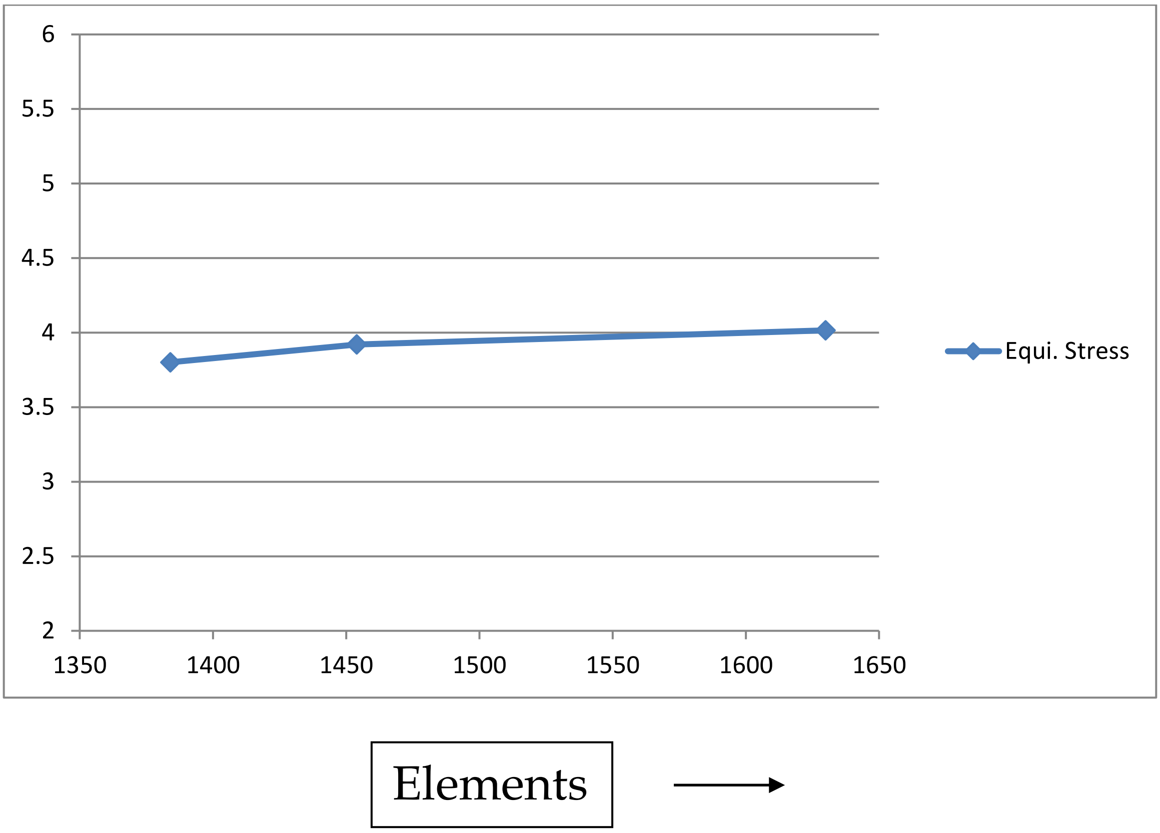
GRAPH 8.2

ON STAIRS

TABLE 8.3

Relevance	Elements	Equi. Stress
30	1384	3.801
35	1454	3.8075
50	1630	4.0152
70	1844	4.027
85	2088	4.0446

Equi. Stress v/s Elements



GRAPH 8.3

CHAPTER-9

CONCLUSION

9. CONCLUSION

Thus the stair climbing trolley can be fabricated in a way such that it could carry the heavy loads over stairs and also used for carrying loads on flat surface from one place to other place with less human effort. This decreases the human effort to carry heavy loads over stairs and also on flat surfaces and proves to be more advantages in all places like industries, schools, college etc.

The improvements that can be made in the stair climber are:

Firstly, the material of the stair climber parts can be changed because now we are used mild steel as material as it will increase the weight of the stair climber. Instead of using steel as material we can use composite materials to reduce weight. Secondly, the mechanism of transmission system could be changed to get efficient output. Instead of using chain drive we can use gear drive.

Thirdly, the power range produced to carry loads could be modified as per loading conditions by changing motor and battery.

Also we can use an electric motor, using chain drive to automate the climb and reduce human effort.

Finally, the size of the Tri-Star plate could be made as adjustable one to climb all sort of stairs by using bolt and nuts or another adjusting mechanisms.

CHAPTER-10

FUTURE SCOPE

10. FUTURE SCOPE

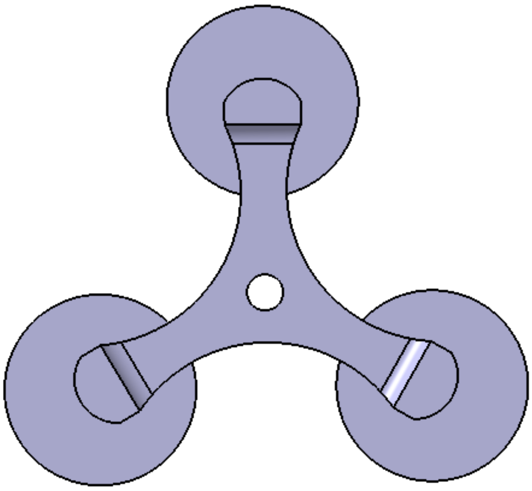


Fig. 10.1 Present version

This is the model acquired through the complete project made so far.
We can now modify it for more ease of climbing the stairs by adding a simple elastic band in the following manner:-

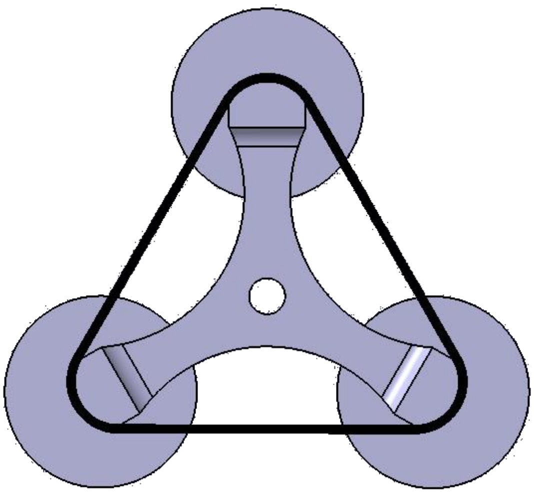


Fig. 10.2 Improved Futuristic version

The difference between the actual model and the futuristic design can be explained as follows:

OLDER VERSION

- Can easily move on Flat surfaces, but is difficult to climb stairs, as we have to apply force > the load it is carrying.
- Applied Pulling Force should be GREATER than the load carrying by the frame**.**

NEW VERSION

- Can easily move on Flat surfaces, also easy to climb stairs, as we have to apply force < the load it is carrying.
- Applied Pulling Force will be LESS than the load carrying by the frame.

Explanation –

It has an extra component called – **Rubber Band** to push the frame upon stairs by overcoming loads and projects a little elastic deformation, which regains its original shape when frame comes to normal flat surface.

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