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Comparative Analysis of Additive Vs Conventional Manufacturing (Gear)

Dr. K. Ramakotaiah[1], J. Koteswara Rao[2], CH. Sai Ganesh[3]
[1]*Professor & Head of the Department, KKR & KSR Institute of Technology & Sciences, Guntur, Andhra Pradesh, India.*
[2]*Assistant Professor, Department of Mechanical Engineering, KKR & KSR Institute of Technology & Sciences, Guntur, Andhra Pradesh, India.*
[3]*PG Student, Department of Mechanical Engineering, KKR & KSR Institute of Technology & Sciences, Guntur, Andhra Pradesh, India.*

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Abstract: *In this report a detailed study on the design and analysis of SPUR GEAR with the Additive manufacturing technique Laser Powder Bed Fusion. The variety of materials for the additive manufacturing are discussed and the compatible material ALSI was selected for GEAR It also focuses on the various simulations of manufacturing the Piston part by utilizing "AUTODESK NETFABB SIMULATION 2020.1" and analysis was also done in ANSYS for the comparison of conventional material with ALI10MG . The residual stresses, von mises stress, hotspots and lack offusion spots from simulation results are discussed and the suitable heat treatment analysis is studied for relieving the stresses. The strength evolution of the as-built ALSI part by LPBF and total deformation, equivalent stress, principal elastic strain are also plotted from ansys and the further heat treated parts under different conditions are studied and the best suitable heat treatment method for the manufacturing of ALSI part by LPBF was concluded which could be beneficial for the manufacturing of the actual part of the gear in automobile industries.*

Key Word: *Additive manufacturing, alsi 10 mg powder bed fusion, gear, Residual stress, von mises stress, total deformation.*

I.INTRODUCTION

The process of adding material using computer control for manufacturing is known as additive manufacturing, or AM for short. In traditional manufacturing, we must take away the material in order to get the desired object. But in additive manufacturing (AM), a completely distinct process, the material is added layer by layer to create the desired object. At the Battelle Memorial Institute, utilizing lasers, the first attempt to fabricate items with photopolymers was made toward the end of the 1960s. Later that year, in 1967, a Danish inventor named Wyn K. Swainson submitted a patent application titled "Method of generating a 3D printed figure via holograph on a dual laser" that was employed by the latter. By Formigrapic, the term "photo chemical machining" was first used Engine Co. began its first commercial printing in the 1970s using a dual laser technique. Below is a list of additive manufacturing classifications..

Fig1.1 types of additive manufacturing

Advantages of additive manufacturing :

The absence of tooling is the main feature that sets additive manufacturing apart from conventional techniques. When compared to injection moulding, the reduction in tool usage means that an additive manufacturing machine may operate with less requirement. When utilized in direct production, additive manufacturing offers a variety of additional benefits, including:

a. Production on demand: With AM machines, qualified designs can be produced without the need for additional add-ons.
b. Additionally, because of the digital process, manufacturing may be scaled as needed.
c. Reduce held inventory: Businesses can produce parts as needed and reduce held inventory since they plan production based on demand.

d. Since production companies can use a comparable technique for the same design with less expensive tools, movement will increase. Businesses continue to produce new SKUs in a timely manner in response to client requests.
e. Localize manufacturing: Additive manufacturing facilities can reduce injection mould tooling expenditures and production labor costs, making it simpler to establish new facilities nearby end users in more expensive regions. Local production is the finest method for delivering goods to customers more quickly.
f. Unique and custom designs: With a high level of skill, designers use additive manufacturing technologies to create designs that conventional manufacturing cannot produce. With more design flexibility, options such as component consolidation and unique support structures will be possible.
g. Many industries, including the dentistry, medical, footwear, and eyeglasses industries, are embracing additive manufacturing (AM) to produce one-of-a-kind goods.

More businesses are utilizing the benefits of additive manufacturing in their production tasks because of the straightforward application of new printing methods, cutting-edge materials, and specialized processes. Businesses employ the capability of additivemanufacturing as an adjunct to more traditional manufacturing processes.

Stereolithography :

Rapid prototyping and stereolithography (SL), both invented by 3D Systems, Inc., were previously used interchangeably because SL was the first and most popular rapid prototyping method. A photosensitive polymer is solidified or cured in this liquid-based process when it comes into contact with an ultraviolet laser. A CAD model is first translated into an STL file, which is where the pieces are "cut in slices" and where the data for each layer is kept, to begin the manufacturing process. The size of each layer and the resolution vary depending on the computer being utilized. To secure the piece and support the dangling structures, a platform is constructed.The UV laser is then used to harden particular areas of each layer in the resin. When one layer is complete, the platform will slide down one layer's thickness, and once the process is finished, extra resin is evacuated and can be reapplied. Micro stereo lithography is a new variation of this method that has been created with a higher resolution. With this method, layers can be less than 10 m thick.

The fundamental idea behind this method is photopolymerization, which transforms a liquid monomer or polymer into a solidified polymer by using ultraviolet light as a catalyst for the processes. This method is also known as UV curing. The stereolithography method results in certain flaws in the finished output. One is overcuring, which affects overhanging sections since a lower layer isn't fused. Another is the scanned line form, which the scanning process introduces. The layer thickness is variable because of the resin's high viscosity, which produces an error in the border position control. If the component needs to go through a surface-finishing procedure that is typically performed by arms, this could result in yet another flaw. All of these flaws are reduced with high-quality equipment. The process of creating a piece using numerous materials is known as multiple material stereolithography. When the process reaches the layer where the change is going to occur, all the resin must be evacuated and filled with the new material in order to construct it with various materials. Since the software can only build subsequent layers, this is required even if the first material is going to be used. A scheduling procedure must be described.

STL File :

The STL format, which stands for Standard Tessellation Language, was first introduced in 1987 by 3D Systems Inc. when they first invented stereolithography. There are many other files, but the STL file is the cornerstone of any additive manufacturing process. Converting continuous geometry from a CAD file into a header, a few small triangles, or a triplet list of x, y, and z coordinates, as well as adding the normal vector to the triangles, is the first stage in creating an STL file format. The more realistic the triangles are, the more improper this method is. The right-hand rule is used to distinguish between interior and exterior surfaces, and vertices cannot share a point with a line. A slicing procedure results in the addition of new edges. The slicing process can lead to file inaccuracies since the algorithm in this case replaces the unbroken contour with free-standing stair steps. The solution is to produce distinct STL files for each feature that has a small radius relative to the size of the part in order to combine them later. Design the dimension in the z-direction to be a multiple of the layer thickness value. The location of STL file production in the data flow of a fast prototyping process is shown below.

Selective laser sintering or powder bed fusion :

Similar powder-based processes include SLS, in which layers of fine nylon powder are fused by a CO2 or nd yag, yb fiber laser under the control of a computer-guided reflector. As each layer is constructed, the build platform descends. Fresh powder is rolled onto the build area by a roller as delivery chambers rise to provide it. The sintered model is enclosed and supported by the non-sintered powder. As a result, the part does not need to have support material printed with it. The elimination of the supplementary support structure is the primary distinction between the sla and sls processes. Therefore, compared to the sla method,the post treatment expenses were lower.

The types of powder used are :
1. Polymer based (low heat i.e. elastic state)
2. Metal based (heated upto melting point)
3. Ceramics (heated upto melting point)

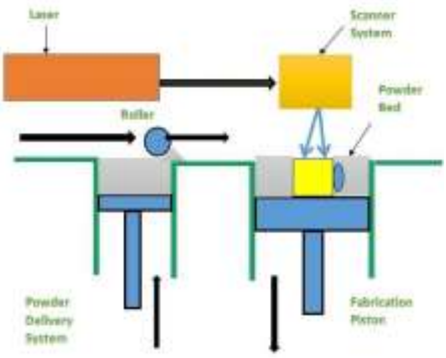

Fig.1.4 line diagram of PBF

Size, shape, and volume of the particles are crucial powder factors. The first commercially successful technology, powder bed fusion, was created at the University of Texas at Austin in the United States under the name of selective laser sintering.

The sls's attributes are as follows:

1. a single or many heat sources for causing the fusing of powdery particles
2. a technique for directing powder fusion to a specific area of each layer and methods for incorporating and blending powder layers

In more detail, the sls was initially created utilizing a point wise layer scanning process to create plastic prototypes. Additional thermal sources have been used, and the procedure has been expanded to include metal ceramic particles.Polymers, metals, ceramics, and composites are the materials produced by SLS. These materials are used for direct digital manufacturing of end use goods since they have similar material qualities to numerous engineering grade polymers, metals, and ceramics.

SLS (selective laser sintering) components :

★ Laser
★ X-Y scanning mirror
★ Powder bed
★ Feeder cartridge
★ Build platform
★ IR heater
★ Resistance heater
★ Powder conveyor

Primary powder bed fusion :

❖ Solid state sintering
❖ Chemical induced sintering
❖ Liquid phase sintering

> Distinct binder of structural material

1. Separate particles
2. Composite particles
3. Coated particles

> In distinct binder of structural material

❖ Full melting

1.5 ASolid state sintering :

Before the invention of Rm, processes for fusing powder as a result of thermal processing were referred to as "sintering." In its traditional understanding, sintering refers to the melting-free fusing of powder particles at a high temperature. This happens between the absolute melting point and melting point, or between those two temperatures. The reduction of the total free energy of the powder particles is what drives solid state sintering. Diffusion between powder particles principally accounts for the sintering mechanism.

Through the equation, surface energy Es is proportional to the total particle surface area SA. Es = Gs*SA

Gs is the surface energy per unit area for a specific material, environment, and temperature.

Surface energy is decreased when particles fuse at high temperatures because the total surface area reduces. The total portion area of the powder bed has decreased, which has resulted in a dull rate of sintering. High sintering temperatures or lengthy sintering durations are needed to attain very low porosity levels.

1. Particles that are tightly packed before being sintered
2. The temperatures of the particles increase as they appear to reduce free energy by reducing surface area.
3. Neck size grows and pore size decreases as sintering proceeds.

The driving force for sintering is directly connected to the surface area to volume ratio for a given set of components since the total surface area in a powder bed fusion of particle size. The free energy driving force increases with the surface area to volume ratio. Smaller particles sinter more quickly and start the sintering process at a lower temperature than bigger components because quarks encounter a strong motivation for necking and reinforcing. The more quickly a layer forms, the more inexpensively the process becomes for rapid manufacturing. To boost construction speeds, the heat source that triggers fusion should move quickly and trigger fusion quickly.

1.5 B Chemically induced sintering :

In order to create a byproduct that binds the powder together, it uses thermally stimulated chemical interactions between two different types of powder and ambient gasses. The aforementioned fusion mechanism is primarily employed for ceramic materials:

- When oxygen is present during laser processing of SiC, SIO2 develops and bonds together a composite of SIC and SIO2.
- ZrO2 produces a composite of ZrB2 and ZrO2 during laser processing of ZrB2 in the presence of oxygen.
- AI is processed using a laser in the presence of N2, and AIN forms and joins the Al and AIN portions.

In this instance, the raw ingredients are pre-mixed and heated with a laser such that they exothermically react to generate the desired result. High melting structures can be produced at low laser energies by combining chemical reaction energy with laser energy. Part porosity is one trait of chemically induced sintering. To obtain characteristics that are useful for the majority of applications, post-process infiltration or high temperature furnace sintering to greater densities is frequently required. Other reactivesubstances could create new reactions as a result of this post-process infiltration.

C Liquid phase sintering :

It is the powder bed fusion method that is the most adaptable. In the powder processing industry, the term "liquid phase sintering" is frequently used to describe the fusion of powder particles when some of the ingredients within a collection of powder particles melt while other constituents remain solid. LPS is utilized in conventional powder metallurgy to create cemented carbide cutting tools instead of melting the parts or directly sintering them. Cobalt is employed as the lower melting point constituent to bind together WA particles, and the molten constituents in LPS act as glue to bond the solid particles together.

The variations in LPS are :

➔ Separate particles
➔ Composite particles
➔ Coated particles
➔ Indistinct particles

Advantages of powder bed fusion :

The most popular and well-known type of metal additive manufacturing at the moment is PBF. The popularity of powder bed fusion is due to a number of factors, including the ability of high-precision lasers and electron beams to produce complicated pieces from a variety of materials.

1. Greater accuracy with distinct tolerance.
2. Numerous combinations are possible
3. Construct substantial components
4. Materials' characteristics are good.
5. High strength and stiffness

Disadvantages :

1. Susceptibility to thermal stress
2. Porosity in internal layers
3. Highly expensive

Critical factors that influence the performance of selective laser sintering :

a. Porosity
b. Relative density
c. Surface roughness
d. Strength
e. Indentation hardness

II.SPUR GEAR GEOMETRY AND MODELING

The most popular kind of gear is a spur gear. Power is transferred between two parallel shafts using it. Spur gears have been around for a very long time. A modern improvement on the wheel and axle is the gear. Gear wheels have protrusions known as teeth that are made to cross another gear's teeth. Gear teeth are said to be in mesh when they fit or interlock in this way. Mesh gears have the ability to transmit force and motion in alternating directions. The gear connecting to the drive gear is known as the driven gear, and the gear delivering the force or motion is known as the drive gear.

Many everyday objects, like the electric screwdriver, oscillating sprinkler, wind-up alarm clock, washing machine, and clothesdryer, utilize spur gears. However, your car won't have many of them.

This is due to how loud the spur gear may be. The gear teeth collide and generate noise each time one of them engages a tooth on the other gear. Additionally, it puts more strain on the gear teeth. The majority of the gears in your car are helical to lessen noise and stress on the gears.

Spur Gear Design and selection:

Objectives:

- Put principles into practice when designing and choosing spur gear systems.
- Calculate the forces acting on the spur gears' teeth, taking into account the clearances and velocity-related impact forces.
- Calculate the permissible force on the gear teeth, taking into account the requirements caused by the tooth shape's angle of involute and the materials chosen for the gears.
- Create genuine gear systems, specifying the materials, manufacturing precision, and other elements required for full spur gear design.
- Recognize and establish the required surface hardness of gears to reduce or eliminate surface wear.
- Recognize how lubrication may cool and lessen the effect on gearing systems. Select standard gears are accessible from manufacturers or wholesalers with inventory.

Modes of Failures in a Spur gear:

The following are some of the common modes of failure in a spur gear:

1. Tooth Breakage (mostly because of fatigue loading)
2. Surface Failures (Because of abrasion, pitting, seizure and scoring)

Benefits of Spur Gear:

1. Spur gears are highly effective in transmitting power.
2. They are portable and simple to set up.
3. They provide a ratio of constant velocity.
4. Spur gear drives do not slip, in contrast to belt drives.
5. Spur gears are incredibly dependable.
6. They are capable of transferring a lot of power (of the order of 50,000 kW).

Drawbacks of Spur Gear:

1. When compared to belt drives, spur gear drives are more expensive.
2. Their center distance is constrained. This is due to the fact that in a spur gear drive, the gears should be meshing and in close proximity to one another.
3. Spur gears make a lot of noise while they're moving quickly.
4. They are not suitable for transmitting power over great distances.
5. Gear teeth are put under a lot of strain.

Applications of Spur Gear:

Spur gears have a wide range of applications.

1. Automobile gearboxes
2. Marine engines
3. Mechanical clocks and watches
4. Fuel pumps
5. Washing Machines
6. Gear motors and gear pumps
7. Rack and pinion mechanisms

Material composition of the *ALSI10* mg(wt.-%) for 30 [illegible] :

Al balance

Element	Composition
Si	11.0

Fe	0.12
Cu	0.005
Mn	0.006
Mg	0.31
Ni	0.005
Zn	0.005
Pb	0.005
Sn	0.005
Ti	0.005

Mechanical properties:

	Yield strength Rp0.2 (mpa)	Tensile strength Rm(mpa)	Elongation at bre	Young's Modulus gpa	Vickers hardness	Roughness average um
As built	272	460	5 +0.5%	71 to 75	113 HV 0.5	5-7
Heat treated	190	450	4.6 +0.5%	67 to 73	98 HV 0.5	5-7

Physical properties:

Particle size	25-63um
Density	2.65g/cm^3
Thermal conductivity	130-190 W/mk
Melting range	570-590 c
Thermal expansion	20*10^-6 k^-1

Fig. 3.4 a line diagram of gear

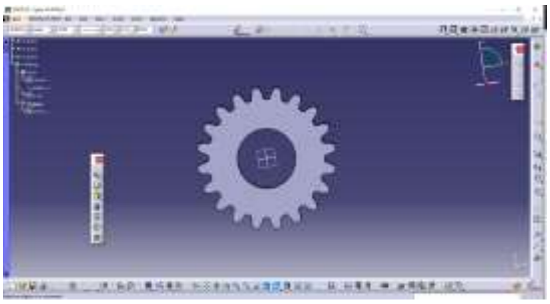

fig. 3d sketch of gear

The gear was drawn in the CATIA V5 R20 a computer aided drafting,computer aided manufacturing tool which was developed by Dassault systems a France based company. The dimensions of the gear are given below.

S. No	Description	Symbol	Value (mm)
1	Number of teeth	T	25
2	Module	M	2
3	Pressure Angle	A	20
4	Pitch circle radius	R_p	25
5	Base circle radius	R_b	23.5

6	Addendum circle radius	Ra	27
7	Dedendum circle radius	Rb	22.5

III.METHODS

3.1 Powder Bed Fusion

One of the more advanced forms of additive manufacturing is powder bed fusion, which involves utilizing a strong laser or electron beam to fuse the metal powder. The procedure involves changing a solid into a liquid and then solidifying a liquid into 12 solids. This manufacturing process is used by the aerospace, automotive, medical, and many other industries because of the wide variety of materials available.

After that, each layer is successively bonded on top of the other. PBF techniques spread powdered material over the previouslylinked layer so that it is ready for processing of the following layer, resulting in discrete production as opposed to continuous manufacturing (though each layer is fully consolidated to adjacent layers).The powdered material is delivered from a hopper and is then evenly distributed over the powder bed construction platform surface using a roller or blade. The ideal thickness of each layer of dispersed powder depends on the processing parameters and the frequently used material (25 to 100 µm).

It's crucial to understand that while different PBF processes may go by different brand names, they all basically follow the same steps. One of the most well-known terms for laser sintering is direct metal laser sintering (DMLS), for instance. Other terms for laser sintering include direct laser melting, selective laser melting, laser metal fusion, selective laser sintering, selective laser melting, and direct metal printing (DMP).

The activities in laser powder bed fusion are depicted in the above picture, and each layer is printed layer by layer before the bed is lowered and the powder is distributed evenly over the surface. This process is continued until the entire component is printed completely into the finished product.

The employers or managers will daily, get an overview of when his employees started working and how long each one worked. The number of screenshots in an employee's database will give an idea about how much time he spent on other tools or websites as compared to the other employees. The managers can use this data to compare employees, understand employee behaviour and take further decisions like assigning certain projects to certain employees, salary hikes, promotions, etc.

IV. BUILD SIMULATION & ANALYSIS

Description of Equipment used for Simulation

The machine was used to simulate the component gear in Aconity Mini with the building volumes of 140 mm X 140 mm X 200mm. Leading-edge laser sintering system for the manufacture of metal products directly from CAD.

Fig. 4.1 setup of machine

Importing and Orientation analysis of the Part :

The Piston's component and simulation analysis were conducted using Autodesk Netfabb 2020.1 software. The gear's 3D component is modeled and then exported as an STL file. The Netfabb home screen imports this file for additional processin.

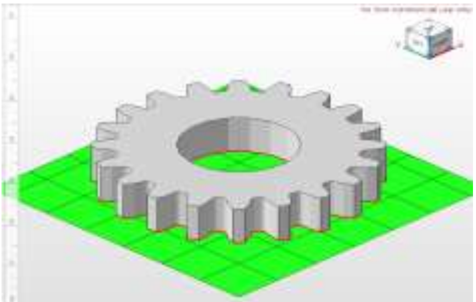

Fig.4.2 I orientation of part

The top 12 spots are found after analyzing the positions of the orientations using the Netfabb orientation analysis setup with the part centered on the build plate. The part's orientation is crucial since it aids in determining the amount of powder needed for thepart, the time needed to build it up, and the amount of material necessary for the supports. Our goal is to select the best orientation possible for which the buildup time, support structures, and powder usage are all kept to a minimum. Giving the part a new finish byremoving the support structures is also an important factor to think about.

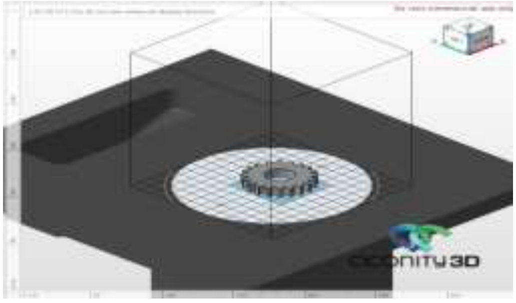

Fig.4.2 II orientation analysis result showing best position of the part

The ideal component orientation makes it easier to refine the finished part by effectively removing the support material. Maintaining the injector component's face parallel to the vertical plane is the optimal orientation for the supplied part, which was obtained in Netfabb's Rank 1 row. The heat generated, as shown in the table, determines the amount of material needed for the support structures and the area of the past they support.

The support structures serve as crucial supports for the buildup portion as it is created layer by layer because they give the partstructural strength while it is being formed and also aid in the efficient drainage of generated heat. The support structures must be created in a manner that after processing, it would be simpler to take them out of the main component.

We proceed to the created support section in Netfabb after positioning the part in the ideal orientation. We can see the red-highlighted portions on the part as the supports section opens. The critical and non-critical areas of the component that needs support are displayed by the cluster detection. Red areas are used to highlight the important sections. To apply support to these parts, either the human selection method or the automatic predefined support scripts offered by the netfabb can be used. The standard SLM volume support is the script that was chosen for the component.

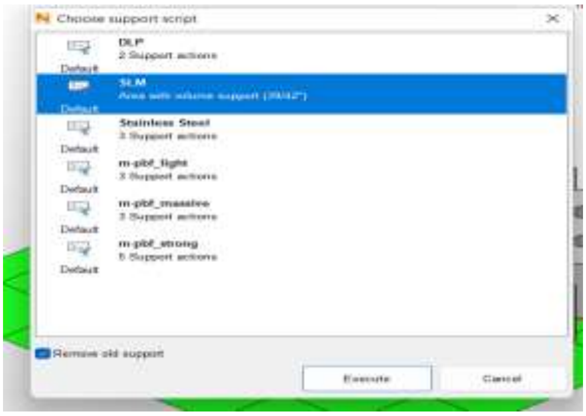

Fig. 4.2 III predefined scripts

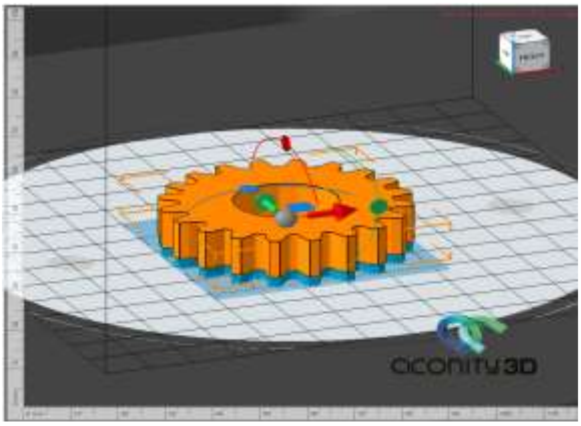

Fig. 4.2 IV gear part with applied support

ASlicing :

1. Transfer parts into Slicing. This generates the contours ("profile", "hull"). Alternatively, load a slice file with the contours

only.
2. Optionally, arrange the contours on the platform using the outboxes as a guide.
3. The buildroom dimensions are simply shown as a general reference. The produced slice files are sized to the minimum requiredVdimensions to include all current outboxes over the whole slicing height unless modified in the slice export.
4. Create fresh slice stacks for hatching if you're utilizing a vector-based exposure (for a moving laser or electron beam, for instance) ("infill", "core").
1. Set optional slice parameters for the various slice stacks, such as laser power and speed.
2. Export the toolpath-containing slice stacks in the chosen format.

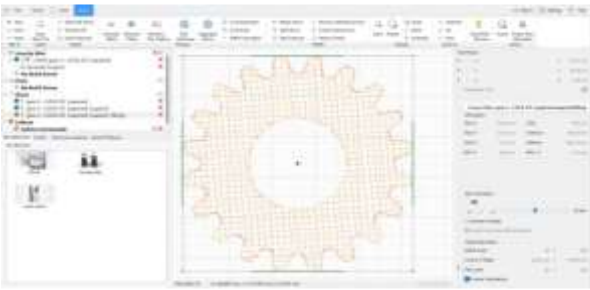

Fig. 4.2 a slicing using for netfabb simulation

Running simulation in netfabb software :

The software that enables STL (Standard Tessellation Language) file saving (to maintain the selected positioning), while the generated supports were saved as a "LI Common 63 Layer Interface" file and Slicing data in SLI (Slice Layer Interface) format to run simulations with metfab simulation software

Fig. 4.3 I importing part into netfabb simulation facility

We must assign specific measures before the simulation can begin after importing the STL file into Netfabb. The process settings can be set once the STL files have been loaded into Netfabb Simulation. For the portion, the supports, and the building plate's first exposure, several process parameters were used.

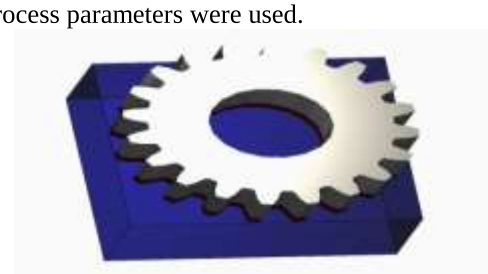

Fig. 4.3 II imported file with pre positioned data

Fig. 4.3 III build plate side with adjustment table

Now we fit the part to the build plate size by using snap to X and Y option in Build plate settings. For better simulation viewing results we need to modify the build plate sizes in X, Y and Z Axes and save the information.

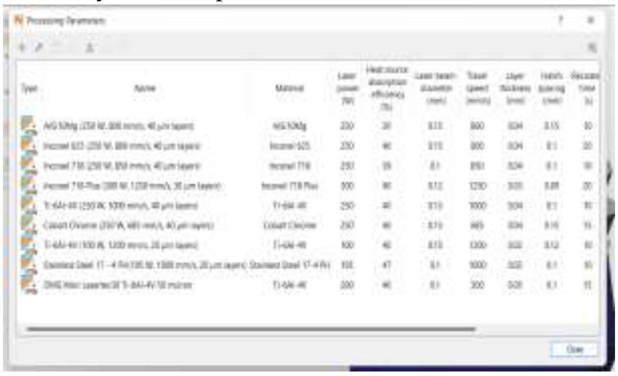

Fig. 4.3 IV material library with large amounts of data to simulate.

AlSi10Mg has now been chosen as the machine's powder material for the simulation. The simulation's process parameters cannot be altered from their default settings without purchasing a new license (Autodesk Netfabb Local Simulation). The issue is that, even though the normal process parameters are known from many sources, they are not inserted when dealing with novel materials and cannot be added (the possession of the machine). The PRM file (Process Parameters), which needs to be imported, is encoded. Therefore, unless using the extended license, it is impossible to run a simulation taking into account a new material.

As regards the powder properties and their actual effects on the printed parts, it must be kept in mind that some of these aspects are still not completely understood, and they are still continuous research topics. Some of the challenges in AM simulation will be won only by running an extremely large number of tests and by experimentally validating the results from the code. What really counts is to find a good compromise between having a detailed analysis and limiting the computation time. Despite software limitations we got a suitable Processing Parameter file in the software library for our part to run the simulation for all kinds of machines.

Fig. 4.3 V mesh setting considered

When it comes to meshing, a 3D mesh is a 3D model's structural framework made up of polygons. 3D meshes define shapes with height, breadth, and depth using reference points along the X, Y, and Z axes. While a 3D mesh can require a lot of polygons to resemble the original object's realism, these comparatively simple shapes enable faster processing than other methods. The most common polygons are quadrangles or triangles, which have vertices that can be divided into X, Y, and Z coordinates and lines. The part obtained is coarser when the mesh is less refined. Therefore, we go to the mesh settings and reduce the layers per element to 6 layers per element in order to refine the mesh of the model. A further reduction would produce a finer mesh, however this figure was chosen due to the restricted computing power available. The simulation output is better when the mesh is more refined.

Fig. 4.3 VI mesh results of gear

Displacement analysis:

We can observe the displacement of the part in different parts in the figure below thanks to the simulation results in Netfabb. After successive layer depositions and cooling rates, deformation of the material's layers causes displacement. A maximum of 0.004 mm displacement and a minimum of 0.00014 mm has been obtained for the gear deposition process.

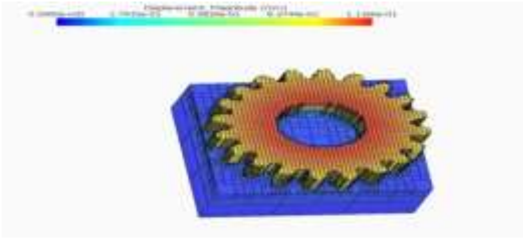

Fig. 4.4 I displacement analysis

Cauchy stress :

The second order tensor known as the Cauchy stress tensor, also known as the true stress tensor, has nine components that collectively define the state of stress at a particular location within the deformed material. For stress analysis of material bodies that go through minor deformations, Cauchy stress is applied. The outcomes of the modeling of Cauchy stress in Netfabb demonstrate a favorable maximum value of 78 Mpa and negative maximum of -48 Mpa.

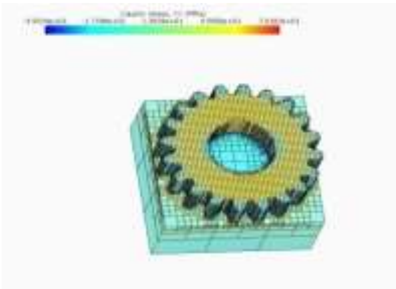

Fig. 4.5 cauchy stress

Principle stresses :

It is the normal stress on the principal plane that has zero shear stress. Maximum principal stress is the maximum of the values of stress acting on the principal plane. In the simulation results shown below, a maximum principal stress of 178 mpa has been observed and a negative maximum of 100 Mpa.

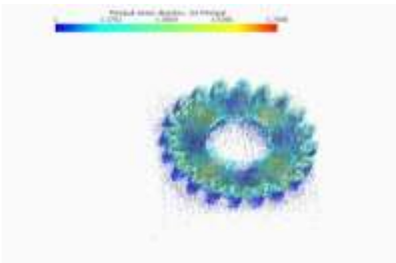

Fig. 4.6 principle stress direction and magnitude

Detailed Analysis of GEAR :

All components were initially simulated at the Part level using default Processing Parameters (PRM) files. However, the following analytical simulations for gear are carried out using a variety of software-available Processing Parameters.

The simulations listed below are useful for a detailed analysis of the component.

1) Set boundary restrictions and take into account trapped powder

2)Examine Lack of Fusion and Hot Spots

3)Predict Residual Stresses and Post Electron Discharge Machining Distortion

4)Stress Relief Heat Treatment Simulation.

Assigning Boundary Conditions & Account for Trapped Powder :

The build plate and component surfaces have a static, uniform heat flux as the thermal boundary condition by default. Modeling the powder directly can increase model accuracy for parts that are tightly packed together, have hollow walls, or have other features where significant heat can be conveyed through the powder. The goals of this are to apply thermal & mechanical boundary conditions to the build plate while taking trapped powder analysis into account. Thermal boundary conditions must be established. To check the heating settings, we navigate to the build plate properties tab. Here, we can see three of them.

1) Start at ambient temperature and let the build plate absorb the construction's heat. There would be no thermal boundary condition.
2) Initial temperature refers to setting a specific temperature at the beginning of the process but not maintaining it.
3) Controlled temperature, where you can choose a temperature that will be held constant during the construction process.

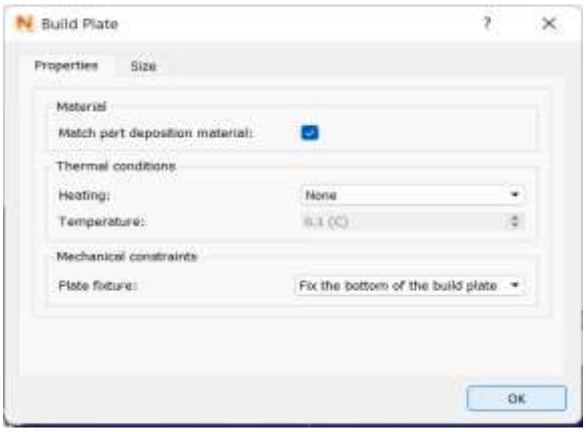

Fig. 4.8 I build plate setting

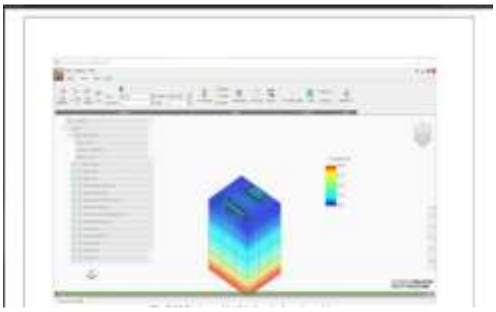

Fig. 4.8 II build plate temperature setting

In a build plate that has been preheated, a temperature of 100C is set by heating the build plate from below. As can be seen, the build plate's bottom generated 100C of heat before the material was deposited. The build plate is kept at 100 C as each layer is laser-fused, causing the previously fused layers to cool and reach temperatures of between 105 and 120 C close to it.

Fig. 4.8 III pre heated build plate before deposition

As shown in the above image, all the layers have fused, and the part is now slowly cooling down. Here, the temperature field is employed with the choice of the initial temperature or the regulated temperature, and the fixture is a mechanical boundary condition with two possibilities fixed; the entire bottom makes all of the part's bottom nodes fixed in all degrees of freedom. It was decided to use a fixture at the base of the construction plate and a control temperature of 100 degrees Celsius to address the issue. We must model all of the loose powder in the study for improved accuracy because this temperature gradient can alter the mechanical reaction. The thermal boundary conditions for such operating conditions were "conduction to loose powder."

Fig. 4.8 IV operating conditions

Predict von mises stresses :

The von mises stresses represent the equivalent stress state of the material before the distortional energy reaches its yield point.Note that the von mises stresses only considers distortional energy.

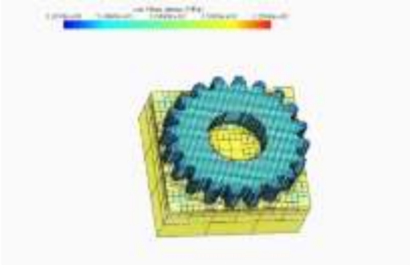

Fig. 4.9 von mises stresses

Analysis of lack of fusion and hot spots :

Poor processing conditions will manifest as aberrant thermal stress, which will result in poor quality. Less heat will create porosity, while greater plate heating will result in a hot spot in the base area. Due to problems with high temperatures, hot spots induce overheating of particularly fragile parts. This lesson walks users through how to conduct a multi-scale analysis in order to foresee these undesirable behaviors.

Fig. 4.10 hotspot volume above 880 c

Interlayer temperature:

The temperature of the build plate and deposited material is known as the interlayer temperature. When a layer is finished, the powder for the following layer is dispersed, and the recoater is put back in place. The simulation's coldest spot is right now. Additionally, it serves as the foundation for the simulation of the following layer or layer group. A finer degree of prediction is made with more temperatures, but each extra temperature requires more computing time.

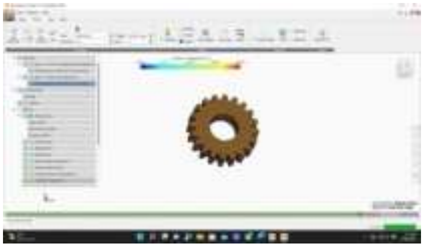

Fig.4.11 inter layer temperature

Analysis By Ansys :

A numerical analytical method known as the finite element method can be used to provide approximations of solutions to a wide range of engineering issues. It is getting a lot of attention in engineering schools and industry due to its diversity and adaptability as an analytical tool. Today, we observe that approximate solutions to issues, rather than perfect closed form solutions, are required in an increasing number of engineering settings.

For many engineering problems, analytical mathematical solutions are not feasible. A mathematical formula used to represent an analytical solution provides values for the desired unknown quantity at any place in the body, making it applicable to an endless number of sites. For issues involving complicated boundary conditions and material qualities.

For the numerical resolution of numerous engineering problems, the finite element approach has developed into a potent instrument. It has grown at the same time that numerical methods for engineering analysis are becoming more prevalent and high-speed electronic digital computers are being used more frequently. This approach was developed as a generalization of the structural idea to a few problems involving elastic continuums that were initially formulated as extremum problems or in terms of distinct equations.

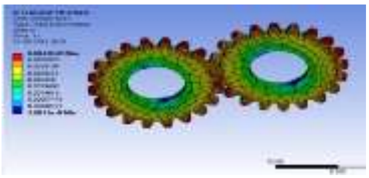

Fig. total deformation

The methodical approach to a static structural issue is as follows:
Step 1: - Structure Description (Domain).

The structure of the solution region is divided into subdivisions or elements as the first stage in the finite element method.

Step 2: Choosing the appropriate interpolation model.

We use an appropriate assumption within an element to approximate the unknown solution because the displacement (field variable) solution of a complicated structure under any given load conditions cannot be anticipated with absolute certainty. The presumed solution must meet certain convergence constraints and be straightforward.

Step 3: - Derivation of the load vectors and element stiffness matrices (characteristic matrices).

The stiffness matrix [K (e)] and the load vector P(e) of element "e" have to be determined from the assumed displacement model by either using equilibrium conditions or an appropriate variation approach.

Step 4: Assembling the equilibrium equations from the element equations.

Since the structure is made up of numerous finite elements, it is necessary to construct the stiffness matrices and load vectors for each element in an appropriate way and express the overall equilibrium equation as

$[K]\varphi = P$

where the constructed stiffness matrix is [K],
The vector of nodal displacement is also known as ΦP is the entire structure's vector or nodal force.

Step 5: Solving the system equation to determine the displacement nodal values (field variable)

In order to take the problem's boundary conditions into account, the general equilibrium equations must be adjusted. The equilibrium equations can be written as [K] = P after the boundary conditions have been taken into account. This expression makes it simple to solve linear problems using the vector ". For non-linear issues, however, the solution must be reached through a series ofsteps, each of which involves changing the stiffness matrix [K] and the load vector P.

Step 6: Calculation of element stresses and strains is step six.

If necessary, the element strains and stresses can be calculated using the necessary solid or structural mechanics equations from the known nodal displacements. The words enclosed in brackets in the preceding phases carry out the general FEM step-by-step approach.

5. ANSYS can perform Finite Element Analysis (FEA) in many areas covering many applications.

Structural Analysis: This type of analysis is the most common application of FEA and is primarily used for mechanical and civil engineering applications. Structural analysis is possible in the following areas.

Static Analysis: This type of analysis is used to determine the displacements and stresses in static loading conditions.

Transient Dynamic Analysis: This type of analysis is used to determine the harmonic response of a structure to time varying loads.

Fig. A Description of gear loaded in ansys

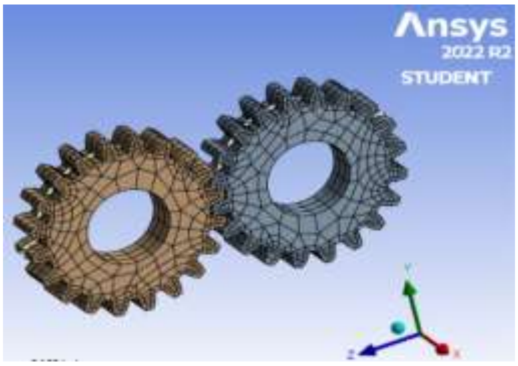

Fig. B. meshing of gears

Stress Analysis :

Static Structural Analysis :
Static underlying examinations uncover shortcomings in structures Static primary examinations are utilized for straightforward direct estimations as well as complicated material, mathematical and contact nonlinear computations. The investigation results help to recognize frail regions with low strength and sturdiness.

ALSI10MG :

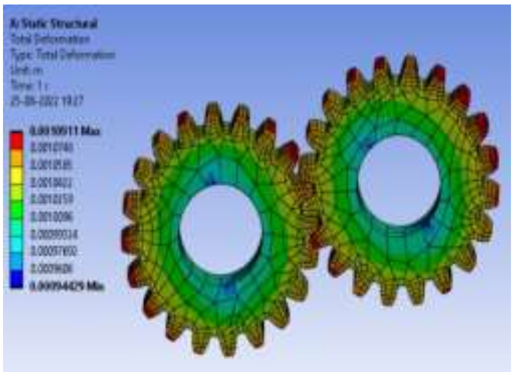

Fig.C total deformation

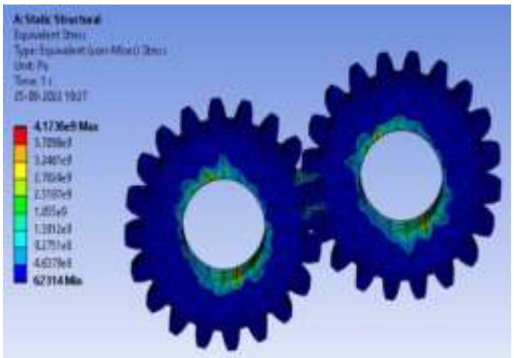

Fig. D equivalent stress

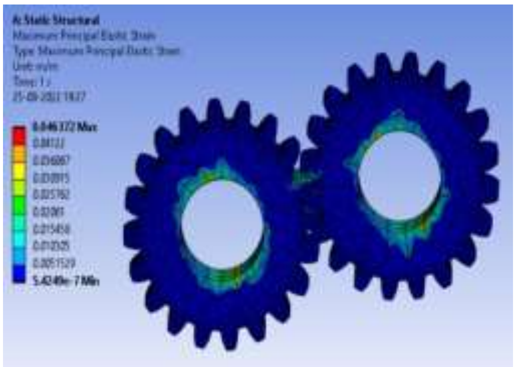

Fig. E maximum principle elastic strain

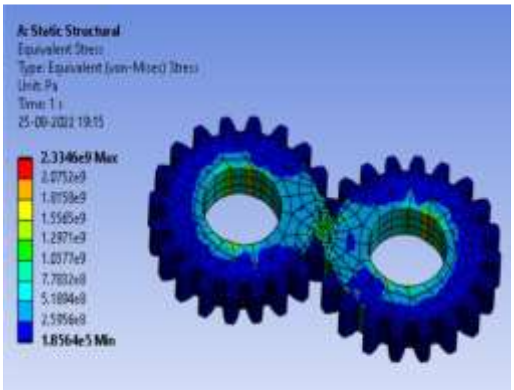

Fig. H equivalent stress

GRAY CAST IRON :

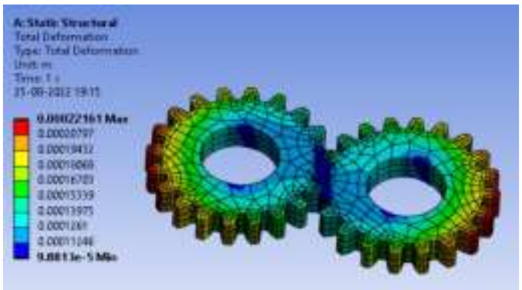

Fig. F total deformation

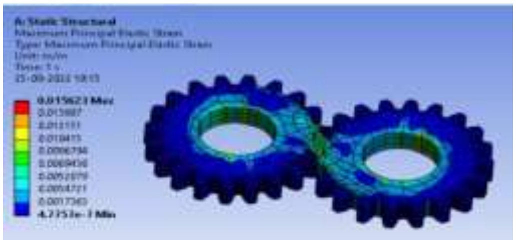

Fig. G maximum principal elastic strain

STAINLESS STEEL

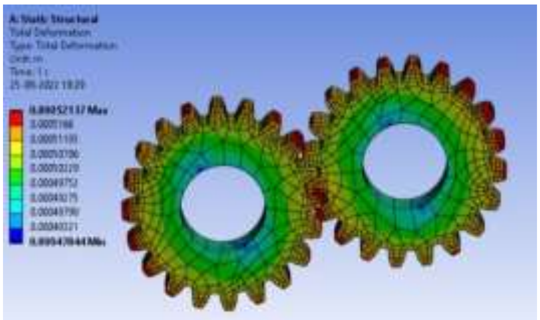

Fig. I total deformation

Fig. J equivalent stress

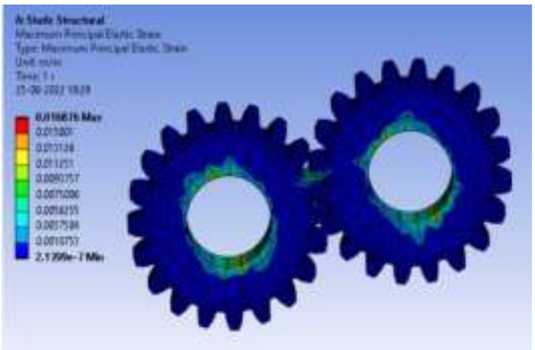

Fig.K maximum principal elastic strain

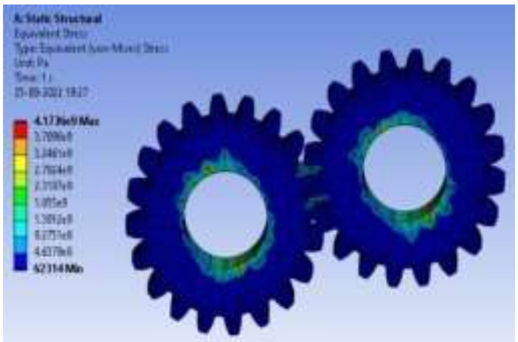

Fig.M equivalent stress

Aluminum Alloy :

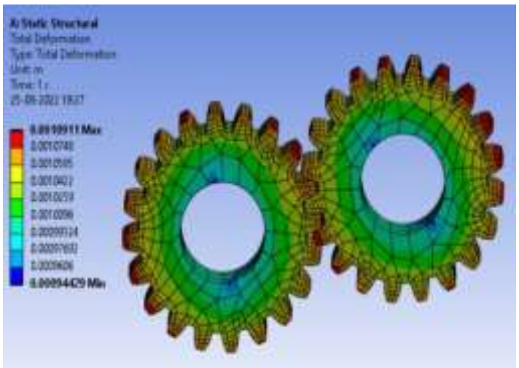

Fig.L total deformation

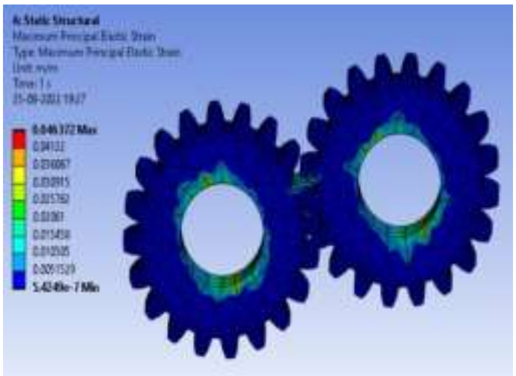

Fig.N maximum principal elastic strain

Transient Structural Analysis :

The distinction between transient primary examinations from static underlying investigations is the utilization of burdens and limit conditions that time-subordinate. For instance, a heap in static primary examinations doesn't change or changes marginally that don't disturb the consistent state conditions. In any case, in transient primary examinations, burdens or limit conditions can change suddenly over the long run.

ALSI10MG :

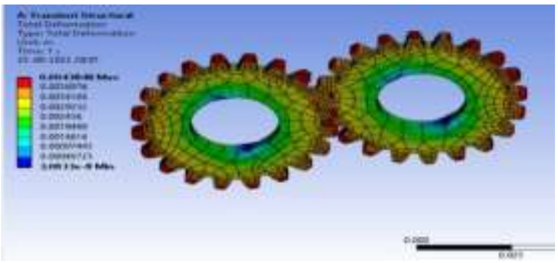

Fig.O total deformation

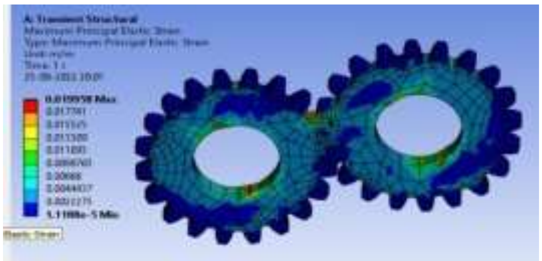

Fig. P maximum principal elastic strain

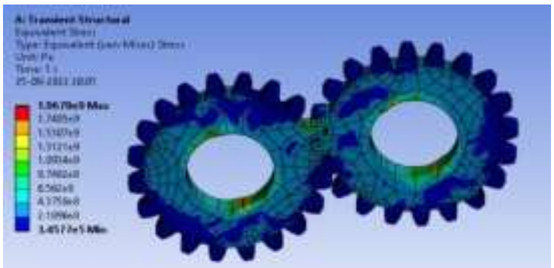

Fig. Q equivalent stress

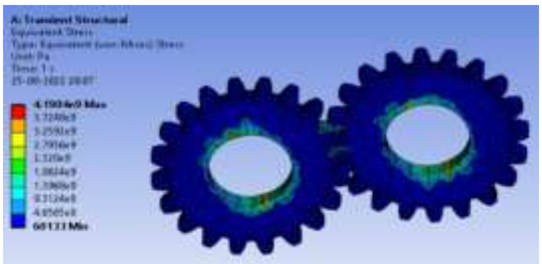

Fig. T equivalent stress

STAINLESS STEEL :

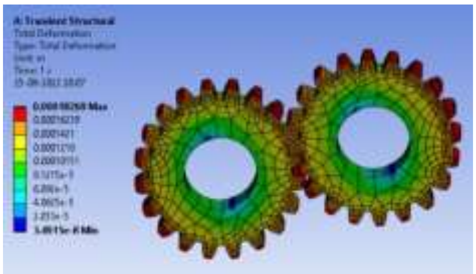

Fig.U total deformation

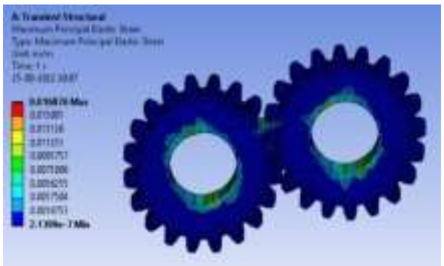

Fig.S maximum principle elastic strain

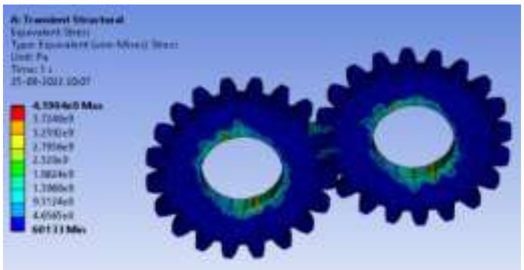

Fig. W equivalent stress

GRAY CAST IRON :

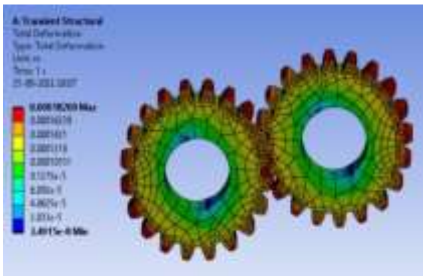

Fig. R total deformation

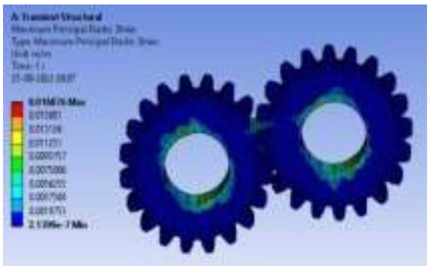

Fig. V maximum principle elastic strain

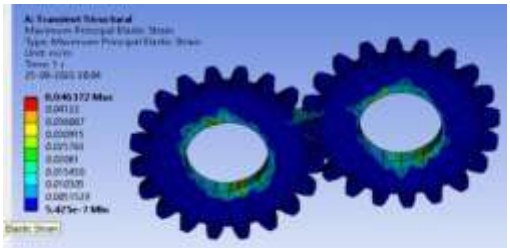

Fig. Y maximum principal elastic strain

ALUMINUM ALLOY :

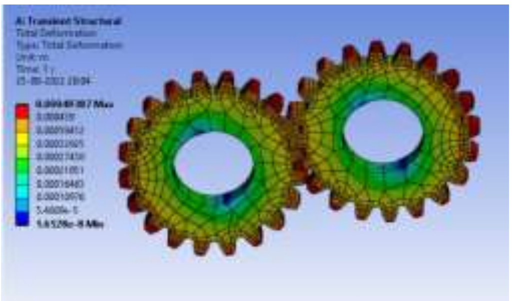

Fig. X total deformation

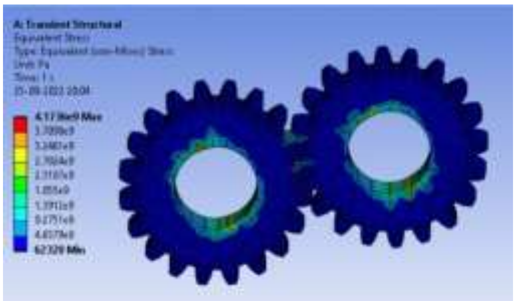

Fig.Z equivlent stress

V.CONCLUSION AND RESULTS

The Foregoing outcomes have endeavored to break down every one of the means which prompted total plan reenactment of stuff for added substance producing. The goal set was to mimic a practical part having equivalent execution and unwavering quality of the current one, yet in addition lighter than that. The fundamental instrument important to play out the errand was running various recreations.Though this technique for reproduction is a subject of study for quite a while, it ultimately acquired practicality because of added substance fabricating,by uprightness of defeating the assembling impediments which are presently allowed by this innovation. In this report total deformation, equivalent stress and maximum principal elastic strain in both static structural and transient structural of slm assembled ALSI10MG part is contrasted and different materials to be specific aluminum alloy,gray cast iron,stainless steel are considered and the outcomes closed underneath, states that the laser powder fabricated ALSI10MG is better

Description	Results	Units
Dimensions	**140 x 140 x 200**	mm
Laser	**250**	W
Build plate support	**40 x 90 x 40**	mm
Layer deposition height	**0.480**	mm
Maximum displacement	**1.257e+02**	mpa
Minimum displacement	**-4.3770E+01**	mpa
Cauchy Maximum positive stress	**1242**	mpa
Cauchy Minimum negative stress	**-480**	mpa
Trapped powder temperature Maximum	**70.2**	Degree celsius
Trapped powder temperature Minimum	**35**	Degree celsius
Hot spot volume Maximum	**0.6970**	
Hot spot volume Minimum	**0.0546**	
Lack of fusion below	**No lack fusion**	
Heat treatment Temperature	**880**	Degree celsius

Transient and static structural analysis :

The results when compared with the above said materials are tabulated below. Here we can observe that the aluminum alloy and alsi10mg have similar results and alsi10mg is far better than the remaining materials. So alsi10mg is lighter and can be preferred for the manufacturing of gear.

S.No	Materials for Gears	Strain Energy		Max. Principal Elastic Strain		Total Deformation (m)		Equivalent(Von-Mises) Stress (N/m^2)	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1	Stainless Steel	0.49547	2.6389 e^{-9}	0.016876	2.1399 e^{-7}	0.0018269	3.4915 e^{-8}	4.1904 e^{9}	60133
2	Gray Cast Iron	0.88196	3.8499 e^{-9}	0.029087	3.7973 e^{-7}	0.0003221	3.7148 e^{-8}	4.2105 e^{9}	57127
3	Al Alloy	1.3292	8.0326 e^{-9}	0.046372	5.425 e^{-7}	0.0004938	1.6528 e^{-8}	4.1736 e^{9}	62320
4	AlSi10Mg	1.3068	1.6077 e^{-7}	0.019958	1.1188 e^{-5}	0.0043848	3.0833 e^{-8}	1.9679 e^{9}	3.4577 e^{8}

Table of Transient structural Stress of various materials

S.No.	Materials for Gears	Max. Principal Elastic Stress		Total Deformation (m)		Equivalent(Von-Mises) Stress (N/m^2)	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1	Stainless Steel	0.016876	2.1399 e^{-7}	0.0005213	0.0004784	4.1904 e^{9}	60130
2	Gray Cast Iron	0.015623	4.7757 e^{-7}	0.0002216	9.8813 e^{5}	2.3346 e^{9}	1.8564 e^{5}
3	Al Alloy	0.046372	5.4249 e^{-7}	0.0010911	0.0009442	4.1736 e^{9}	62314
4	AlSi10Mg	1.7095 e^{9}	-3.7513 e^{8}	0.0118	0.010096	1.7359 e^{9}	3.6958 e^{5}

Table of Static Structural Stress

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