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Modeling And 3d Printing of Industrial Gear Box

Mrs. P. VARA LAKSHMI[1], B. AJAY KUMAR[2], A. SUBRAMANYAM[3], S. GANESH[4]

Assistant Professor, Dept. Of Mechanical Engineering, Gurunanak Institute Of Technology, Khanapur, India[1]

UG Scholars, Dept. Of Mechanical Engineering, Guru Nanak Institute Of Technology, Khanapur, India.[2,3,4]

Abstract: The Main Aim Of This Paper Is To Focus On The Mechanical Design On Assembly Of Gears In Gear Box When They Transmit Power At Different Speeds. Examination Is Additionally Directed By Differing The Materials For Gears, Aluminum Alloy And So On., By And By Utilized Materials For Riggings And Apparatus Shafts Is Solid Metal, Cast Steel. In This Paper To Supplant The Materials With Aluminum Material For Diminishing Weight Of The Item. Stress, Uprooting Is Investigated By Considering Weight Diminishment In The Rigging Box At Higher Speed. It's A Result Of Solid Works. In The Present Work Every One Of The Parts Of Differential Are Outlined Under Static Condition And Displayed. The Required Information Is Taken From Diary Paper.

Keywords: Mechanical Design ,Gear Assembly, Gearbox, Power Transmission, Aluminum Alloy, Cast Iron, Cast Steel, Material Optimization, Weight Reduction, Stress Analysis, Displacement Analysis, High-Speed Performance, Solidworks, Static Condition &Differential Modeling.

I. INTRODUCTION

INTRODUCTION OF TRANSMISSION

A transmission is a machine in a power transmission framework, which gives controlled use of the power. Regularly the term transmission alludes just to the gearbox that utilizations riggings and apparatus trains to give speed and torque transformations from a pivoting power source to another gadget.

In British English, the term transmission alludes to the entire drive prepare, including grasp, gearbox, prop shaft (for raise wheel drive), differential, and last drive shafts. In American English, in any case, the term alludes all the more particularly to the gearbox alone, and itemized use contrasts

The most well-known utilize is in engine vehicles, where the transmission adjusts the yield of the inward ignition motor to the drive wheels. Such motors need to work at a moderately high rotational speed, which is wrong to start, ceasing, and slower travel. The transmission diminishes the higher motor speed to the slower wheel speed, expanding torque all the while. Transmissions are likewise utilized on pedal bikes, settled machines, and where distinctive rotational rates and torques are adjusted.

Regularly, a transmission has various rigging proportions (or basically "gears") with the capacity to switch between them as speed fluctuates. This exchanging might be done physically (by the administrator) or naturally. Directional (forward and turn around) control may likewise be given. Single-proportion transmissions additionally exist, which just change the speed and torque (and once in a while heading) of engine yield.

In engine vehicles, the transmission for the most part is associated with the motor crankshaft through a flywheel or grasp or liquid coupling, somewhat in light of the fact that interior ignition motors can't keep running beneath a specific speed. The yield of the transmission is transmitted by means of the driveshaft to at least one differentials, which drives the wheels. While a differential may likewise give equip diminishment, its basic role is to allow the wheels at either end of a pivot to pivot at various rates (basic to evade wheel slippage on turns) as it alters the course of revolution.

Traditional apparatus/belt transmissions are by all account not the only instrument for speed/torque adjustment. Elective systems incorporate torque converters and power change (e.g. Diesel-electric transmission and water powered drive framework). Mixture designs additionally exist. Programmed transmissions utilize a valve body to change gears utilizing liquid weights in conjunction with an ecm.

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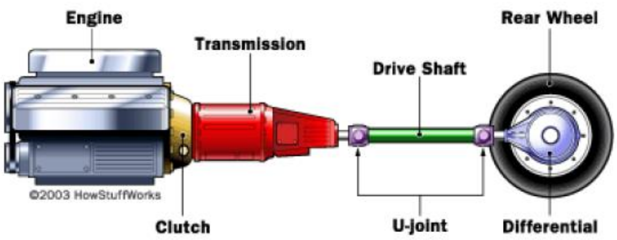

Figure 1. 1 Arrangement Of Power Transmission In Vehicle

1.1 Manual Transmission

Manual transmission to understand the basic idea behind a standard transmission, the figure 2 shows a very simple two-speed transmission in neutral:

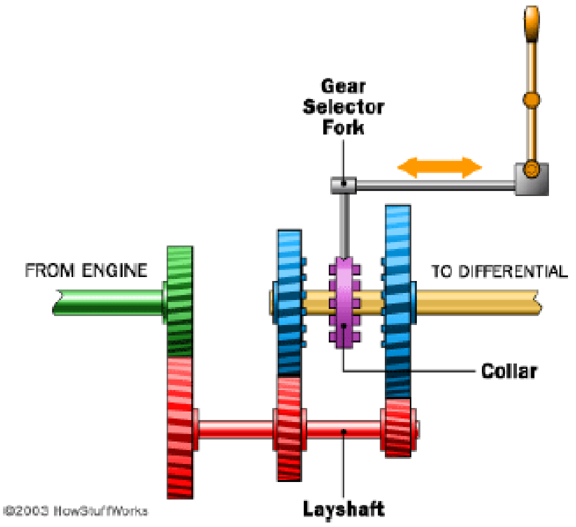

Figure 1. 2 Layout Of Transmission Of Vehicle

See at each of the parts in this chart to see how they fit together:
The green shaft originates from the motor through the grip. The green shaft and green rigging are associated as a solitary unit. (the grasp is a gadget that gives you a chance to associate and disengage the motor and the transmission. When you push in the grasp pedal, the motor and the transmission are disengaged so the motor can run regardless of the possibility that the auto is stopping. When you discharge the grip pedal, the motor and the green shaft are specifically associated with each other. The green shaft and apparatus turn at an indistinguishable rpm from the motor.)

The red shaft and apparatuses are known as the layshaft. These are additionally associated as a solitary piece, so the greater part of the riggings on the layshaft and the layshaft itself turn as one unit. The green shaft and the red shaft are specifically associated through their fit riggings so that if the green shaft is turning, so is the red shaft. Along these lines, the layshaft gets its energy straightforwardly from the motor at whatever point the grasp is locked in.

The yellow shaft is a splined shaft that interfaces straightforwardly to the drive shaft through the differential to the drive wheels of the auto. In the event that the wheels are turning, the yellow shaft is turning.

The blue apparatuses ride on course, so they turn on the yellow shaft. In the event that the motor is off however the auto is drifting, the yellow shaft can turn inside the blue apparatuses while the blue riggings and the layshaft are still.

The motivation behind the neckline is to interface one of the two blue riggings to the yellow drive shaft. The neckline is associated, through the splines, straightforwardly to the yellow shaft and twists with the yellow shaft. Nonetheless, the neckline can slide left or ideal along the yellow shaft to draw in both of the blue riggings. Teeth on the neckline, called puppy teeth, fit into openings on the sides of the blue apparatuses to connect with them.

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1. **1.1.1 First Gear**

Figure 3 demonstrate how, when changed into first gear, the neckline draws in the blue rigging on the privilege:

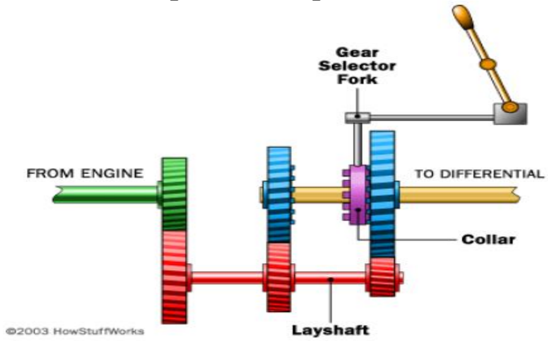

Figure 1. 3 First Gear Of The Transmission System

In this photo, the green shaft from the motor turns the layshaft, which turns the blue rigging on the privilege. This apparatus transmits its vitality through the neckline to drive the yellow drive shaft. In the mean time, the blue apparatus on the left is turning, however it is freewheeling on its bearing so it has no impact on the yellow shaft.

At the point when the neckline is between the two apparatuses (as appeared in the principal figure), the transmission is in unbiased. Both of the blue apparatuses freewheel on the yellow shaft at the diverse rates controlled by their proportions to the layshaft.

The 5 speed manual transmission for standard on auto today. The inside resemble the figure 4. Apparatus handle inside the auto is utilized to change the gear. There are three forks controlled by three poles that are locked in by the move lever. Taking a gander at the move bars from the best, they resemble this in switch, first and second apparatus:

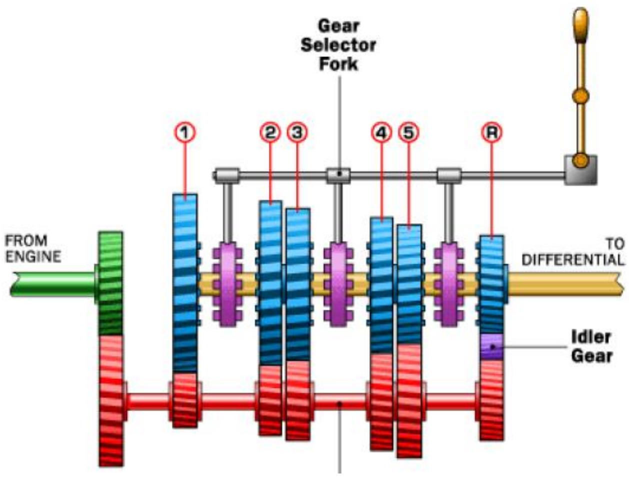

Figure 1. 4 Transmission System

1.2 Gear Ratio Concept and Analysis for Compound Gear

The manual transmission using the simple compound gears. The ratio for the overall gears is show at the equation 1.

Geometry relation (n3 /n2) = (n2/n3) = (d2/d3) .... (1.0)

Kinematic relation (ω2/ω1) = (n2/n3) = (α2/α1) …..……………... (1.1)

Where: n = rpm

- N = number of teeth (other books the symbol is t)
- D = pitch diameter
- Ω = angular velocity (rad/s)
- Α = angular acceleration (rad/s2)

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Condition (1) applies to any apparatus set regardless of whether the rigging are goad, helical, angle or worm. The total esteem sign are utilized to allow finish flexibility in picking positive and negative headings. For the situation the goads and parallel riggings, the bearings normally relate to the correct hand govern and are sure for counter-clockwise revolution. (shigley's : 2008). Basic apparatus prepare appear at figure 6, for the case the general rigging proportion is:

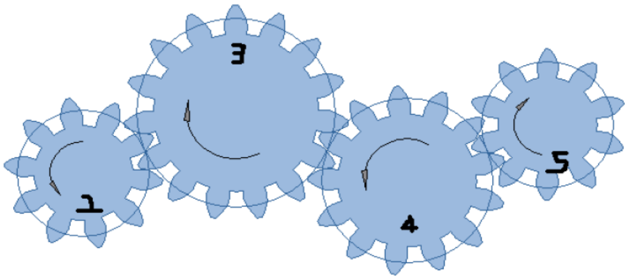

Figure 1. 5 Involute Gear

1.3. Gear Train

Representation from armed force benefit corps preparing on mechanical transport, (1911), fig. Transmission of movement and power by equip wheels, compound prepare

An apparatus prepare is a mechanical framework shaped by mounting gears on an edge with the goal that the teeth of the riggings lock in.

Apparatus teeth are intended to guarantee the pitch circles of connecting with gears move on each other without slipping, giving a smooth transmission of pivot starting with one rigging then onto the next.

The transmission of revolution between reaching toothed wheels can be followed back to the antikythera system of greece and the south-pointing chariot of china. Delineations by the renaissance researcher georgius agricola demonstrate equip trains with tube shaped teeth. The execution of the involute tooth yielded a standard rigging plan that gives a steady speed proportion.

Highlights of riggings and apparatus trains include:

- The proportion of the pitch circles of mating gears characterizes the speed proportion and the mechanical favorable position of the rigging set.
- A planetary apparatus prepare gives high rigging lessening in a minimal bundle.
  It is conceivable to configuration intend teeth for gears that are non-round, yet still transmit torque easily

	Engine	Economy speed	car speed	optimum	car speed	max power	car speed
	Ratio	3100 rpm	kmh	4400 rpm	kmh	6000 rpm	kmh
Gear 1	3.182	974.23	26.08	1382.78	37.02	1885.61	50.48
Gear 2	1.842	1682.95	45.06	2388.71	63.95	3257.33	87.21
Gear 3	1.25	2480.00	66.40	3520.00	94.24	4800.00	128.51
Gear 4	0.865	3583.82	95.95	5086.71	136.19	6936.42	185.71
Gear 5	0.75	4133.33	110.66	5866.67	157.07	8000.00	214.18
Reverse	3.143	986.32	26.41	1399.94	37.48	1909.00	51.11
differential	4.267						

Figure 1. 6 Table Of The Transmission Ratio And Speed

1.4. Uses

Gearboxes have discovered use in a wide range of frequently stationary applications, for example, wind turbines. Transmissions are likewise utilized as a part of rural, modern, development, mining and car hardware. Notwithstanding standard transmission furnished with gears, such hardware makes broad utilization of the hydrostatic drive and electrical flexible speed drives.

II. LITERATURE REVIEW

Dogan. [1] have examined the reason for rattling and clacking clamor and presumed that torsional vibration is the fundamental reason of vibration. For this examination, dogan has utilized basic gearbox geometry. This geometry comprise of just transmission packaging. The primary preferred standpoint of dogan examine is that he has begin reproducing such a perplexing geometry of transmission gearbox. He has utilized ekm reproducing program.

Abouel. [2] has performed comparative investigation on auto gearbox.

Abouel-seoud et al. [3] have utilized vibration reaction examination strategy for the explanatory investigation of auto gearbox framework. He has performed explanatory and test investigation of an auto transmission framework. By utilizing physical properties, he has ascertained the radiation effectiveness, and the vibration reaction was measured.

Vandi et al. [4] have introduced the execution of a streamlined motor driveline model to finish a current vehicle dynamic model. The motor model depends on maps which are communicated as capacity of motor speed and load.

Yu et al. [5] have considered the dynamic normal for the basic transmission gearbox packaging with limitation jolt position. Dim cast press ht200 was utilized as transmission packaging material. The fem based reproduction strategy was utilized and the reenactment result was confirmed with trial comes about. For test investigation the transmission packaging was imperative on a hanging base. The excitation was given utilizing hammer.

Lucente et al. [6] have considered the demonstrating of robotized manual transmission framework accommodating in displaying of manual transmission framework at starting stage.
Previously mentioned look into work was performed on basic geometry of transmission gearbox lodging. This work can be reached out to examination of full transmission gearbox gathering. Full transmission framework have gearbox and lodging and limited component examination (fea) recreation is performed on these segments.

Yu et al. [7] have contemplated the transmission gearbox lodging utilizing one material dim cast press ht200 as it were. The conceivable utilization of different materials like dim cast press fg 260, al composites and steel compounds aisi 4130 can be investigated.

Nacib et al. [8] have played out the disappointment examination of substantial gearbox of helicopters. To avert separate and mishap in helicopters equip blame recognition is critical. Range examination and cepstrum investigation strategy is utilized to distinguish harm outfit.

Gordon et al. [9] have considered the wellspring of vibration. A games utility vehicle with sensor and information securing framework is utilized to discover the vibration source. This examination was centered around vehicle vibration reaction from street surface highlights.

III. ANALYSIS AND DISCUSSION

INTRODUTION OF SOLIDWORKS

Solid works is a 3d solid showing group which empowers customers to develop full solid models in a copied space for both layout and examination. In solid works; you draw considerations and investigate diverse roads with respect to particular frameworks to make 3d models. Solid works is used by understudies, makers, engineers, and diverse specialists to convey clear and complex parts, assemblages, and delineations. Arranging in a showing group, for instance, solid works is profitable in light of the way that it saves time, effort, and money that would some way or another or another be spent prototyping the diagram. It is widely used in engineering, manufacturing, and product development industries. The software allows users to create complex models, assemblies, and drawings with precision and ease.

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3.1 Solid Works – Let's Begin

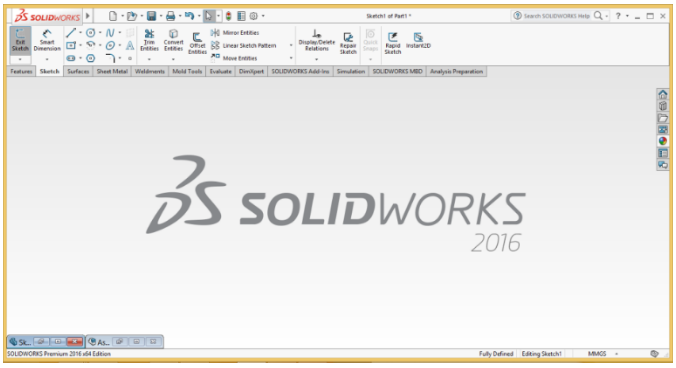

Figure 3. 1 Solid Works Default Page

1. Opening SolidWorks and Setting Up the Workspace

1. Launch SolidWorks.
2. Click on **New** and select the type of document:

- **Part** (for individual components)
- **Assembly** (to combine multiple parts)
- **Drawing** (for technical drawings)

➢ To create a new file, click on file - new or click the new file icon in the main toolbar.

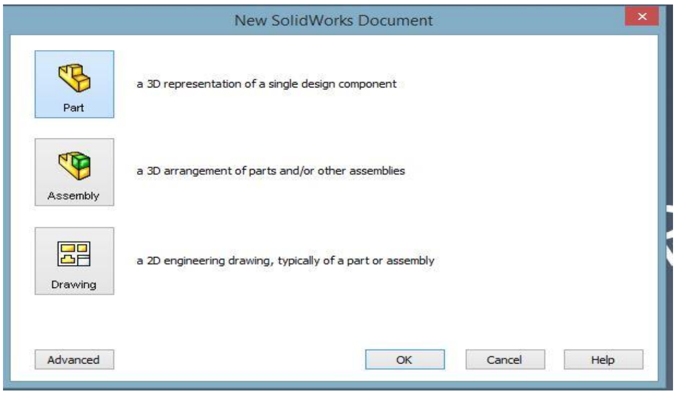

Figure 3. 2 Parts Of Solid Works

Key Features of SolidWorks:

- **3D Modeling**: Create detailed 3D models of components and assemblies.
- **Parametric Design**: Use dimensions and constraints to control design changes.
- **Simulation & Analysis**: Perform stress tests, motion analysis, and thermal analysis.
- **Sheet Metal & Weldments**: Design sheet metal components and welded structures.
- **Drawing & Documentation**: Generate 2D engineering drawings from 3D models.
- **Rendering & Animation**: Create realistic images and animations for presentations.

Step-by-Step Process to Use SolidWorks

3. Set up units (MMGS, IPS) and workspace preferences.

2. Creating a Basic Sketch

1. Click on **Sketch** from the toolbar.
2. Select a **Plane** (Front, Top, Right) to start the sketch.
3. Use sketch tools (Line, Circle, Rectangle, Arc) to create the desired shape.
4. Apply **dimensions** using Smart Dimension.

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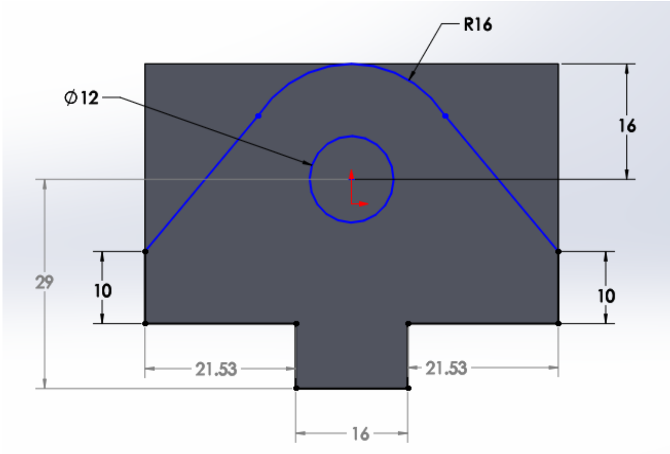
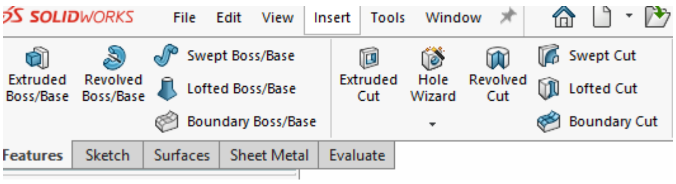


5. Use **relations** (horizontal, vertical, equal) to define constraints.
6. Click **Exit Sketch** when done.

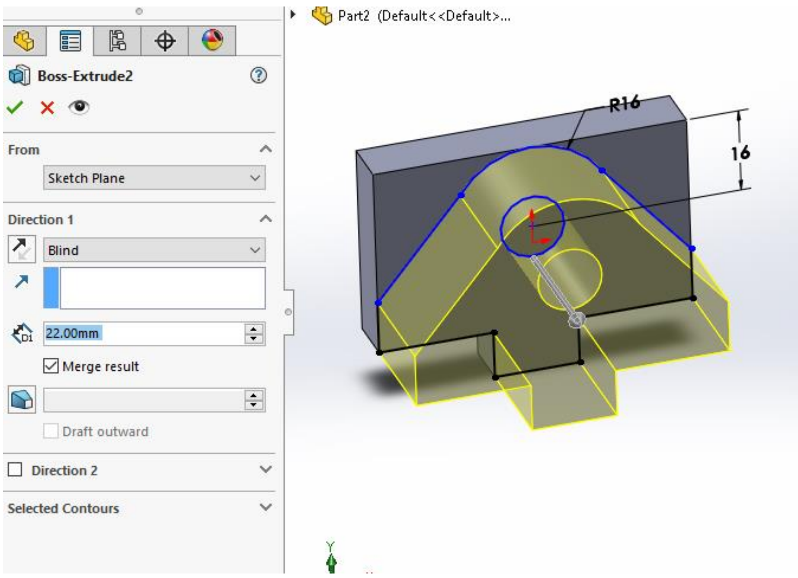
3. Extruding or Revolving the Sketch



2. Click on **Features** and select **Extrude Boss/Base** to add material.
3. Set the depth and direction for extrusion.
4. Alternatively, use **Revolve Boss/Base** for circular objects.
5. Click **OK** to complete the feature.

4. Modifying the 3D Model

1. Use **Fillet** or **Chamfer** to smooth edges.
2. Apply **Cut Extrude** to remove material.
3. Use **Shell** to create a hollow object.
4. Utilize **Pattern** (Linear, Circular) to replicate features.



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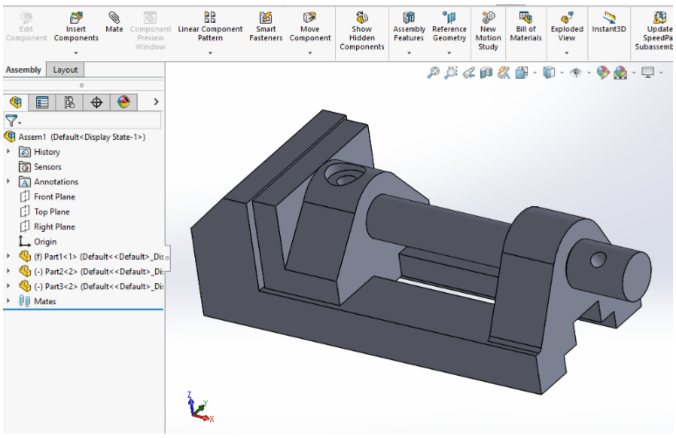
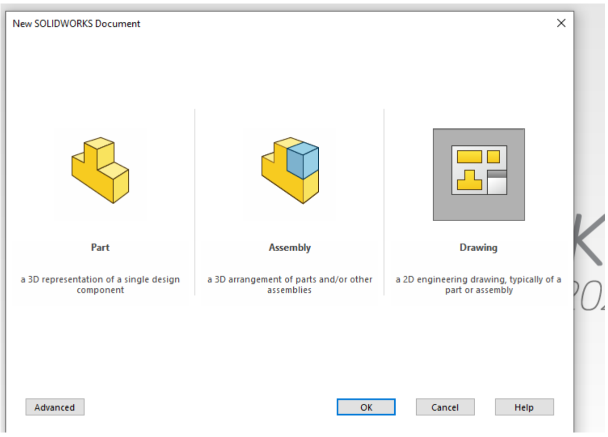
5. Assembling Components

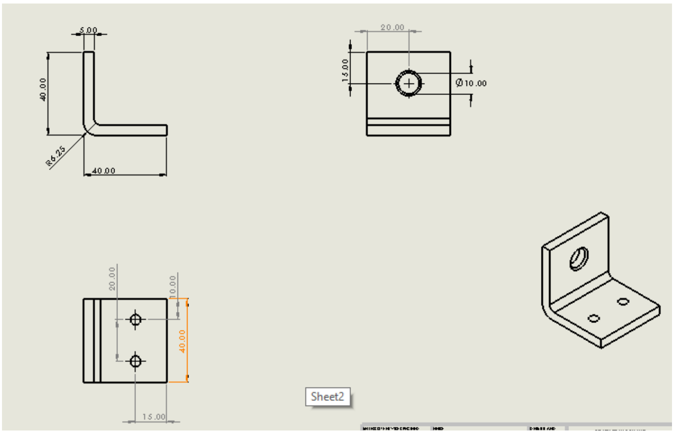
1. Open a new **Assembly** file.
2. Insert parts using **Insert Components**.
3. Apply **Mates** (Coincident, Concentric, Parallel) to define relationships.
4. Adjust position and alignment of components.
5. Save the assembly file.



6. Creating 2D Drawings

1. Open a new **Drawing** document.
2. Import the 3D model into the drawing.
3. Choose **Standard Views** (Front, Top, Right, Isometric).
4. Add **Dimensions**, **Annotations**, and **Title Block**.
5. Export as **PDF** or **DXF/DWG**.





7. Rendering and Animation

1. Use **Photoview 360** for realistic rendering.
2. Set up lighting, materials, and backgrounds.
3. Use **Motion Study** to create animations.
4. Export animations as videos for presentations.

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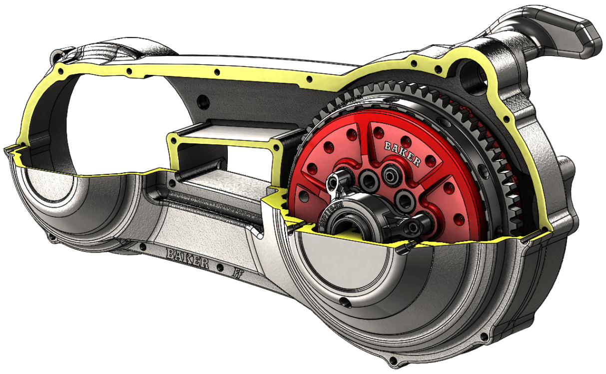

3.2. Modeling Of GEAR TRAINS

Working Principle

A two-gear industrial gearbox functions based on **meshing gears** to transfer motion and torque. The smaller driving gear (pinion) rotates and engages with the larger driven gear, altering the speed and torque output. The key principles include:

- **Speed Reduction**: A smaller driving gear and a larger driven gear result in reduced output speed and increased torque.
- **Torque Amplification**: The gear ratio determines the torque multiplication factor.
- **Direction of Motion**: The driven gear rotates in the opposite direction to the driving gear.

6. 3.2.1. Part 1-Shaft

➢ To design the body go to solid works software and open it. In solid work, select part module in new file then it will enter into part module.

➢ Later select that plane the click on sketch tools and create circle

➢ After that extrude tool and select circle as a profile and z line as a path.

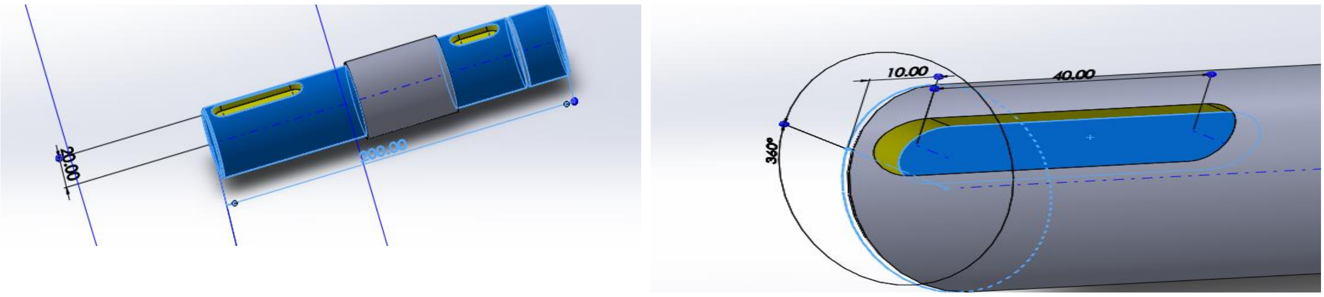

Figure 3. 3 Shaft

7. 3.2.2. Part 1-Gear

➢ To design the body go to solid works software and open it. In solid work, select part module in new file then it will enter into part module.

➢ Latr gog to tool import in library and select aisi standards and select in transmission

➢ Then select helical gear and specify as require in terms of ratios

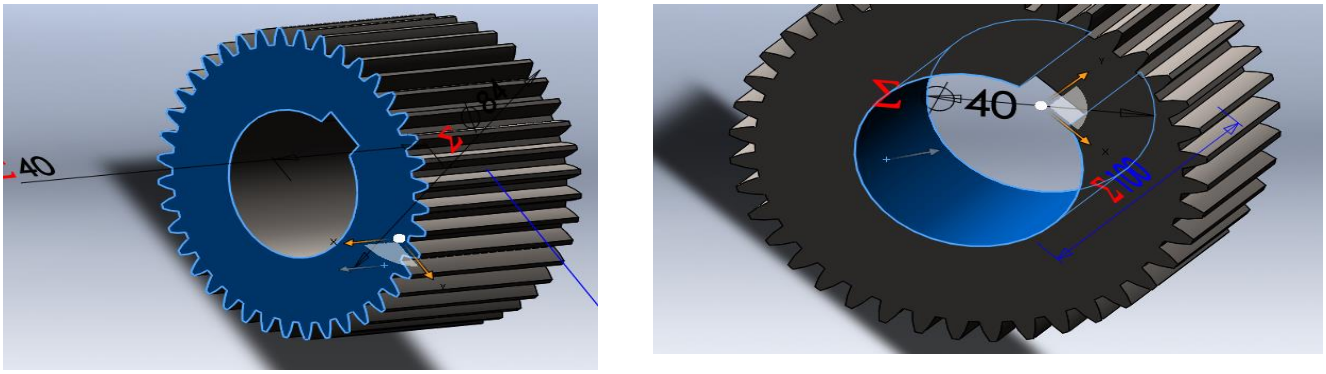

Figure 3. 4 Gear

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8. 3.2.3. Drivers Assembly

➢ To design the body go to solid works software and open it. In solid work, select part module in new file then it will enter into part module.

➢ Import bodies one by ones as shown in figure

Gear 2

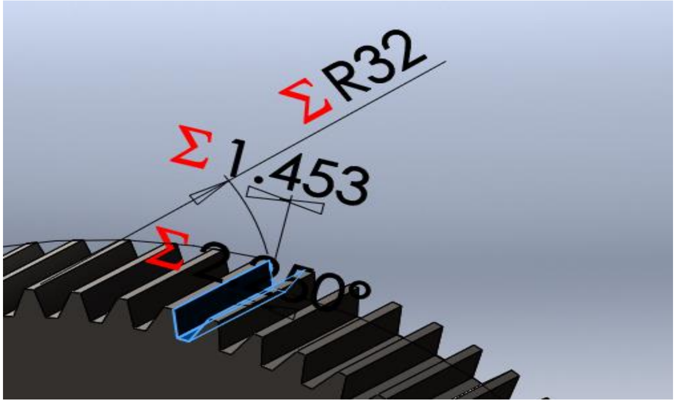

Figure 3. 5 Assembly Of Driven Transmission

9. 3.2.3. Driven Assembly

➢ To design the body go to solid works software and open it. In solid work, select part module in new file then it will enter into part module.

➢ Import bodies one by ones as shown in figure

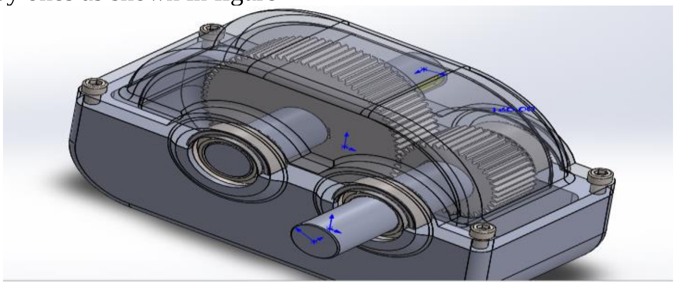

Figure 3. 6 Assembly Of Driver Transmission

10. 3.2.4. Assembly

➢ To design the body go to solid works software and open it. In solid work, select part module in new file then it will enter into part module.

➢ Import bodies one by ones as shown in figure

➢ Later go to pattern and select circular pattern and select above circle as a pattern item.

➢ Select above plane as a reference for pattern , specify 12 in number of pattern then ok

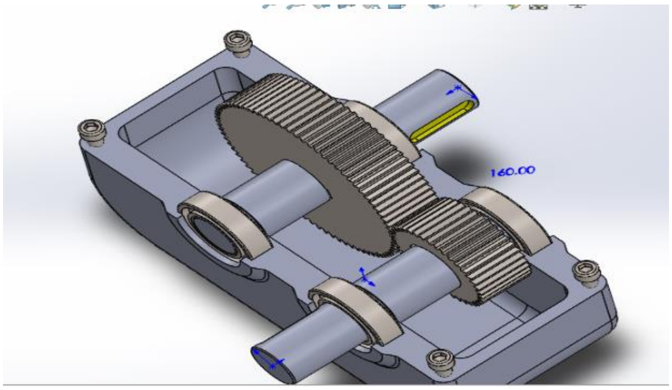

Figure 3. 7 Isometric View

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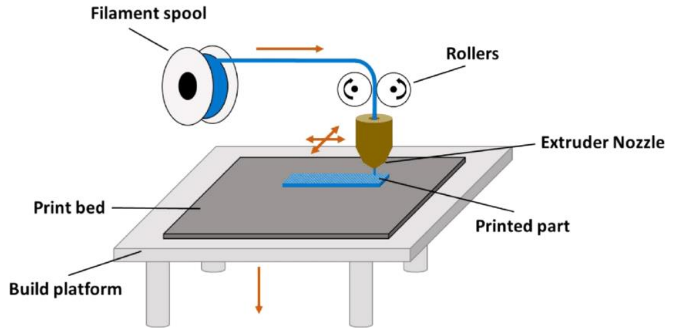
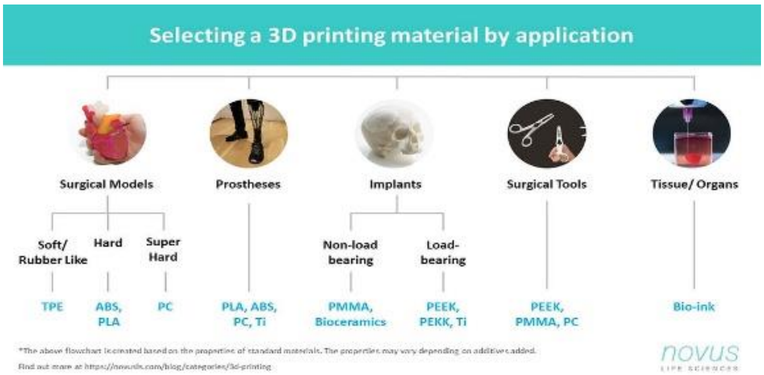
Introduction to 3D Printing

3D printing, also known as additive manufacturing, is a process of creating three-dimensional objects by depositing material layer by layer based on a digital design. It is used in various industries, including manufacturing, healthcare, automotive, and aerospace, due to its ability to create complex designs with high precision.



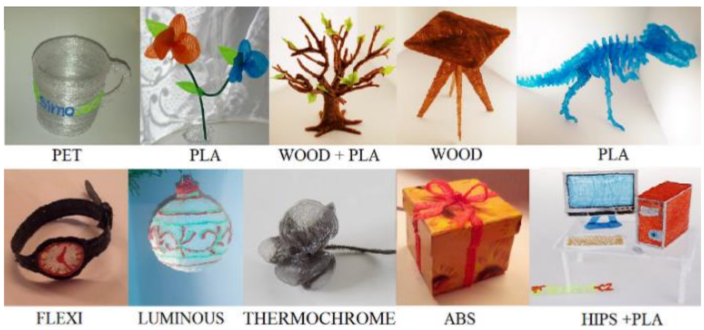
Materials Used in 3D Printing

Different types of materials are used in 3D printing depending on the technology and application. These materials include:



1. Plastics

- **PLA (Polylactic Acid)**: Biodegradable, easy to print, commonly used for prototyping and educational purposes.
- **ABS (Acrylonitrile Butadiene Styrene)**: Strong, durable, and heat-resistant; widely used in industrial applications.
- **PETG (Polyethylene Terephthalate Glycol-Modified)**: Tough, impact-resistant, and moisture-resistant; commonly used for food-safe applications.
- **Nylon**: Strong, flexible, and wear-resistant; used for functional parts and mechanical applications.
- **TPU (Thermoplastic Polyurethane)**: Flexible and rubber-like material used for soft, elastic components.



2. Resins (For SLA and DLP Printing)

- **Standard Resin**: Provides high detail and smooth finishes, used in prototyping and model-making.
- **Tough Resin**: Offers impact resistance and durability for functional parts.
- **Flexible Resin**: Used for rubber-like components and ergonomic designs.

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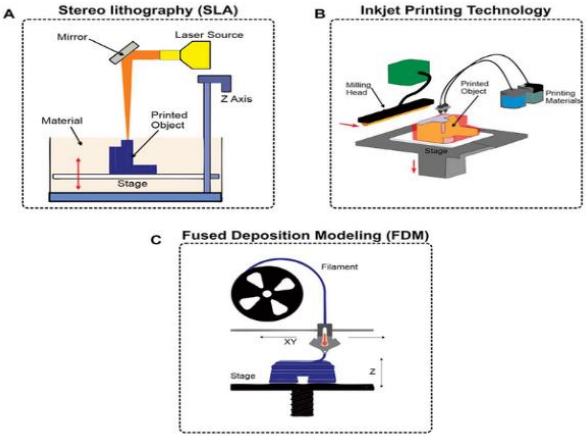
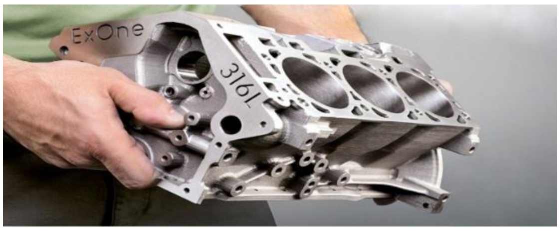
- **Dental and Medical Resin**: Biocompatible and used in medical applications such as dental aligners and prosthetics.
-



3. Metals

- **Stainless Steel**: Strong, corrosion-resistant, and used in aerospace, automotive, and medical industries.
- **Titanium**: Lightweight, strong, and biocompatible; used in aerospace and medical implants.
- **Aluminum**: Lightweight and corrosion-resistant; used in industrial and automotive applications.
- **Gold & Silver**: Used for jewelry and decorative items.



4. Ceramics

- Used for creating heat-resistant components, artistic applications, and biomedical implants.

5. Composites and Advanced Materials

- **Carbon Fiber Reinforced Filament**: Provides high strength-to-weight ratio and is used in aerospace and automotive parts.

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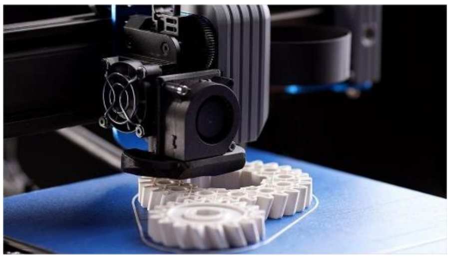
- **Glass Fiber Reinforced Filament**: Used for impact-resistant and high-strength applications.
- **Wood Filament**: A blend of PLA and wood fibers, used for aesthetic and artistic models.

6. Powders (For SLS and Binder Jetting)

- **Nylon Powder**: Used for industrial prototyping and functional parts.
- **Metal Powders**: Used in powder bed fusion technologies for metal part production.
- **Ceramic Powders**: Used in high-temperature applications and biomedical implants.



Key Features of 3D Printing:

- **Rapid Prototyping**: Quickly create prototypes for testing and development.
- **Customization**: Easily produce customized objects without additional costs.
- **Material Efficiency**: Reduces waste compared to traditional manufacturing methods.
- **Complex Geometries**: Enables the creation of intricate and detailed designs.
- **Cost-Effective**: Reduces production costs for small-batch manufacturing.

Step-by-Step Process of 3D Printing

1. Designing the 3D Model

1. Use 3D modeling software such as **SolidWorks, AutoCAD, Fusion 360, or Tinker cad**.
2. Create a digital design or modify an existing 3D model.
3. Ensure the model is properly scaled and dimensioned.
4. Save the file in a compatible format like **STL, OBJ, or AMF**.
5.

2. Preparing the 3D Model for Printing

1. Import the model into **slicing software** (e.g., Cura, PrusaSlicer, or Simplify3D).
2. **Configure print settings:**
- Layer height (resolution)
- Infill percentage (density)
- Support structures (for overhangs)
- Print speed and temperature settings
3. Generate the G-code file for the 3D printer.

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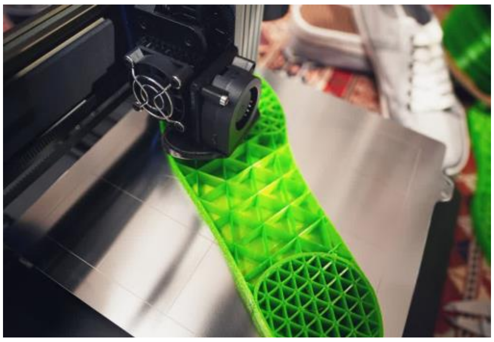
3. Setting Up the 3D Printer

1. Choose the appropriate **3D printing technology**:
- **FDM (Fused Deposition Modeling)** – Uses thermoplastic filament.
- **SLA (Stereolithography)** – Uses liquid resin and UV light.
- **SLS (Selective Laser Sintering)** – Uses powdered material and a laser.
2. Load the required material (filament, resin, or powder) into the printer.
3. Calibrate the print bed to ensure proper adhesion and leveling.
4.

4. Printing the Model

1. Transfer the G-code file to the printer via **USB, SD card, or Wi-Fi**.
2. Start the print job and monitor the first few layers for proper adhesion.
3. Allow the printer to complete the process (can take minutes to hours depending on complexity).
4. Avoid disturbing the printer during operation to prevent errors.
5.



5. Post-Processing the Print

1. **Remove the Print**: Carefully detach the printed object from the print bed.
2. **Cleaning**:
- Remove any support structures.
- Sand or smooth rough edges if necessary.
-

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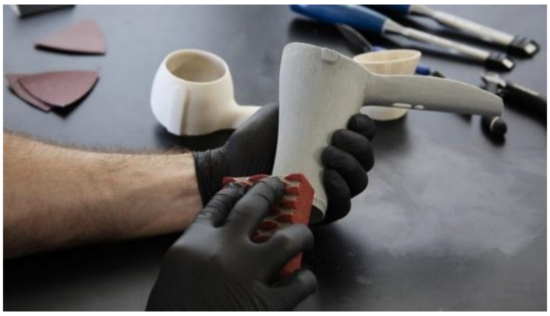
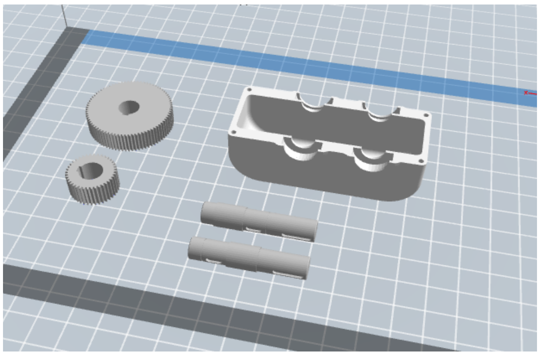
3. **Finishing Options**:
- **Painting**: Use acrylic or spray paint for enhanced aesthetics.
- **Polishing**: Apply a chemical or mechanical finish for smooth surfaces.
- **Assembly**: Join multiple parts if the model is printed in sections.



6. Quality Inspection and Testing
1. Check dimensions and accuracy using calipers or measurement tools.
2. Perform functional tests if the object has moving parts.
3. Identify and correct any defects for reprinting if necessary.

7. Applications of 3D Printing
- **Medical**: Prosthetics, dental implants, and tissue engineering.
- **Automotive & Aerospace**: Lightweight parts and custom components.
- **Education**: Teaching tools and architectural models.
- **Consumer Goods**: Jewelry, footwear, and home decor.



PLA (Polylactic Acid)
- **Pros**: Biodegradable, easy to print, no toxic fumes, good detail.
- **Cons**: Brittle, low heat resistance, not suitable for mechanical parts.
- **Applications**: Prototyping, toys, educational models, decorative items.

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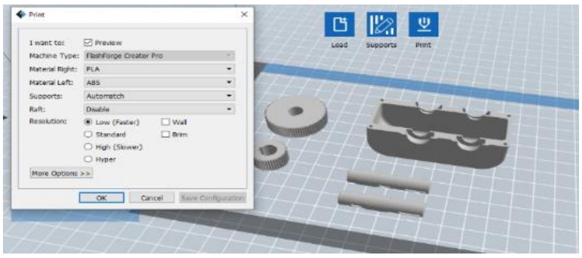
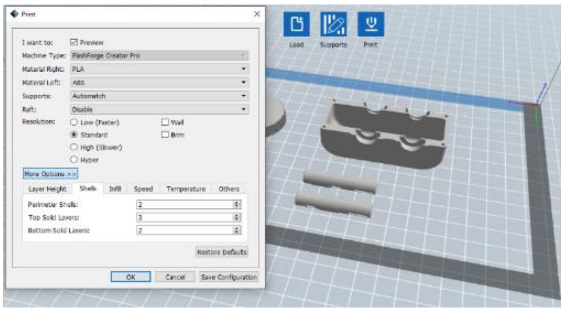
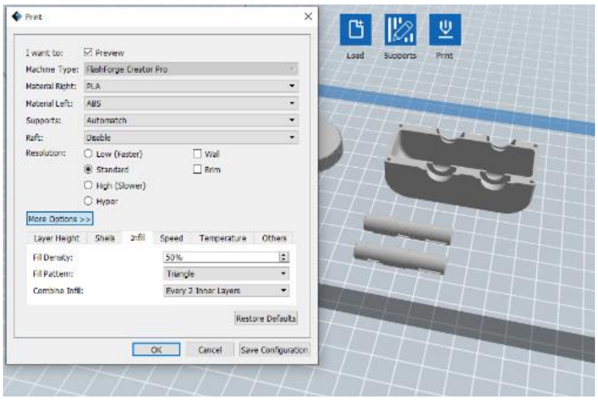


A **shell** consists of the **outer walls and perimeters** of a 3D-printed object. It acts as a protective layer surrounding the **infill** and determines the overall durability of the print.

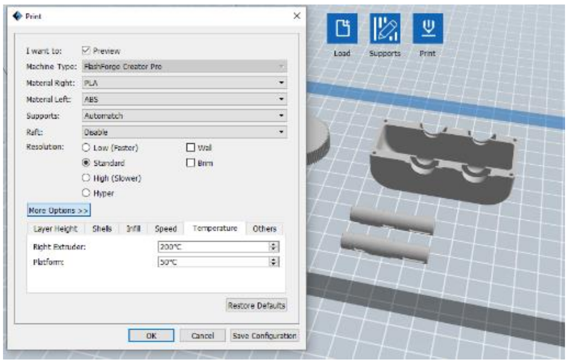


Standard: 1.2 mm (3 perimeters at 0.4 mm nozzle size)
For Strength: 2.4 mm or more (6 perimeters)
For Lightweight Prints: 0.8 mm (2 perimeters)



Infill density is measured as a **percentage (%)** representing how much of the internal volume is filled with material.

- **0% Infill** → Hollow print
- **100% Infill** → Completely solid print
- **Typical range**: **10% - 50%**, depending on strength requirements
-



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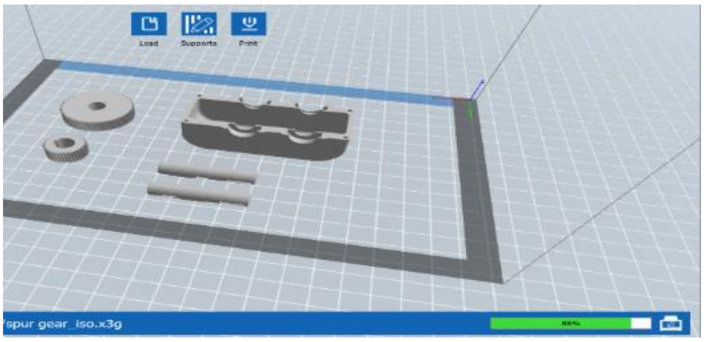
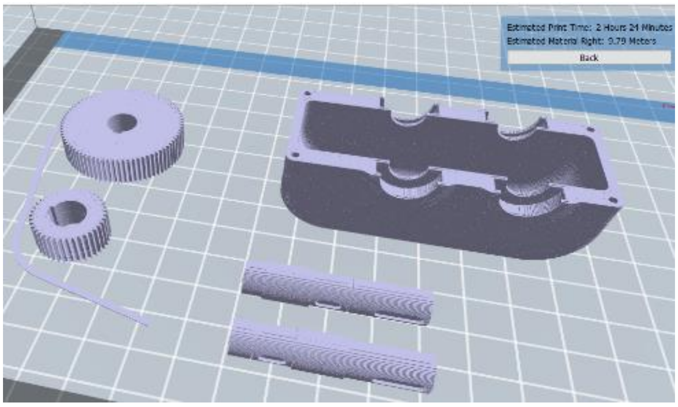
Temperature plays a **crucial role** in 3D printing, affecting **print quality, adhesion, strength, and material properties**. It includes settings for the **hot end (nozzle), heated bed, and cooling fan**.



Slicing is the process of converting a **3D model (STL, OBJ, or 3MF file)** into machine-readable **G-code** for a 3D printer. The **slicer software** translates the model into **thin layers (slices)** and generates the necessary movement instructions for the printer.



IV. RESULTS AND DISCUSSION

4.1. 3D MODELLING OF THE INDUSTRIAL GEARBOX

The gearbox was modelled using [e.g., SolidWorks/AutoCAD/Fusion 360] based on industrial specifications. The model included key components such as the gear train, casing, shaft, bearings, and fasteners. Special attention was given to gear tooth profiles, shaft alignment, and casing clearances. Parametric design facilitated modifications and ensured accurate assembly constraints.

The final model was validated using motion simulation tools within the CAD environment to ensure proper meshing and rotational synchronization of gears. Exploded views and cross-sectional renderings were used to verify internal component fit.

4.2. 3D PRINTING PROCESS

The model was exported in STL format and sliced using [e.g., Cura/PrusaSlicer]. Printing was carried out using an FDM printer ([e.g., Creality Ender 3, Prusa i3 MK3S]) with PLA as the primary material due to its ease of use and cost-effectiveness. Support structures and infill patterns were optimized to reduce print time and material usage.

Key print settings included:

Layer height: 0.2 mm
Infill: 20% (grid pattern)
Nozzle temperature: 200°C
Bed temperature: 60°C
Printing time for the full gearbox assembly was approximately [X] hours. Post-processing involved support removal, light sanding, and assembly using screws or snap-fit joints.

4.3. RESULTS EVALUATION

The assembled 3D printed gearbox closely resembled the CAD model, with tolerances maintained within ±0.5 mm. Moving parts (e.g., gears, shafts) operated smoothly, although minor friction was observed due to the limitations of FDM-printed surface finishes.

Observations:

Gears successfully transmitted motion under light loads, demonstrating proof-of-concept functionality.
Gear backlash was slightly higher than expected, attributed to resolution limits and PLA shrinkage.
The casing aligned well, and all fasteners fit without significant adjustments.
Weight and cost of the model were significantly lower than a metal prototype, making it suitable for educational and visualization purposes.

Limitations:

PLA is not suitable for high-load or high-temperature environments.
Print resolution and material limitations affect the accuracy of gear teeth profiles.
Mechanical properties are not representative of actual industrial materials.

4.4. DISCUSSION

The project demonstrated the feasibility of using 3D printing for the rapid prototyping of complex mechanical systems such as gearboxes. While the printed gearbox is not suitable for real-world industrial applications, it serves as a valuable tool for design validation, educational demonstrations, and iterative development.

Future work could explore printing using higher-strength materials (e.g., nylon, PETG, resin) or using SLS/SLA printing for improved accuracy. Tolerance compensation techniques and post-print machining could also improve functional performance.

V. CONCLUSION

A two-gear industrial gearbox is a fundamental yet essential component in power transmission systems. Its design allows for efficient speed control, torque amplification, and direction changes in various industrial applications. Using **SolidWorks**, engineers can accurately model, analyze, and optimize gearboxes for enhanced performance and durability. Proper lubrication, alignment, and material selection ensure the longevity and efficiency of the gearbox in industrial operations.

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B. Ajay Kumar (22835a0306)
A. Subramanyam (22835a0302)
S. Ganesh (22835a0342)

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