Design, Analysis and Manufacturing of Planetary Gear System by using Rapid Prototype Technique used as Clock Mechanism

K. Sambhavi1 K. Aruna Prabha2

1,2VNR Vignana Jyothi Institute of Engineering & Technology, Bachupally, Nizampet, Telangana, India

Abstract— Rapid prototype is also known as additive manufacturing or 3d printing. Construction of the part or assembly is usually done using rapid prototype technology. With the use of this technology creating and printing the functional end usable parts is directly done from our office, home, collage or any other place with the help of computer and 3D printing machine. The use of rapid prototype technique is becoming more popular in mechanical industries, ornaments and jewelers making industries, medical, educational institutes, fashion industries, food industries, for creation of new models and for many other purposes. This project deals with design, analysis and manufacturing of prototype of complex virtually unlimited internal and external geometry of planetary gear wheel which is used in clock mechanism by using the technology of rapid prototype. To design the model of the prototype CATIA is used where CATIA stands for Computer Aided Three-dimensional Interactive Application. It is the most powerful and widely used CAD (computer aided design) software of its kind in the world, CATIA plays a major role in the design process. In mechanical engineering CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing. CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. Here to design the gear consideration of input parameters such as number of gear’s teeth, Gear diameter are taken and then it is modeled. After modeling is done then analysis is done using ANSIS software. ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment. ANSYS can import CAD data and also enables to build geometry with its "preprocessing" abilities. Similarly in the same preprocessor, finite element model which is required for computation is generated. After defining loadings and carrying out analyses, results can be viewed as numerical and graphical. ANSYS can carry out advanced engineering analyses quickly, safely and practically by its variety of contact algorithms, time based loading features and nonlinear material models. To analysis the model which is designed by using CATIA need some input parameters like angular velocity, moment etc. Finally after these processes manufacturing of model of planetary gear is done using 3D printing machine with the help of rapid prototype techniques.

Key words: Designing, Analysis, Manufacturing

I. INTRODUCTION

A. Introduction to Planetary Gear

Planetary gearbox is widely used in industrial machineries and machine tools to obtain speed reduction, which in turn increases the torque. These gearboxes are used in many applications such as power transmission system and hybrid transmission systems. Planetary gear trains are one of the main subdivisions of the simple planetary gear train arrangement. The Planetary gear train arrangement in general has a central “sun” gear which meshes with and is surrounded by planet gears. The outer most gear, the ring gear, meshes with each of the planet gears. The planet gears are held to a cage or carrier that fixes the planets in orbit relative to each other. Planetary gear is a widely used industrial product in mid-level precision industry, such as printing lathe, automation assembly, semi-conductor equipment and automation system. Planetary gearing could increase torque and reduce load inertia while minimized the speed.

To compare with conventional gearbox, planetary gear box has several advantages. One advantage is its unique combination of both compact arrangement and outstanding power transmission efficiencies. A typical efficiency loss in a planetary gearbox arrangement is only 3% per stage. This type of efficiency ensures that a high proportion of the energy being input is transmitted through the gearbox, rather than being wasted on mechanical losses inside the gearbox. Another advantage of the planetary gearbox arrangement is load distribution. Because the load being transmitted is shared between multiple planet gear, torque capability is greatly increased. Higher load ability, as well as higher torque density is obtained with more planet gear in the system. The planetary gearbox arrangement also creates greater stability due to the even distribution of mass increased rotational stiffness.

Fig. 1: Planetary Gear System.
B. Introduction to CATIA

CATIA (Computer Aided Three-Dimensional Interactive Application) started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CAD/CAM CAD software to develop Dassault's Mirage fighter jet. It was later adopted in the aerospace, automotive, shipbuilding, and other industries.

CATIA is the leading product development solution for all manufacturing organizations, from OEMs (original equipment manufacturer), through their supply chains, to small independent producers. The range of CATIA capabilities allows it to be applied in a wide variety of industries, such as aerospace, automotive, industrial machinery, electrical, electronics, shipbuilding, plant design, and consumer goods, including design for such diverse products as jewelry and clothes.

CATIA is the only solution capable of addressing the complete product development process, from product concept specification through product-in-service, in a fully integrated and associative manner. Based on an open, scalable architecture, it facilitates true collaborative engineering across the multidisciplinary extended enterprise, including style and form design, mechanical design and equipment and systems engineering, managing digital mock-ups, machining, analysis, and simulation. By enabling enterprises to reuse product design knowledge and accelerate development cycles, CATIA helps companies to speed-up their responses to market needs thing. Much beyond pure CAD software packages, which provide geometry modeling features for design-centric companies, CATIA delivers the keys to PLM (Product lifecycle management) for process-centric companies:

- Product to market. CATIA is about product creation. From the earliest product concept to production tooling, its concurrent engineering and design-in-context capabilities create value by enabling companies to create products and bring them to the market.
- Time to market. The unequalled process coverage of CATIA, combined with the native associatively among all of its applications, gives CATIA customers the means to shorten the time to market.
- Right to market. CATIA's integrated analysis, simulation, synthesis, and optimization applications provide product engineering validation at each design step to ensure product quality and market acceptance.
- Lead the market. CATIA's advanced capabilities for collaborative engineering, knowledge capture, and re-use boost innovation and help to lead the market.

<table>
<thead>
<tr>
<th>Name/Version</th>
<th>Version</th>
<th>Release Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATIA V5</td>
<td>R</td>
<td>1998</td>
</tr>
<tr>
<td>CATIA V6</td>
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<tr>
<td>CATIA V6</td>
<td>R</td>
<td>2014</td>
</tr>
</tbody>
</table>

Table 1: Release History Of Catia.

C. Introduction to ANSYS

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.

So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment.

ANSYS software with its modular structure as seen in the graph below gives an opportunity for taking only needed features. ANSYS can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules.

Fig. 2: Graph of ANSYS Software with Its Modular Structure

ANSYS can import CAD data and also enables to build geometry with its "preprocessing" abilities. Similarly in the same preprocessor, finite element model which is required for computation is generated. After defining loadings and carrying out analyses, results can be viewed as numerical and graphical.

ANSYS can carry out advanced engineering analyses quickly, safely and practically by its variety of contact algorithms, time based loading features and nonlinear material models.

II. RELATED WORK

This project is to design the model of planetary gear using cad software CATIA V5R20 and analysis the model using ANSYS R15 and to be manufactured with the help of rapid prototype technique by using 3D printing machine to show the mechanism of the planetary gear in clock mechanism.

III. SCOPE OF PROJECT

This project unveils and outlines the use and ease of design, analysis and manufacturing of planetary gear by rapid prototype techniques. With this knowledge designing and manufacturing of new models in many fields like medical, educational institutes, fashion technology, manufacturing industries, food industries and many more with their requirement model can be printed.
IV. DESIGNING, ANALYSIS AND MANUFACTURING OF PLANETARY GEAR METHODOLOGY AND DISCUSSION.

A. Design of planetary gear with the help of CAD software CATIA

Modeling of planetary gear is carried out using CATIA V5R20, an advanced CAD software.

1) Designing gear using CATIA:

Start CATIA, select mechanical design in start menu and in mechanical design select part design.

In the part design, name the part as sun gear.

Select formulas [f(x)] icon, in formulas menu select new parametric type icon as Real type and name it as “N” i.e. number of teeth in sun gear with value 10. And add the other parameter as length with name “M” i.e. module of value 2. In same process “P_R” as name i.e. pitch radius of the sun gear and with the value 20/2=10mm.

In same process clearance circle radius CR is named and formula CR=0.94 x “P_R” is added. Similarly addendum circle radius and dedendum circle radius with name “R_A” and “R_D” with formulas R_A=P_R+M and R_D=P_R-(1.25 x M) are added.

With adding of parameters the list of parameters and their values are formed automatically.

Applying these parameters to work bench started with selecting the plane YZ. Two circles PR and CR are drawn with origin as center by applying parameter from formula editor so that the radius of two circles will be adjusted automatically and will be constrained.

Two construction lines L1 and L2 with starting points as the centre of the circles are drawn with angle between them 20° and one more vertical line L3 is drawn between these two line with the angle with respect to the line L1 is 90/N x 1°. Circle is drawn by taking the center as the point where other line L3 coincides with CR circle up to the point where L1 coincides with PR circle. Two circles R_A and R_D are drawn with the center as origin by applying parametric formula editor. Half tooth profile is formed by trimming the unwanted parts and by using fillet with of radius 0.39 x M fillet is made between tooth profile and dedundum circle. By using mirror option the tooth profile is mirrored with respect to line L1. The point of the mirrored profile of the tooth and the circle is coincided. With this, first teeth of sun gear is formed remaining 9 are formed by using circular pattern command where the parameter is complete crown, instances are 10, reference element is X axis. Exist sketch using pad command mirror extend up to 8mm each side solid model of sun gear with 10 teeth is designed in similarly process all the remaining parts of planetary gear are modeled using CATIA.

![Fig. 3: Design of sun gear using CATIA.](image)

2) Tabulated form of required input parameters to design the model of planetary gear

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Sun Gear</th>
<th>Planet Gear</th>
<th>RING GEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number Of Teeth</td>
<td>10</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Pressure Angle</td>
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<td>20°</td>
</tr>
<tr>
<td>Pitch Diameter</td>
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</tr>
<tr>
<td>Addendum</td>
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<tr>
<td>Sub</td>
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<tr>
<td>Dedendum</td>
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<td>Sub</td>
<td>1.0m</td>
<td>1.0m</td>
<td>1.0m</td>
</tr>
</tbody>
</table>

Table 2: Tabulated form of required input parameters to design the model of planetary gear

B. Analysis of Planetary Gear using ANSYS

Analysis of the model is done by ANSYS R15 software. ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment. ANSYS can import CAD data and also enables to build geometry with its “preprocessing” abilities. Similarly in the same preprocessor, finite element model (a.k.a. mesh) which is required for computation is generated. After defining loadings and carrying out analyses, results can be viewed as numerical and graphical. ANSYS can carry out advanced engineering analyses quickly, safely and practically by its variety of contact algorithms, time based loading features and nonlinear material models. To analysis the model we need some input parameters like angular velocity, moment etc.
Manufacturing of Planetary Gear using Rapid Prototype Technique by using 3D Printer

Manufacturing of planetary gear is done by using rapid prototype technique using 3D printer. 3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the entire object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object. It all starts with making a virtual design of the object you want to create. This virtual design is made in a CAD (Computer Aided Design) file using a 3D modeling program or with the use of a 3D scanner. A 3D scanner makes a 3D digital copy of an object.

Here to print (manufacture) the models by using the 3d printer we need to convert CAD file to STL file format so the input parameters for printing the models are CAD drawings in STL format.
V. FUTURE RECOMMENDATIONS

There are several future recommendations that should be considered they are:

- To study and development of model of planetary gear.
- Development of the planetary gear by considering various parameters according to the need of mechanism.
- Creating the model by using the CATIA as a tool with proper parameters.
- Identification of the bottlenecks and other issues in the printing the model while creating the model in CATIA and according to that designing is optimized.

VI. CONCLUSION

In conclusion, the model that is design and manufactured is in working state, that is, the planetary gear which is manufactured using CAD software (CATIA V5R20) to design, ANSYS R15 software to analysis and rapid prototype technique to print the model by 3d printing machine, to show the mechanism of clock is able to work with the desired functions. This prototype of planetary gear can be applied to the clock mechanism in real time with the same values or can also change according to their requirements by using this procedure as guidelines. This model of planetary gearing system is which is manufactured using rapid prototype achieves high reduction ratio and it is smaller and light in weight.

REFERENCES

