International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 4, October 2014

Research Paper

DESIGN, MODELLING AND ANALYSIS OF A 3 STAGE EPICYCLIC PLANETARY REDUCTION GEAR UNIT OF A FLIGHT VEHICLE

K Akhila[1]* and M Amarnath Reddy[2]

*Corresponding Author: K Akhila, ✉ akhila.kakera@yahoo.com

In this project, a three stage epicyclic planetary reduction gear unit is designed to meet the output specifications. All the components are modelled in CATIA to check the assembly and the interference. The modelled components are used for analysis to check for their strength. Heavy vehicles consists of four control surfaces for steering and stabilization purpose. The control surface are to be rotated depending upon the requirement of the system. This rotation of control system is achieved through actuators. Actuators can be of different types. They are pneumatic, hydraulic and electro-mechanical. In the present project, we use electro mechanical actuators. Electro-mechanical actuators basically consists of prime mover, motor and transmission mechanism. This transmission system can be screw type or gears type. In this project, we use gear type of transmission system, which is designed depending upon the requirement. Generally motor rotates with very high speed and low torque. But the final requirement is “low speed and high torque”. This is achieved by connecting a reduction gear unit which reduces the speed and increases the torque. Planetary gear is one of the epicyclic gear, which is a gear system consisting of One or more outer gears, or planet gears, revolving about a central, or sun gear. And it can be wildly used in industry, such as printing lathe, automation assembly, and semiconductor equipment and automation system since its commercial value. Our project is aimed to build a 3D model of multiple layers of planetary gear by Using Catia software.

Keywords: Epicyclic planetary reduction, CATIA software, Actuators

INTRODUCTION

Necessity of Epicyclic Planetary Reduction Gear in Flight

A speed reduction unit is a gearbox or a belt and pulley device used to reduce the output revolutions per minute (rpm) from the higher input rpm of the power plant. This allows the use of small displacement internal combustion automotive engines to turn aircraft propellers within an efficient speed range.

[1] M.Tech Student, Department of Mechanical Engineering, Mallareddy College of Engineering & Technology, Jawaharlal Nehru Technological University, Hyderabad, India.

[2] Associate Professor, Department of Mechanical Engineering, Mallareddy College of Engineering & Technology, Jawaharlal Nehru Technological University, Hyderabad, India.

History and Operation

The Wright brothers recognised the need for propeller reduction gearing in 1903, but it was not generally used on aircraft engines until larger engines were designed in the 1920s. Large engines with high crankshaft speeds and power outputs demanded propeller reduction, pilots noted the increase in performance of similar aircraft fitted with reduction gearing.

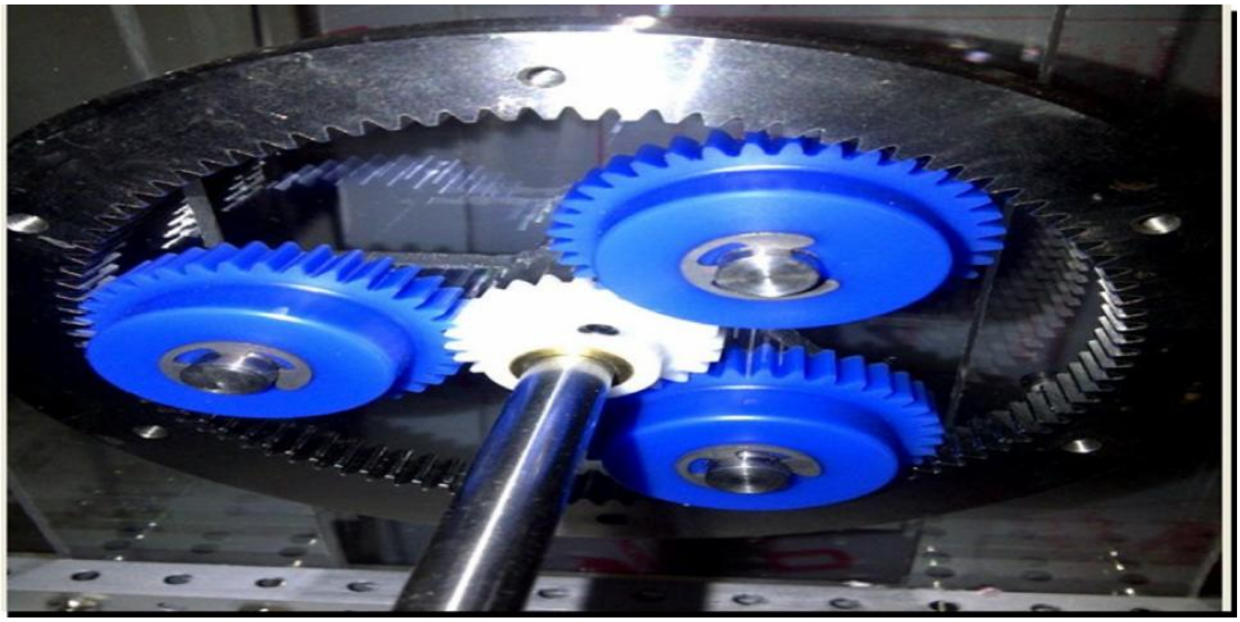
Design and Working Principle

The heart of the planetary gearbox is the reduction group composed by the sun pinion (1) and three or more satellites (2) mounted on pins (4) which are supported by the satellite carrier (5). The sun pinion transmits it's motion to the satellites. The satellites then turn inside the ring gear (3) which is static. As consequence the satellite carrier rotates. The motion of the carrier can be transmitted to an output shaft or to another reduction group. The reduction obtained is determined by the relation between the number of teeth on the sun pinion (Z1) and the number of teeth on the ring gear (Z2).

Like a compound gear train, planetary trains are used when a large change in speed or power is needed across a small distance. There are four different ways that a planetary train can be hooked up.

A planetary gear train is a little more complex than other types of gear trains. In a planetary train at least one of the gears must revolve around another gear in the gear train. A planetary gear train is very much like our own solar system, and that's how it gets its name. In the solar system the planets revolve around the sun. Gravity holds them all together. In a planetary gear train the sun gear is at the center. A planet gear revolves around the sun gear. The system is held together by the planet carrier. In some planetary trains, more than one

Figure 1: Planetary Gearbox



planet gear rotates around the sun gear. The system is then held together by an arm connecting the planet gears in combination with a ring gear.

A planetary gear train consists of two gears mounted so that the center of one gear revolves around the center of the other. A carrier connects the centers of the two gears and rotates to carry one gear, called the planet gear, around the other, called the sun gear. The planet and sun gears mesh so that their pitch circles roll without slip. A point on the pitch circle of the planet gear traces an epicycloid curve. In this simplified case, the sun gear is fixed and the planetary gear(s) roll around the sun gear.

LITERATURE SURVEY

History

In the 2nd century AD treatise Almagest, Ptolemy used rotating deferent and epicycles that form epicyclic gear trains to predict the motions of the planets. Accurate predictions of the movement of the Sun, Moon and the five planets, Mercury, Venus, Mars, Jupiter and Saturn, across the sky assumed that each followed a trajectory traced by a point on the planet gear of an epicyclic gear train. This curve is called an epitrochoid.

Epicyclic gearing was used in the Antikythera Mechanism, circa 80 BCE, to adjust the displayed position of the moon for its elasticity, and even for the precession of the ellipticity. Two facing gears were rotated around slightly different centers, and one drove the other not with meshed teeth but with a pin inserted into a slot on the second. As the slot drove the second gear, the radius of driving would change, thus invoking a speeding up and slowing down of the driven gear in each revolution.

The sun and planet gear converted the vertical motion of a beam, driven by a steam engine, into circular motion using a 'planet', a cogwheel fixed at the end of the connecting rod (connected to the beam) of the engine. With the motion of the beam, this revolved around, and turned, the 'sun', a second rotating cog fixed to the drive shaft, thus generating rotary motion. An interesting feature of this arrangement, when compared to that of a simple crank, is that when both sun and planet have the same number of teeth, the drive shaft completes two revolutions for each double stroke of the beam instead of one. The planet gear is fixed to the connecting rod and thus does not rotate around its own axis.

Epicyclic gear stages provide high load capacity and compactness to gear drives. There is a wide variety of different combinations of planetary gear arrangements. For simple, epicyclic planetary stages when the ring gear is stationary, the practical gear ratio range varies from 3:1 to 9:1. For similar epicyclic planetary stages with compound planet gears, the practical gear ratio range varies from 8:1 to 30:1. Using differential-planetary gear arrangements it is possible to achieve gear ratios of several-hundred-to-one in one-stage-drive with common planet gears, and several thousand- to-one in one-stage drive with compound planet gears. A special two stage planetary arrangement may utilize a gear ratio of over one-hundred-thousand-to-one.

The reasons why epicyclic gearing is used have been covered in this magazine, so we'll expand on the topic in just a few places. Let's

Figure 2: Types of Gearing

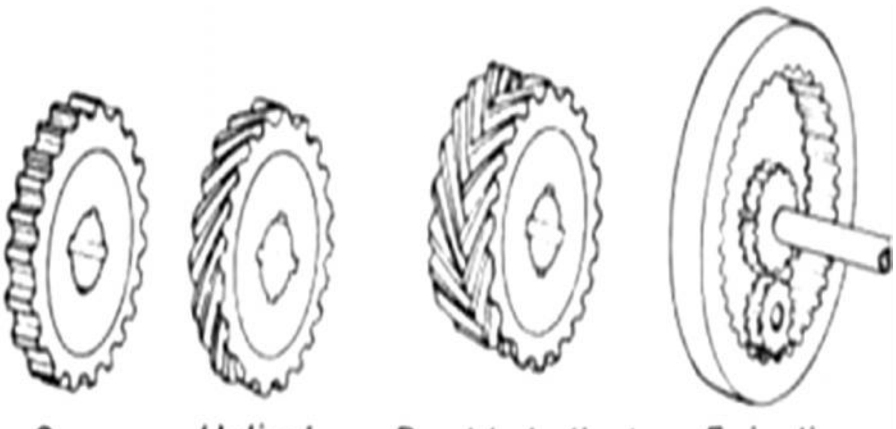


Figure 3: Formulas for Calculating Gear Ratios

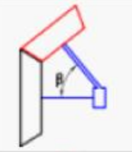
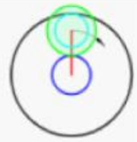
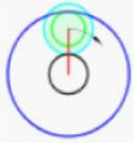
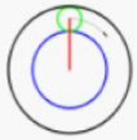
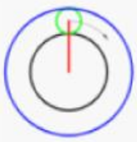
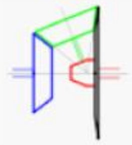
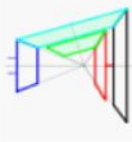
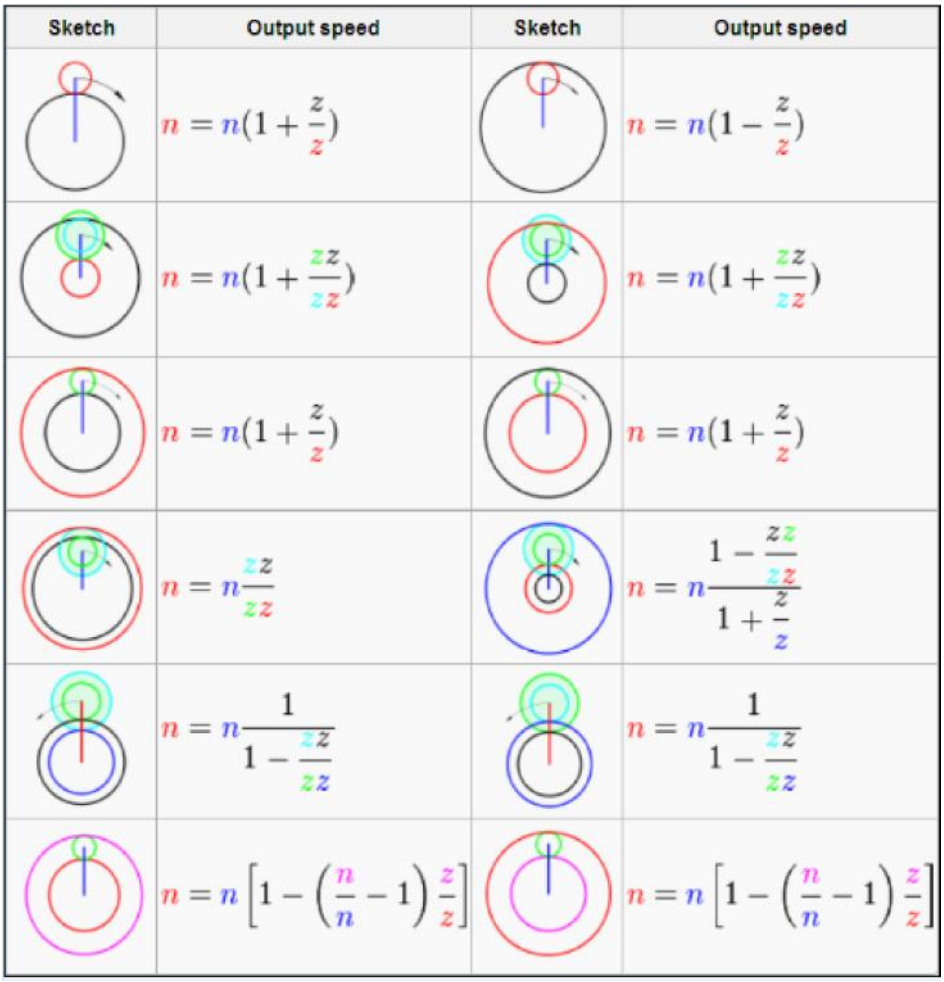
Sketch	Output speed	Sketch	Output speed
	$n = n(0 + \frac{z}{z})$		$n = n(\cos\beta + \frac{z}{z})$
	$n = n\frac{1}{(1 + \frac{zz}{zz})}$		$n = n\frac{1}{(1 + \frac{zz}{zz})}$
	$n = n(1 + \frac{z}{z})$		$n = n(1 + \frac{z}{z})$
	$n = n\frac{1 - \frac{zz}{zz}}{1 + \frac{z}{z}}$		$n = n\frac{1}{1 + \frac{z}{z}}$
	$n = n\frac{1 - \frac{zz}{zz}}{1 + \frac{z}{z}}$		$n = n(1 - \frac{zz}{zz})$
	$n = n\frac{1 + \frac{nz}{nz}}{1 + \frac{z}{z}}$		$n = n\frac{1 + \frac{nz}{nz}}{1 + \frac{z}{z}}$

Figure 3 (Cont.)



Sketch	Output speed	Sketch	Output speed
	$n = n(1 + \frac{z}{z})$		$n = n(1 - \frac{z}{z})$
	$n = n(1 + \frac{zz}{zz})$		$n = n(1 + \frac{zz}{zz})$
	$n = n(1 + \frac{z}{z})$		$n = n(1 + \frac{z}{z})$
	$n = n\frac{zz}{zz}$		$n = n\frac{1 - \frac{zz}{zz}}{1 + \frac{z}{z}}$
	$n = n\frac{1}{1 - \frac{zz}{zz}}$		$n = n\frac{1}{1 - \frac{zz}{zz}}$
	$n = n\left[1 - \left(\frac{n}{n} - 1\right)\frac{z}{z}\right]$		$n = n\left[1 - \left(\frac{n}{n} - 1\right)\frac{z}{z}\right]$

begin by examining an important aspect of any project: cost. Epicyclic gearing is generally less expensive, when tooled properly. Just as one would not consider making a 100-piece lot of gears on an N/C milling machine with a form cutter or ball end mill, one should not consider making a 100-piece lot of epicyclic carriers on an N/C mill. To keep carriers within reasonable manufacturing costs they should be made from castings and tooled on single-purpose machines with multiple cutters simultaneously removing material.

Magnetism, which is used in everything from toys and door catches to electric motors and medical imaging systems, is the subject of ongoing research by commercial organizations and academic institutions. Improved field strengths and design techniques mean that smaller and lighter magnets can replace larger composite magnets or create new opportunities.

PROPOSED SYSTEM

The main aim of the project is to design and analyze a three stage epicyclic planetary reduction gear unit is designed to meet the output specifications with a reduction ratio 64:1. All the components are modelled in

CATIA to check the assembly and the interference. The modelled components are used for analysis to check for their strength.

Our aim is to obtain the reduction ratio 64:1 for a 3-stage epicyclic planetary reduction gear.

Materials-steel

Steps involved in the project

1. Designing
2. Modeling
3. Analysis

For modeling of the planetary gear, we have used CATIA software which is parametric 3D modeling software. For analysis we have used ANSYS, which is FEA software.

SYSTEM DESIGN

A 3 Stage epicyclic planetary reduction has been designed in the following way as follows:

Figure 4: Assembly of First Stage

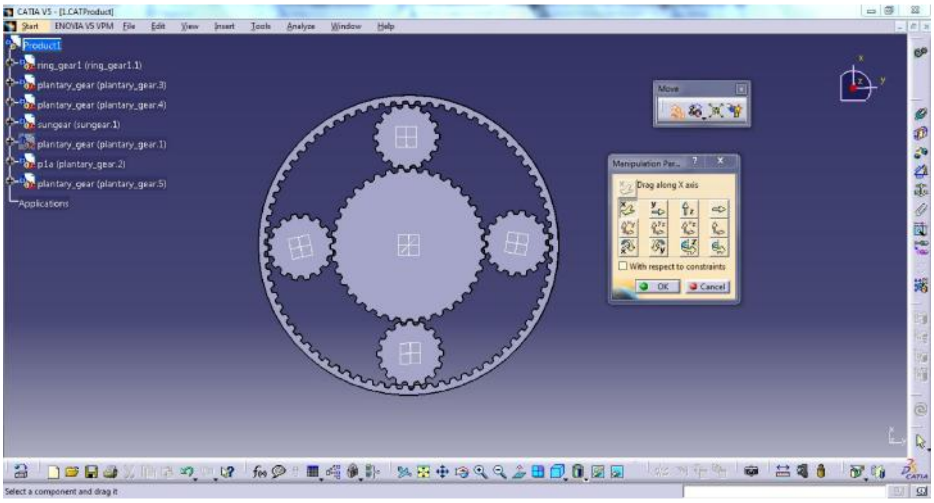


Figure 5: Assembly of Second Stage

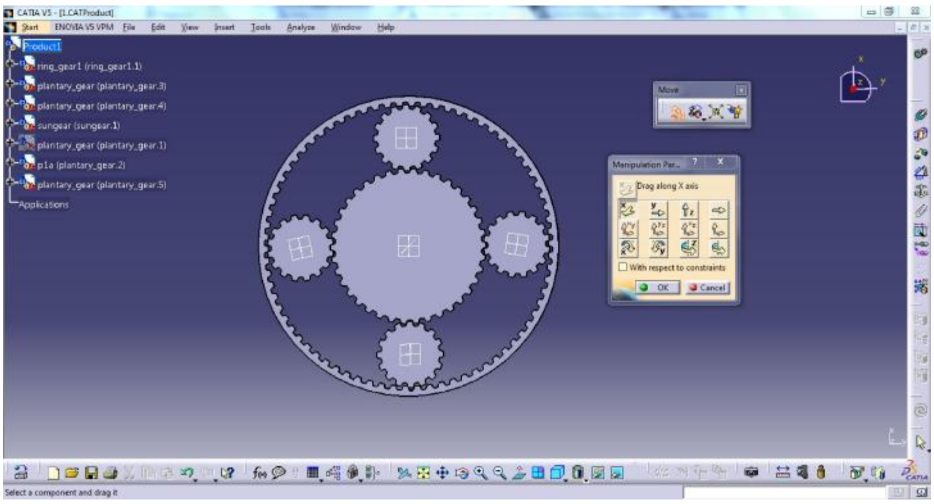


Figure 6: Assembly of Third Stage

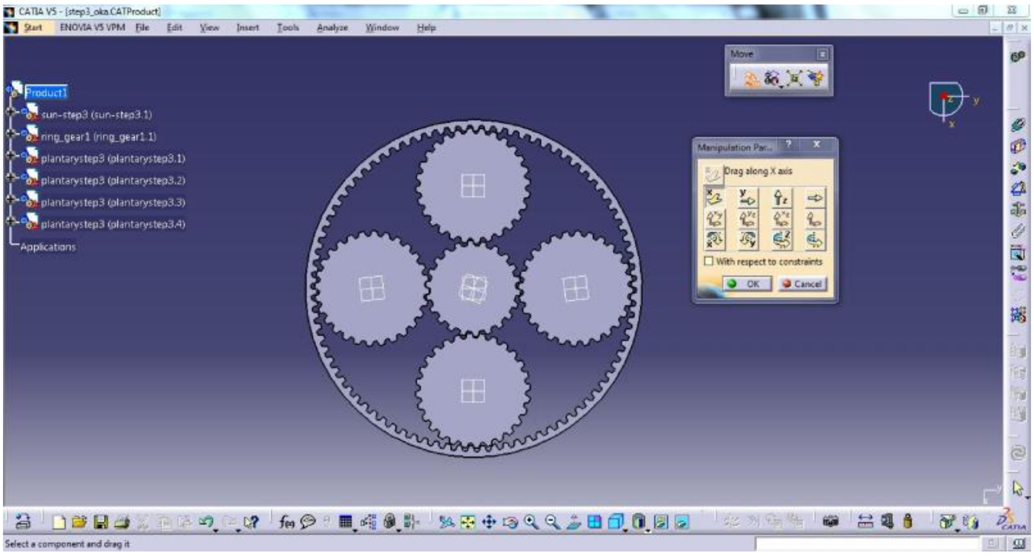
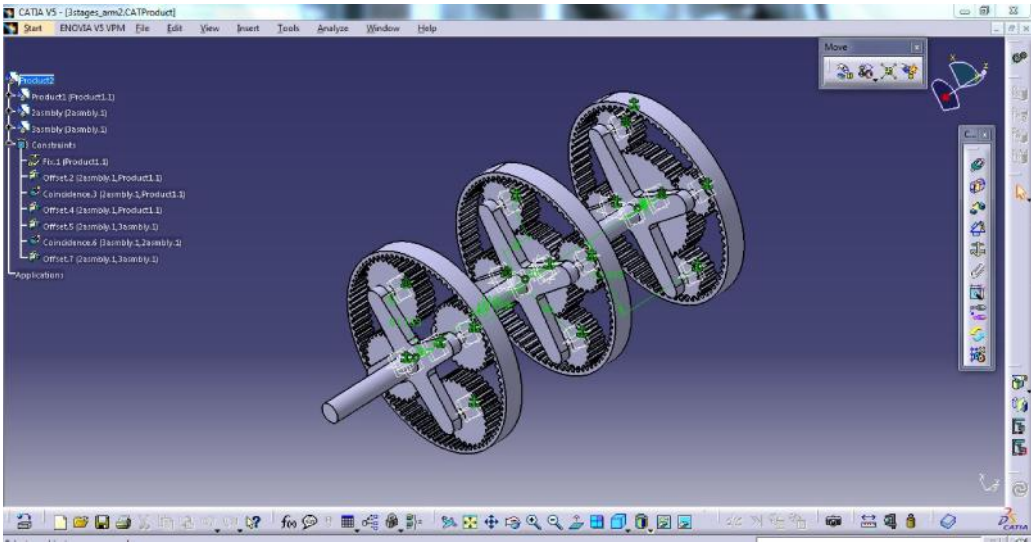


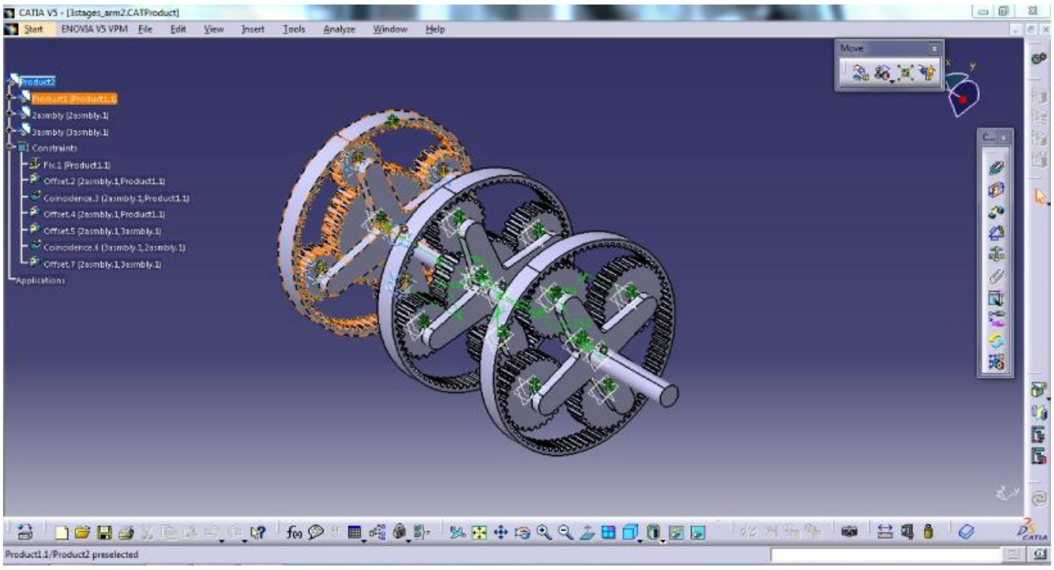
Figure 7: Final Assembly of a 3 Stage Epicyclic Planetary Reduction Gear with an Arm at Each Stage



RESULTS AND DISCUSSION

A 3 stage epicyclic planetary reduction gear was designed with the help of CATIA software. All the three stages are designed separately and then assembled together with the help of arm and shaft of required dimensions. The reduction ratio is obtained as 64:1. The maximum and minimum stresses along with displacement can be obtained after performing analysis on the gear unit. The analysis is done only for the second stage because it gives more accurate and average maximum and minimum stresses. Reduction ratios at the three stages are obtained as First

Figure 8: Final Assembly of 3 Stage Epicyclic Planetary Reduction Gear



stage ratio-3.8:1, Second stage-3.7:1, Third stage-4.6:1.

ANALYSIS

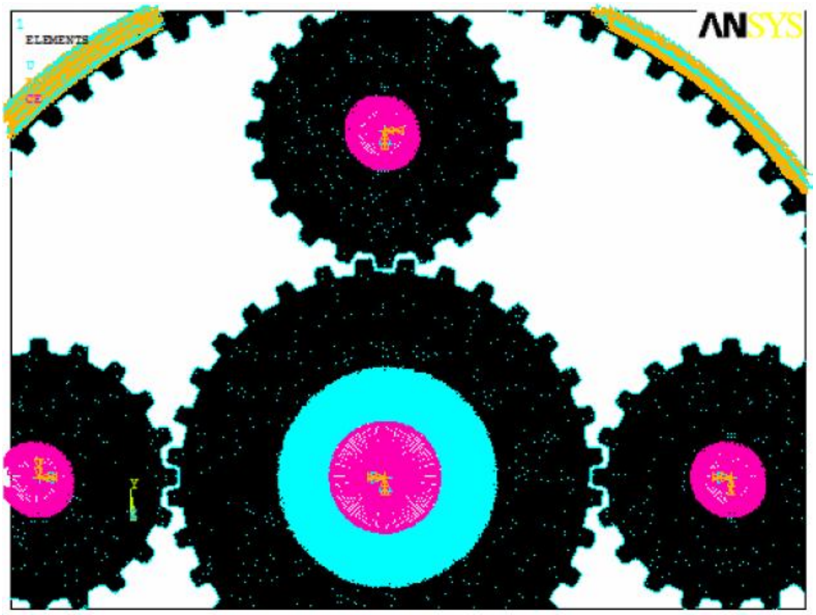
After performing analysis on the second stage of epicyclic planetary reduction gear unit, maximum stresses and minimum stresses are obtained as follows:

Nodal solutions

Maximum stress: 2.7706 N/M

Minimum stress: –5.77 N/M

Figure 9: Meshing All the Components Together in Ansys



Maximum displacement: 2.7708 m

CONCLUSION

In this project, we have created a CAD model, a simulation video and a solid model of a three-layer planetary gear system using Catia. We have learned the solid modeling technique, assembling knowledge and the simulation process through the project. We think our project could be extended to more layers of Gear system and more planet gears per system. And the redutction ratio can also be changeable from 64:1 to various other ratios as 36:1, 4:1.

BIBLIOGRAPHY

1. Gunston Bill (2006), *Development of Piston Aero Engines*, Patrick Stephens Limited, Cambridge, England.
2. Guttery T E (1969), *The Shuttleworth Collection*, Wm. Carling & Co., London.