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Structural Analysis of Planetary Gear System

Focusing on the System Mainly Used in Wind Turbines

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Abstract:- Here, we are performing a generative structure analysis of planetary gears. Generative Structural Analysis (GSA) enables designers to understand how structures behave and accurately calculate the displacements and stresses of a part or assembly under various loading conditions. One of the main tasks in structural research and analysis is to determine the internal workings and support reactions of structures with mechanical loading, pinching deformation, and subsidence of supports. Parameters considered include stress concentration, equivalent stress, and total strain. Use a variety of programs such as Solid Works. This project covers the basics of generative structural analysis (GSA). Gain the knowledge to effectively use Structural Finite Element Analysis software to reduce design time. This gives people the opportunity to apply their knowledge using real-life scenarios and examples.

Keywords:- *Gears, Planetary Gearing System, Sun Gear, Planet Gear, Ring Gear, Etc.*

I. INTRODUCTION

Planetary gears consist of three types of gears: sun gears, planetary gears, and ring gears. The sun gear is located in the center (yellow) and transmits torque to a planetary gear (blue) that is usually mounted on a moving carrier (green). The planetary gear rotates around the sun gear and meshes with the outer ring gear (pink). Planetary gears can vary in complexity from very simple to complex systems depending on the application. A planetary gear train (also called a planetary gear) consists of two gears mounted so that the center of one gear rotates about the center of the other gear. The carrier connects the centers of the two gears and rotates the planetary gear and the sun gear to engage the pitch circle so that it rolls without slipping. A point on the pitch circle of a planetary gear represents an epicycloid. In this simple case, the sun gear is stationary and the planet gear rotates around the sun gear.

The combination of planetary gear, sun gear, and ring gear is called planetary gear. Generally, the ring gear is fixed and the sun gear is driven. A planetary gear or planetary gear is a gear system consisting of one or more external or planetary gears or gears that rotate around a central sun gear or sun wheel. Typically, planetary gears are mounted on a movable arm or holder that can rotate relative to the sun gear.

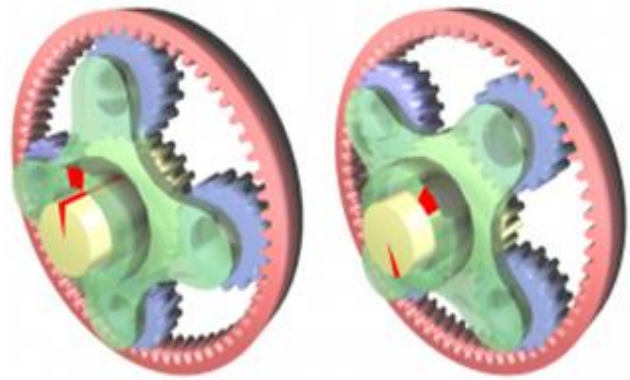

Fig 1 Components of Planetary Gears

Epicyclic gearing systems also incorporate the use of an outer ring gear or annulus, which meshes with the planet gears. Planetary gears (or epicyclic gears) are typically classified as simple or compound planetary gears. Simple planetary gears have one sun, one ring, one carrier, and one planet set. Compound planetary gears involve one or more of the following three types of structures: meshed-planet (there are at least two more planets in mesh with each other in each planet train), stepped-planet (there exists a shaft connection between two planets in each planet train), and multi-stage structures (the system contains two or more planet sets).

Compared to simple planetary gears, compound planetary gears have the advantages of a larger reduction ratio and a higher torque-to-weight ratio.

The axes of all gears are usually parallel, but in special cases such as sharpeners and differentials, they can be angled by introducing elements of bevel gears (see below). Also, the axes of the sun, carrier, and rings are usually coaxial. A planetary gear consisting of a sun, a carrier, and two interlocking planetary gears is also available. One planet meshes with the sun gear and the other planet meshes with the ring gear. In this case, when the carrier is fixed, the ring gear rotates in the same direction as the sun gear, and the direction can be changed compared to a general planetary gear.

- *Dimensional calculations:*

Before going for the analysis of the gearing system we must calculate the dimensions of different gears.

So that the planet gear teeth mesh properly with both the sun and ring gears, assuming

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- N_P equally spaced planet gears, the following equation must be satisfied:

$$(N_S + N_{R)} / N_P = A$$

Ns =Number of teeth in Sun gear
Np = Number of teeth in Ring gear
A is a whole number.

If one is to create an asymmetric carrier frame with non-equiangular planet gears, say to create some kind of mechanical vibration in the system, one must make the teething such that the above equation complies with the "imaginary gears". For example, in the case where a carrier frame is intended to contain planet gears spaced 0°, 50°, 120°, and 230°, one is to calculate as if there are 36 planetary gears (10° equiangular), rather than the four real ones.

➢ *From the Specs of History:*

Around 500 BC, the Greeks invented the idea of an epicycle, a circle moving in a circular orbit. With the aid of this theory, Claudius Ptolemy was in the Almagest in 148 AD. It was able to approximate the planet's observed path across the sky. The Antikythera Mechanism, circa 80 BC to 500 BC had a gear train that could exactly match the Moon's elliptical path across the sky, correcting the 9-year precession of the path as well (the Greeks thought the motion they saw was not elliptical, but epicycles).

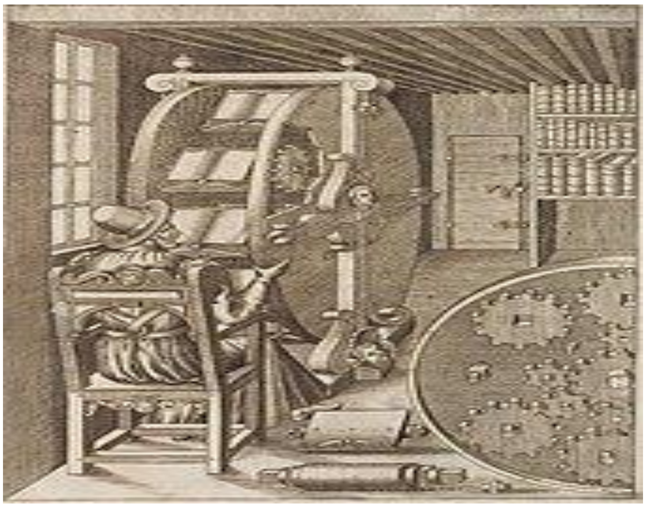

Fig 2 Making of Gears

In his 2nd century AD treatise The Mathematical Syntax (also known as the Almagest), Claudius Ptolemy used rotating eccentrics and epicycles to form planetary gear trains to predict planetary motion. Accurate predictions of the motions of the Sun, Moon, and five planets across the sky—Mercury, Venus, Mars, Jupiter, and Saturn—assumed that each planet followed a path traced by a point on the planet gear's planet gear train.

This curve is called the epitrochoid. Planetary gears were used in the Antikythera Mechanism around 80 BC. Corrects the indicated position of the Moon to account for the ellipticity of the orbit and the precession of the orbital advance. Two opposing gears rotated, one drove the other, but the pin was inserted into the slot of the second rather than interlocking teeth. As the slot drives the second gear, the radius of travel changes, speeding up and slowing down with each rotation of the driven gear. Richard of Wallingford, England St.

Albans Abbey was later depicted as the planetary gear of a 14th-century astronomical clock. In 1588, Italian military engineer Agostino Ramelli invented the book wheel, a vertically rotating bookshelf that contained two stages of planetary gears to keep books in the right direction. French mathematician and engineer Desargues designed and built the first mill with epicycloid teeth. c. 1650

➢ *Objective:*

As the necessity of speed reduction and torque reduction increases with time more research and development were done on planetary gearing systems. The problem statement of this project is:

- To improve the skill and knowledge of Mechanical engineering students in designing and importance of project developing planetary gearing system.
- The cost for the current planetary gear system is too expensive we will look forward to lessening it.

II. SOFTWARE AND MATERIAL USED

SolidWorks software program was used for designing and evaluating gearing devices. SolidWorks is a multi-platform software suite for computer-aided design (CAD), pc-aided manufacturing (CAM), computer-aided engineering (CAE), 3D modeling, and Product lifecycle management (PLM), evolved via the French employer Dassault systems. Since it helps multiple stages of product improvement from conceptualization, design, and engineering to production, it's far taken into consideration a CAx-software program and is sometimes referred to as a 3D Product Lifecycle control software suite. Like most of its opposition, it facilitates collaborative engineering via an incorporated cloud service and has helped to be used throughout disciplines together with surfacing & form layout, electric, fluid, and electronic systems design, mechanical engineering, and structures engineering.

Material selection is critical in all aspects of engineering design. There are many engineering design criteria, and facts must be taken into account when selecting a specific material for a specific design. The choice of materials is one of the key features of an effective design and determines the reliability of the design from an industrial and economic point of view. A great design may not be a profitable product if the product is not matched with the right combination of materials. Therefore, it is important to know which material is best for a particular design.

How to get ideas for the best design materials? In this aspect, engineers use myriad facts about materials to make informed decisions. They primarily focus on material properties defined for a specific design. Environmental conditions. When selecting a material for a particular application, sufficient and appropriate testing should be performed to ensure that the material is suitable for the intended application during the intended life of the product.

The material considered in this analysis was alloy steel. Alloy steel is the most common form of steel and is relatively inexpensive. It also offers material properties that allow for more applications than iron. This property of carbon steel is useful because it provides good surface wear properties, but the only problem is that the core remains hard.

Material Specification	Hardness Case Rc	Hardness Core Bhn	Typical Heat Treatment, Characteristics, and Uses
Case-Hardening Steels			
AISI 1020 AISI 1116	55-60	160-230	Carburize, harden, temper at 350°F. For gears that must be wear-resistant. Normalized material is easily machined. Core is ductile but has little strength.
AISI 4130 AISI 4140	50-55	270-370	Harden, temper at 900°F, Nitride. For parts requiring greater wear resistance than that of through-hardened steels but unable to tolerate the distortion of carburizing. Case is shallow, core is tough.
AISI 4615 AISI 4620	} 55-60	170-260	Carburize, harden, temper at 350°F. For gears requiring high fatigue resistance and strength.
AISI 8615 AISI 8620	} 55-60	200-300	The 86xx series has better machinability. The 20 point steels are used for coarser teeth.
AISI 9310	58-63	250-350	Carburize, harden, temper at 300°F. Primarily for aerospace gears that are highly loaded and operate at high pitch line velocity and for other gears requiring high reliability under extreme operating conditions. This material is not used at high temperatures.
Nitralloy N and Type 135 Mod. (15-N)	90-94	300-370	Harden, temper at 1200°F, Nitride. For gears requiring high strength and wear resistance that cannot tolerate the distortion of the carburizing process or that operate at high temperatures. Gear teeth are usually finished before nitriding. Care must be exercised in running nitrided gears together to avoid crazing of case-hardened surfaces.
Through-Hardening Steels			
AISI 1045 AISI 1140	24-40	...	Harden and temper to required hardness. Oil quench for lower hardness and water quench for higher hardness. For gears of medium and large size requiring moderate strength and wear resistance. Gears that must have consistent, solid sections to withstand quenching.
AISI 4140AISI 4340	24-40	...	Harden (oil quench), temper to required hardness. For gears requiring high strength and wear resistance, and high shock loading resistance. Use 41xx series for moderate sections and 43xx series for heavy sections. Gears must have consistent, solid sections to withstand quenching.

Fig 3 Standards Taken During Material Selection

The geometric condition that requires the center distance for the sun-planet and planet-ring gear meshes to be the same is obvious when illustrated. The equation to express this relationship can be expanded as a function of the working pitch diameters:

$$|a_{12}| = |a_{23}|$$

$$|d_{w1} + d_{w2}| = |d_{w2'} + d_{w3}|$$

Specifically refers to the working pitch diameter of the planet-ring gear mesh, which may differ from the sun-planet mesh due to profile shifts, tooth counts, and center distance differing from nominal (a condition with zero profile shift or backlash). Below illustrates a layout diagram for a 4-planet gear train:

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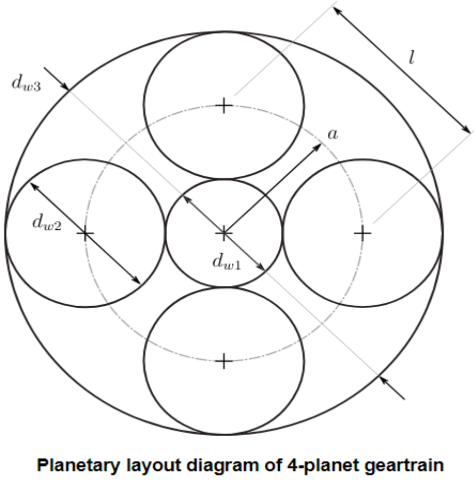

Fig 4 Planetary layout diagram of geartrain

III. MESHING TEETH

This envelope diagram looks like a valid design, but remember that every gear requires an integer number of teeth. In addition to this requirement, each planet's prongs must engage both the sun and the rings. The determination of the actual conditions for tooth engagement depends on the number of teeth, the number of satellites, and the distance between satellites. To understand this requirement, let's imagine a planetary gear assembly. First, we place the sun at the origin with every rotation angle.

The teeth are then rotated to connect to the sun, adding the first planet to the desired carrier position. Then place the ring on the starting point and rotate the teeth to join with the planet. Now imagine adding a second planet somewhere in the carrier without allowing the sun or rings to rotate. Only in certain carrier positions can a second planet mate with the sun and rings.

➢ *Meshing and Boundary Condition:*

The goal of finite element analysis (FEA) is to model some physical phenomenon using a numerical method called the finite element method (FEM). To quantify physical phenomena such as wave propagation or fluid flow, mathematical equations must be used. Most physical phenomena can be solved using partial differential equations (PDEs), but for most real world problems this is very difficult.

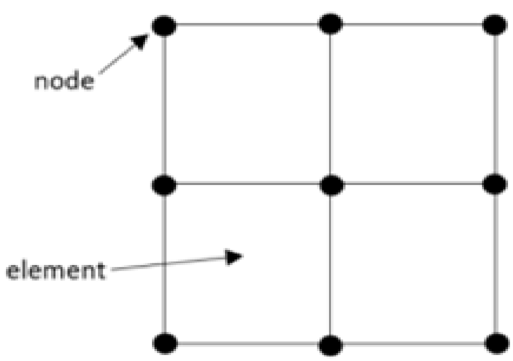

Fig 5 Basic Meshing Structure

All continuous objects have infinite degrees of freedom (DOF) and cannot be solved by hand. FEM thus creates a grid that divides the area into a number of discrete elements from which solutions can be computed. The data is then interpolated over the entire domain. Meshing is one of the key components to obtaining accurate FEM model results. Mesh elements must consider several aspects to accurately discretize stress gradients.

In general, the smaller the grid size, the more accurate the solution because it better selects circuits based on their physical domain. The downside is that higher accuracy results in larger simulations and therefore longer solution times. No need to spend extra time modeling a dense mesh if a coarse mesh gives you the desired result! Engineers often perform convergence studies to find the optimal balance between accuracy and solution time.

Fig 6 Actual Photographs of Gears

➢ *Static Analysis of Planetary Gears*:

In this section, you need to define the results needed to evaluate the mode. The analysis is done in the same program in which the 3D model was created, namely SolidWorks, which simplifies design. The entire process from the beginning of model creation to the definition of boundary conditions cannot be considered as a separate step, as it is an integral part of the analysis phase.

The assay setup was chosen as a static structure.

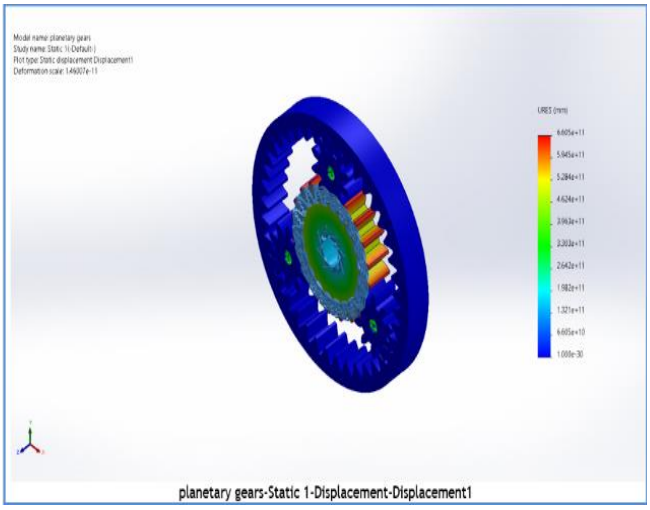

Fig 7 Analysis of Geartrain

The static structural analysis identifies displacements, stresses, strains, and forces in a structure or component due to loads that do not cause significant inertial and damping effects. Assumes stable load and operating conditions. That is, it is assumed that the load and response of the structure change slowly with time. Static loading of a structure can be performed using either the ANSYS or ABAQUS solvers. Types of loads that can be applied in static analysis:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

IV. RESULTS AND EVALUATION

As discussed in the previous section of the Analysis, we considered three major analyses of the model, stress analysis, factor of safety plots a total deformation. To dive deep into the results, we hovered the model using the probe, which further helps us understand the loads/deformation acting on the various elements of the model. As the default mesh was selected and only 617 elements were created, the results were much more approximate but still very accurate to predict the desired results.

➢ *The Following Results Were Obtained from the Three Analyses One by One Below:*

- Stress analysis: These results helped me understand various stresses acting on the component, and the identified stress-prone areas were near to the joints between two pipes and at the sections of abrupt change in the shape of the pipe.
- Normal deformation: The normal deformation results helped us understand the deformation of various elements under a load of 1500N. In the event of a frontal impact, it is logical that the maximum deformation would be at the front of the chassis). The maximum deflection is only 3.469 mm, which is very small compared to the dimensions of the model.

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