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Design and Analysis of Planetary Drive Speed Reducer: A Review

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ABSTRACT

A planetary gear system consists of a central gear called the sun gear and a set of planet gears that spin around it. The system is encircled by a ring gear. It may accomplish large reduction ratios while remaining very small. The impacts exerted on the gear system are susceptible to a wide range of manufacturing mistakes. An in-depth analysis of planetary gearbox design is first conducted in this research. Following the design phase, this study employs the finite element approach to probe the stress fluctuation caused by misalignments. Misalignments caused by tolerances on the centre distance between gears and components are the source of the strains in this case. This document provides a literature review of studies that have focused on planetary gearbox analysis and design.

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I. INTRODUCTION

A planetary gearbox is made up of a central gear and one or more gears that spin around it. Planetary gear systems are defined by their small size, co-axial arrangement of driving and driven shafts, ability to reduce speeds relative to their overall size, large torque conversion possibilities, number of possible combinations of inputs and outputs, and orientation of drives [1]. Planetary gears have a more compact design and significant space and weight savings compared to parallel axis gears. This is because the load is transmitted through several tooth contacts in planetary gears, and the input and output shafts are arranged co-axially, making the gearbox smaller. Another benefit of using several planets is that their radial loads cancel each other out when they're evenly placed on the carrier. As a result, the co-axial components' bearings and gear housing can only be made to support stresses from the outside and keep the gears in the correct alignment [2]. A planetary gear with three planets can transmit three times the torque of a fixed-axis gear system of the same size because the number of planets in the system determines how the transferred torque is distributed among the gear mesh points. Having a high rotational rigidity and little elastic windup is crucial for applications that need enhanced positioning precision and repeatability. This is particularly true when the loading circumstances are unpredictable. The torsional rigidity of the planetary gearbox is increased due to the load being distributed across N contacts as a result of the load distribution among numerous sites [3]. Instabilities may occur in planetary gear systems because of the constantforce that is exerted. They have critical speeds that, in the event of divergence instabilities, isolate the borders. Planetary gear gyroscopic systems operating at high speeds are not energy efficient and might be unstable [4]. Planetary gear gearboxes provide the benefit of dividing the input torque into many parallel routes. In a planetary gear system with n planets, the input torque is transmitted in 1/n steps along each sun-planet-ring route. Nevertheless, this holds truest in planetary gear systems when all the planets evenly distribute the weight. One of the three primary parts of a planetary gearing system stays set while the other two work as inputs and outputs, respectively, to transfer power to and from the system. The number of teeth in each gear and the component that is kept fixed determine the input rotation to output rotation ratio [5]. Planet gears' capacity to distribute loads and very low weight are its most appealing characteristics. In addition, the fact that these gears are so small might be because the weight is distributed across multiple planets and the rollers that hold up the rim help to balance the stresses on the outside of the gears. The globe gear rim undergoes elastic deformation in response to tooth loads, therefore balancing the load inside. Critical stresses around the gear's circumference are affected by the distribution of externally imposed tooth loads by the gear and its thin rim [6]. When pinion placement mistakes are present in transmissions, the parallel routes do not distribute the load evenly.

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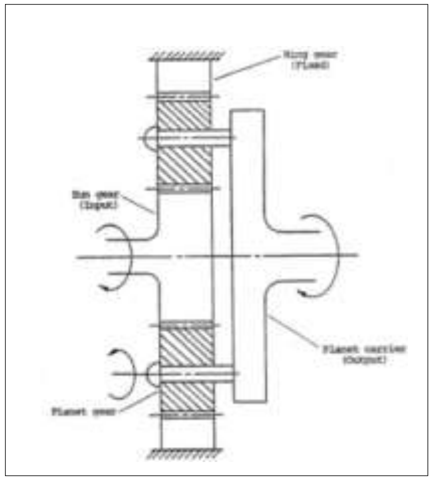

Figure1. APlanetaryGearTrain[2]

Important considerations for gearbox architecture and torque ratings arise from the fact that planetary gears share the load. The pressures applied to the system may be significantly altered by improperly positioned pinions. The distribution of load within a planetary gear system is the source of the stresses experienced by the gear system [7]. The majority of the stresses applied to a gear system are contact stresses and fillet stresses. Errors in manufacture or location of planet gears may affect stress analysis in planetary systems, in addition to stresses caused by contact and fillet forces. In actuality, when looking at gear transmission from a load transmission perspective, abrupt variations in load occur. In other words, the amount of force that acts on a set of teeth is proportional to the stiffness of their meshing. Because of this, a changes in the distribution of loads at different places of contact. One constraint that designers face is stress analysis for gear teeth. The main goal of stress analysis is to identify potential failure or fracture points by concentrating on areas of high stress. We use finite element method (FEM) to see variations in stresses at the locations where high stresses are induced, and we focus on the change in contact stress that is generated in meshing gear teeth along with the misalignments that lead to further stresses. This gear system's design and analysis were the subject of a small number of literature evaluations, from which the following conclusions were drawn: Compared to the traditional gear system, the planetary gear system is smaller, lighter, and more torque dense. A single-stage planetary gear system was the primary focus of the research. Design and analysis of planetary gears have previously been the subject of much study. Although single-stage differential planetary gears are best suited for low-torque applications, they may achieve large reduction ratios when necessary. With regard to high reduction ratios, Dr. Alexander Kapelevich [8] noted that a gear system that is too big and cumbersome would be the outcome of choosing less than three stages. Manufacturing faults and assembly variances caused forces that severely damaged the whole planetary gear system [9].

Designof a3-StagePlanetaryGearbox

A total of three stages were considered, with the first stage consisting of helical gears and the latter two stages being planetary gears, after taking into account the power input to the gear system and any other pertinent characteristics. Due to the high power input and the need for a larger reduction ratio, the planetary gear system was the ideal choice due to its compactness compared to other gear systems. In the beginning, design characteristics that characterised a planetary gear system included the number of planets each gear stage would have, the number of teeth on each gear, the gear module, the pitch circle diameter, and the torque transferred in each gear stage, as stated in the Handbook of Gear by G.M. Maitra. The rationale for maintaining a constant number of planets at 4 per planetary stage was that, with each planet at right angles to each other, the radial forces would be anti-symmetrical, preventing any imbalance caused by centrifugal forces cancelling each other out. All the other gear parameters are computed once the number of planets is rounded off [1]. According to

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Robert G. Parker's study, one of the most important goals in many sectors is to maximise power density and increase load sharing across planets. To do this, thin ring rings are necessary, which causes the ring gear to be elastically deflected. The ring gear is particularly vulnerable because to its absence of extra restraint from the bearings [10], but the sun and planets might potentially undergo elastic deformation. According to G.G. Antony, a lightweight and compact package with a high torque capability is a must-have for automation applications. In order to prevent extra system inertia caused by changes in high dynamic loads, planetary gearboxes spread the torque to be transferred over numerous gear mesh points, which means that high torque density is necessary for automotive applications. The number of planets chosen determines this distribution. This indicates that four-planetary gears may transmit four times the torque of a regular gear system of the same size. [3].

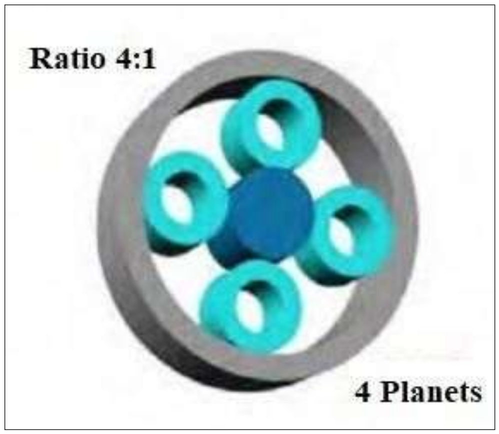

Fig.2SimplePlanetaryStages with4Planets[3]

It is stated in Tobias Schulze's study. Although there is little experimental study on planetary gear systems, Christopher G. Cooley discovered that no findings have been obtained for planetary gears running at high speeds at this time. There was no need to calculate the movements of the individual gear bodies in the situations that he used in his study; all that was required was the measurement of the housing. Using inductance vibrometers, he conducts experimental investigations on the sun and ring gear movements of a manufacturing planetary gear. Additionally, he conducts modal tests on stationary planetary gears. By equipping each gear with an accelerometer, it is able to monitor the vibrations of each gear individually. [12]. To reduce the fillet bending stress as much as possible, Costopoulos proposed in his article a new design for asymmetric gear teeth. One of the design approaches he proposed in his article was to make the gear teeth as thick as feasible at the root fillet region and the mating teeth as thin as possible at the tip. Also, the typical 20 involute's useful working characteristics are preserved by avoiding sharp and pointed teeth. Additionally, he discussed how the involute working section of the driving side of the gear is insensitive to centre distance mistakes and how it has standard rated pitting and scoring resistance. A circular root fillet, rather than the usual trochoidal one, was proposed for the working side's root, with the circular tip of the generating hobbing tool serving as its inspiration. The rationale for this change was to improve the gear teeth' bending resistance in comparison to the traditional trochoidal one. [13]. In order to demonstrate the power flow analysis, torque, and velocity using the suggested approach, Fuchun Yang researched the topic. Results from the power analyses demonstrated how easy and effective the technique offered in the article is. This article also analysed the impact of certain characteristics on the efficiency of each node and system. When the system's efficiency is positive, the findings shown that power loss on certain nodes is dominating and that partial shafts may self-lock. These findings informed design recommendations for enhancing node and system efficiency [14].

StressAnalysis

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Two approaches to the analysis of stress in meshing gear teeth were shown by Seok-ChulHwanga. One option is to apply the focused force directly to the load location. It is thus possible to determine the gear's bending stress. The ease of use of this approach has led to its widespread adoption [15]. The gear system is also vulnerable to assembly-related and manufacturing-parameter fluctuations. All of these mistakes and differences affect where the planet's teeth sides interact with the solar gear and the internal gear. Because of its relative tangential location inside the carrier, a planet is likely to bear greater burden than the others if the mistakes or variations cause it to be pushed ahead of the others [16]. The goal of Toni Jabbour's research is to determine the distribution of bending stress at the tooth root as well as the contact stress along each contact line. Then, under these circumstances, the tooth-root stress and the contact stress were calculated, taking into account the critical load conditions. The critical configurations for which the bending and contact stresses are highest are determined by simulating the pair of gears for various degrees of rotation. These findings were recorded: As the number of teeth rises, the contact ratio of the pair of gears determines the location of the point of contact that causes critical tooth-root stress in spur gears. Finding the critical contact stress at the pitch circle radius is possible. At a distance of 1.65 mm from the point of contact, the critical tooth-root stress for helical gears is attained, and the contact stress is placed at a radius equal to the gear's pitch circle radius. Both stresses are achieved when the sum of the contact lines is at its shortest [17].

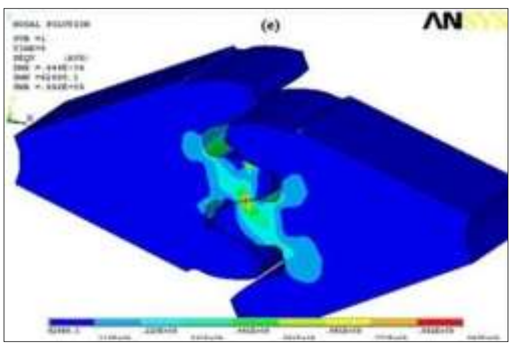

Fig.3ContactStresses[18]

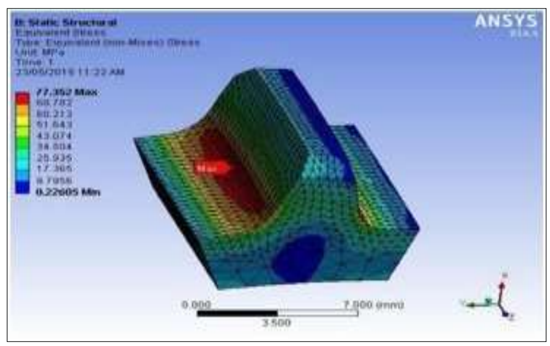

Fig.4ToothStressAnalyses[19]

In this study, Sarfraz Ali N presents a high-level overview of optimising the geometry of spur gears subjected to static stress. Here, the stress calculation of a gear tooth at the fillet is performed using the Lewis bending equation, and it is further evaluated using the Finite element analysis approach using ANSYS 14.5 software. The findings demonstrate how the root fillet influences the gear tooth's bending stresses and propose the optimal radius by taking both von-mises stresses and deformation into account. The year 19 According to the findings presented by Seok-ChulHwanga in his study, the stresses in certain areas are affected by changes in the contact stress between spur and helical gears in relation to the contact position. At the lowest point of single-tooth contact, we measure the highest value of the contact stress and compare it to the contact stress computed using the AGMA standard and the Hertzian contact stresses technique [15]. This article by Li Shuting examines the effects on tooth contact stresses, load-sharing ratio, and mesh stiffness of modifying the tooth profile, relieving lead, and transmitting torque in a planetary gear system using two spur gears. Additionally, the influence of lead crowning and gear shaft misalignment on tooth mesh stiffness is studied. The adjustment of the tooth profile is also discovered to have a much greater impact on the tooth load-sharing ratio and mesh stiffness. The investigation also reveals that lead relieving significantly decreases tooth mesh stiffness but has no effect on the gears' load-sharing ratio [20]. When estimating the contact stresses, Hassan stressed how crucial it was to take into account the contact ratio, approach angle, recess angle, contact, and duration of contact. The stress levels were higher than what would be considered an accurate estimate of contact stress using these techniques. Performing this stress analysis was no picnic and would have been impossible without finite element analysis. Instead of using the standard approaches, a unique approach was employed to differentiate

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between the two distinct contact zones in order to apply the finite element method to contact stress in this specific research. The first body was called the contact area, while the second body was called the target region. Elements designated for the target area were used, whereas elements designated for the contact region were employed. The ANSYS APDL programme, which offers a substantial method for this, was used for all of this. Depending on the formulation, a computer programme was created to map one set of teeth in contact at various points of contact. With a chosen angular interval value of 3°, ten contact examples were considered for the study of contact progress at each 3° interval. In order to conduct contact finite element analysis under the specified load and material conditions, ten finite element models were constructed using these ten examples [21].

Conclusion

Research publications that focused on planetary gearbox design and analysis were carefully evaluated in this report. Using the finite element approach, this paper considers the design of a planetary gearbox and conducts stress studies to evaluate the variation of stresses caused by misalignments. Misalignments, which may be the consequence of tolerances on the centre distance between gears or on components, are the source of strains, according to the examined data.

• It packs a lot of reduction power into a small footprint. • A considerable number of manufacturing mistakes might impact the stresses introduced into the gear system, according to the major finding from the studied results.

References

[1] G.M.Maitra,HandbookofGearDesign,NewDelhi:TataMcGrawHill,2010.

[2] R.K.J.L. F.a.A.P. R.August,"Dynamicsof PlanetaryGearTrains," NASA, pp.1-220,1984.

[3] N. U. L. G.G. Antony, "Precision Planetary Servo Gear heads," Neugart USA Corp, [Online].Available:www.neugartusa.com.

[4] R. Christopher G.Cooley, "Mechanical stability o fhigh-speed planetary gears," InternationalJournal of MechanicalSciences, pp. 60-71, 2013.

[5] W. S. Sagar B Malkapure, "Load Sharing Analysis Of Planetary Gear Box," IJRET: InternationalJournal of Research in Engineering and Technology, vol. Vol:3, no. ISuue: 08, pp. 150-155,2014.

[6] R. N. Raymond G Drago, "Stress Analysis of planet gears with integral bearings, 3D finiteelement model development and test validation," Advanced Power Train Technology group,Philadelphia.

[7] A.K.H.L.AvinashSingh,"InternalGearStrainsAndLoadSharingInPlanetaryTransmissions,"InternationalDesignEngineeringTechnicalConferences&ComputersandInformationin EngineeringConference, pp. 1-12, 2007.

[8] D. A. Kapelevich, "High Gear Ratio Epicyclic Drives Analysis," Gear Technology, June 2014.[Online].Available:www.geartechnology.com.

[9] P. K. PrabhakarVitthalPawar, "Design of Two Stage Planetary Gear Train for High ReductionRatio",InternationalJournal ofResearchinEngineeringandTechnology,Vol. 04,no.15,2015.

[10] X. W. Robert G. Parker, "Parametric Instability of Planetary Gears Having

ISSN:2096-3246
Volume53, Issue 01, Mar, 2021
https://doi.org/10.5281/zenodo.12707143

ElasticContinuumRingGears,"Journalof Vibrationand Acoustics, pp.1-11, 2012.

[11] T. Schulze, "Design and Optimization of Planetary Gears Considering All Relevant Influences,"GearTechnology, pp. 96-102, 2013.

[12] R. G. P. Christopher G. Cooley, "The geometry and frequency content of planetary gear single - modevibration,"MechanicalSystemsand SignalProcessing, 2013.