OPTIMIZATION OF MODEL AND STRUCTURAL ANALYSIS HYPOID GEAR

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Abstract:
The purpose of this work is to analyze structural behaviour of differential hypoid gear. For the studying of the structural analysis of the gear is made up of the different composite materials & as well as alloy materials compared with conventional metallic materials. As, composite materials provide enough strength and emerged as a good alternative for replacing metallic gears which is Ni-Cr steel. The alloy materials considered here is Aluminium alloy, Grey cast iron, and the composite material is Epoxy E-Glass unidirectional and compare with existing gear material Ni-Cr steel. This work makes an attempt to replace the metallic gears of Ni-Cr steel with alloy & composite materials based on static structural analysis results. For the analysis purpose the solid model is created by using CATIAV5R20 design software and ANSYS 17.1 is used to determine the Total deformation, Von-Mises stress and the equivalent elastic strain for the different selected materials at three different speeds.

Key words: Hypoid gear, von mises stress, alloy steel, Epoxy E-Glass.

1. INTRODUCTION
Now a day’s gears are used in many applications for transmission of motion from one shaft to another shaft. The gears drives are positives which are transmit exact velocity ratio, the gear drives are transmit motion when two shafts distances are less than compared to the belt, chains, rope drives. The gear drive is used when the shaft having long centre distances this time some idler gears are using between driver and driven gears for transmission of motion from one to another shaft. Thus providing the idler gears the cost also increased and maintained cast also high than compared to the other power transmission drives like belt, ropes and chain drives, for this reason the gear drives not recommend for transmission of motion from large centre distances from driving shaft to the driven shaft. Now a day’s gears are various types are available in the market, based on the type of application, purpose and working condition the gear materials is selected, because the selection of the material is most important for manufacturing of the any component, because the tensile strength, young’s modules, corrosion resistance, efficiency and life of the material etc. can be depended into the selection of the material.

This work makes an attempt to replace the conventional metallic gears of Ni-Cr steel gear material with the alloy & composite materials having application for high power transmission system & reducing of the stress same as a gearbox were in automobile industries. For this purpose 3-D solid model of the differential hypoid gear made in CATIA V5R20 design software and ANSYS 17.1 finite element method analysis software were used to carry out the static analysis in order to identify the behaviour of the conventional Ni-Cr steel gear material and identified replacements of different alloy & composite materials under the different loading criteria’s. Then the simulation of the results determines the total deformation, Equivalent Von-Misses Stress, and Equivalent Strain of the different selected materials at three different rpms.
2. METHODOLOGY

1. To develop a solid model of Differential Hypoid gear by using CATIA V5R20 design software and data book.
2. Select the Conventional materials and alternative materials (alloys & composite).
3. Here we are comparing the Aluminium alloy Grey cast iron, and Epoxy E-Glass Unidirectional and compare with the Ni-Cr steel.
4. Apply the boundary conditions.
5. To calculate the Von Mises stresses strains and displacements by using ANSYS17.1 Analysis tool.
6. Analyze the static structural behaviour of various different selected materials under different torques.
7. Compare the analysis results of Von-misses stress, Equivalent elastic strain and Total deformation with the existing journal [6].

3. FEM ANALYSIS OF THE GEAR

In this project numerical method of the FEM based static structural analysis carried out by using ANSYS 17.1 analysis software. FEM (Finite element analysis) a computer-based analysis technique is used of the studying the behaviour of structures under the applied blundered conditions. The ANSYS 17.1 analysis software determine results like the total deformation, Equivalent Von – misses Stress, and Equivalent elastic strain under the applied boundary conditions. The 3D model for numerical analysis developed in CATIA V5R20 design and these models have been imported in ANSYS as IGES file format for further.

4. MATERIAL PROPERTIES

The various mechanical properties of the selected material were given in the table below.

| Properties               | Ni-Cr Steel | Aluminium Alloy | Grey cast iron | Epoxy E-Glass UD |
|--------------------------|-------------|-----------------|----------------|------------------|
| Model type               | Linear elastic isotropic | Linear elastic isotropic | Linear elastic isotropic | Linear elastic isotropic |
| Failure Criteria         | Max Von-Mises stress | Max Von-Mises stress | Max Von-Mises stress | Max Von-Mises stress |
| Yield Strength           | 172.339 MPa   | 280 MPa         | 138 MPa        | 350 MPa          |
| Tensile Strength         | 413.613 MPa   | 310 MPa         | 240 MPa        | 650 MPa          |
| Young's Modulus          | 180000 MPa    | 71000 MPa       | 110000 MPa     | 200000 MPa       |
| Poisson’s Ratio          | 0.28         | 0.33            | 0.29           | 0.22             |
5. TORQUE CONSIDERATION

For the analysis purpose of the differential hypoid gear the applied boundary conditions are friction less supports, that means all gears are rotated in applied rpms and three different rpms were uses for conducting of the static structural analysis. Based on the selection of the different materials and applied boundary conditions the results are generated. The various torques and rpms for the analysis is mention in the below table.

| Sr. no | TORQUE (N-M) | RPM |
|--------|--------------|-----|
| 1      | 490          | 1800|
| 2      | 390          | 3600|
| 3      | 130          | 5400|

6. STATIC STRUCTURAL ANALYSIS

This analysis, which is numerical method of the ANSYS software analysis, the static structural analysis which is a system based analysis, that means, resulting the static structural analysis is generated by computer based on the selection of various different materials an applied boundary conditions the computer solve the results with the help of preloaded formulas and theorems the results will be generated. The static structural analysis is mainly conducted to find the selected material for gear manufacture can withstand or not for the applied loads and generation stress, temperatures etc. during motion. To finding the best material for the manufacturing of the differential hypoid gear is mandatory.

In this work, the FEA tool were used to identify the structural behaviour of various alloy materials and composite material under certain boundary conditions there by determining total deformation, equivalent Von-mises stress and maximum strain for each alloy material and as well as composite material then the comparison was done with previous existing metallic gear material which is Ni-Cr steel. In this research work FEM structural analysis simulation results were shown the behaviour of Ni-Cr steel, Aluminium Alloy, Grey Cast Iron alloy materials and Epoxy E-Glass UD composite material at the applied boundary conditions the results of the static structural analysis were shown below as:

For The Ni-Cr Steel Torque = 490 N-m

Figure 1: Von Mises Stress For Ni-Cr Steel = 118.05MPa

Figure 3: Von Mises Stress For Ni-Cr Steel = 472.22MPa
Figure 2: Total Deformation for Ni-Cr steel = 0.020104 mm
At Torque = 130 N-m

Figure 4: Total Deformation for Ni-Cr steel = 0.080417 mm
For the Aluminium Alloy Torque = 490 N-m

Figure 5: Von Mises Stress for Ni-Cr Steel = 1062.5 MPa

Figure 7: Von Mises Stress for Aluminium Alloy = 40.628 MPa

Figure 6: Total Deformation for Ni-Cr Steel = 0.18094 mm
For the Aluminium Alloy At Torque = 390 N-m

Figure 8: Total Deformation for Aluminium Alloy = 0.017663 mm
For the Aluminium Alloy At Torque = 130 N-m

Figure 9: Von Mises Stress for Aluminium Alloy = 162.51 MPa

Figure 11: Von Mises Stress for Aluminium Alloy = 365.66 MPa
Figure 10: Total Deformation For Aluminium Alloy = 0.070653 mm

Figure 12: Total Deformation For Aluminium Alloy = 0.15897 mm

For The Epoxy E-Glass_UD Torque = 490 N-m

For The Epoxy E-Glass_UD Torque = 390 N-m

Figure 13: Von-Mises Stress For Epoxy E-Glass_UD = 39.239 MPa

Figure 15: Von-Mises Stress For Epoxy E-Glass_UD = 156.96 MPa

Figure 14: Total Deformation For Epoxy E-Glass_UD = 0.067215 mm

Figure 16: Total Deformation For Epoxy E-Glass_UD = 0.26886 mm

For The Epoxy E-Glass_UD Torque = 130 N-m

For The Epoxy E-Glass_UD Torque = 130 N-m
Figure 17: Von-Mises Stress For Epoxy E-Glass, UD = 353.15 MPa

For The Grey cast Iron Torque = 490 N-m

Figure 18: Total Deformation For Epoxy E-Glass, UD = 0.60493 mm

@ Torque = 390 N-m

Figure 19: Von-Mises Stress For Grey Cast Iron = 108.97 MPa

For The Grey cast Iron Torque = 130 N-m

Figure 20: Total Deformation For Grey Cast Iron = 0.030367 mm

Figure 21: Von-Mises Stress For Grey Cast Iron = 435.89 MPa

Figure 22: Total Deformation For Grey Cast Iron = 0.12147 mm

For The Grey cast Iron Torque = 130 N-m

Figure 23: Von-Mises Stress For Grey Cast Iron = 980.76 MPa

Figure 24: Total Deformation For Grey Cast Iron = 0.27331 mm
Table 3: Comparison table for materials at 1800RPM

| Materials        | Stress MPA | Strain      | Total Deformation (mm) | Density (Kg/m³) |
|------------------|------------|-------------|------------------------|-----------------|
| Ni-Cr Steel      | 118.05     | 0.00074772  | 0.020104               | 7800            |
| Epoxy E-Glass UD | 39.239     | 0.0032399   | 0.067215               | 7700            |
| Aluminium Alloy  | 40.628     | 0.00065256  | 0.017663               | 2770            |
| Grey Cast Iron   | 108.97     | 0.0011294   | 0.030367               | 7200            |

Table 4: Comparison table for materials considered at 3600 rpm

| Materials        | Stress MPA | Strain      | Total Deformation (mm) | Density (Kg/m³) |
|------------------|------------|-------------|------------------------|-----------------|
| Ni-Cr Steel      | 472.22     | 0.00299     | 0.080417               | 7800            |
| Epoxy E-Glass UD | 156.96     | 0.01296     | 0.26886                | 7700            |
| Aluminium Alloy  | 162.51     | 0.0026102   | 0.070653               | 2770            |
| Grey Cast Iron   | 435.89     | 0.0045177   | 0.12147                | 7200            |

Table 5: Comparison table for materials considered at 5400 rpm

| Materials        | Stress MPA | Strain      | Total Deformation (mm) | Density (Kg/m³) |
|------------------|------------|-------------|------------------------|-----------------|
| Ni-Cr Steel      | 1062.5     | 0.0067295   | 0.18094                | 7800            |
| Epoxy E-Glass UD | 353.15     | 0.029159    | 0.60493                | 7700            |
| Aluminium Alloy  | 365.66     | 0.0058731   | 0.15897                | 2770            |
| Grey Cast Iron   | 980.76     | 0.010165    | 0.27331                | 7200            |

7. CONCLUSIONS
1. The developed Hypoid gear compared with existing gear material, which has Ni-Cr steel. The analysis was done, torque at 1800 rpm, 3600 rpm, and 5400 rpm under static loading condition.
2. The results of the static structural analysis of von-misses stress, strain, and deformations shows the aluminium alloy is a valid replaceable material in the presence of previous established gear material which has Ni-Cr steel.
3. The hypoid gear was manufactured with the help of aluminium alloy material the 50% of stress was reduced and the aluminium alloy has low density, based on low density the overall weight of the gearbox was reduced.
4. By decreasing of the weight of the gearbox the efficiency of the gear will be increased.
5. After the aluminium alloy material the next suitable material is Epoxy E-glass unidirectional composite material is suitable for manufacturing of the hypoid gear.

8. FUTURE SCOPE OF THE WORK

In the present investigation of static analysis of hypoid gear is analyzed by single composite material in as a future work, the number of composites and some advanced alloy, nano materials with different rpms was also tested for manufacturing of the hypoid gear to overcome of the gear teeth failure by applying of the excessive loads.

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