DESIGN OF COMPOSIT MESH GEAR BY USING ANSYS

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Abstract— *An industrial gearbox is defined as a machine for the majority of drives requiring a reliable life and factor of safety, and with the pitch line velocity of the gears limited to below 25 m/s, as opposed to mass produced gearboxes designed for a specific duty and stressed to the limit, or used for very high speeds etc., e.g. automobile, aerospace, marine gearboxes. A gear box is an mechanical device that is used for speed & torque conversions from prime mover to output shaft. As the speed of shaft increases the torque transmitted decreases and vice versa. To the competent engineer, the design of a gear unit, like any other machine, may seem a fairly easy task. However without experience in this field the designer cannot be expected to cover all aspects of gearbox design. The purpose of this paper is to review the basic design for an industrial gearbox. It should help the researcher not familiar with gear boxes; lay out a reliable working design. And it is intended for the reader to use his own experience in selecting formulae, stress values etc., for gearbox and components. Gear surface temperature has been then investigated in detail through three components: ambient, bulk and flash temperatures. Through extensive experimental investigations and modeling on gear surface temperature variations, a general relation has been built up between gear surface temperature and gear load capacity. The method has been related to test results under different operating ambient temperature and gear geometries. Good agreement has been achieved between the proposed method predictions and experimental test results. Experimental investigation on polymer composite (glass fibre reinforced nylon with PTFE as internal lubricant) gears have also been carried out and two forms of failure have been found, root and pitch fractures.*

Keywords— Bending Stress; Contact Stress; Gear Analysis; ANSYS; Static Load

1. INTRODUCTION

Composite materials, often shortened to composites or called composition materials, are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure. Composites are made up of individual materials referred to as constituent materials. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. Polymer composite materials exhibit excellent strength and stiffness in combination with low density. These properties are especially attractive in structures where transport of goods and people using non-renewable fuels are utilized. Decreased weight with equal transport capacity lowers the total cost and fuel consumption. For several years now glass fiber composites have been used in products such as containers, pleasure boats and automotive parts. Traditionally carbon and aramid fiber composites are utilized in more demanding applications like aircraft and aerospace industry.

The main focus of the paper is:-

1) To develop and to determine bending stresses using ANSYS and compare the results with conventional methods.

2) To generate the profile of spur gear teeth and to predict the effect of gear bending using a three dimensional model and compare the results with those of the Lewis equation.

3) To compare the accuracy of results obtained is ANSYS by varying mesh density.

2. MATERIALS

MATERIALS CHOSEN

The following materials were chosen for the study purpose.
Material: PEEK + Sic + with internal lubricant as PTFE.

1. PROPERTIES OF PEEK

PEEK is high temperature resistant engineered thermoplastic with excellent chemical and fatigue resistance plus thermal stability. They exhibit superior mechanical and electrical properties. With a maximum continuous working temperature of 250 ° C, they have excellent retention of mechanical properties up to 300° C in a steam or high-pressure water environment. Superior chemical resistance has allowed them to work effectively as a metal replacement in harsh Environment They are inert to all common solvents and resist a wide range of organic and inorganic liquids. When extensive machining is required, a secondary annealing process should be considered. PEEK, a unique semi-crystalline, high temperature engineering thermoplastic, is an excellent material for a wide spectrum of applications where thermal, chemical, and combustion properties are critical to performance. Especially significant, in this regard, is PEEK's ability to retain flexural and tensile properties at very high temperatures in excess of 250°C (482°F). The addition of glass fiber and carbon fiber reinforcements enhances the mechanical and thermal properties of the basic PEEK material.

2. GRADES OF PEEK

PEEK (Unfilled)

This general purpose grade is unreinforced and offers the highest elongation and toughness of all PEEK grades.

Unfilled PEEK is available in sheet and rod forms and is also available in black. Black PEEK is ideal for instrument components where aesthetics are important, as well as for seal components where ductility and inertness are important.

3. PEEK (30% Glass Filled)

The addition of glass fibers significantly reduces the expansion rate and increases the flexural modulus of PEEK. This grade is ideal for structural applications that require improved strength, stiffness, or stability, especially at temperatures above 300°F (150°C). Glass-filled PEEK is light brown or tan in colour and mostly used for injection moulding.

a. PEEK (30% Carbon Filled)

The addition of carbon fibers enhances the compressive strength and stiffness of PEEK, and dramatically lowers its expansion rate. It offers designers optimum wear resistance and load carrying capability in a PEEK-based product. This grade provides 3½ times higher thermal conductivity than unreinforced PEEK dissipating heat from the bearing surface faster.

b. PEEK (Bearing Grade, Ketron HPV)

This grade of PEEK, containing carbon fiber reinforced with graphite and PTFE lubricants, offers the lowest coefficient of friction and the best mach inability for all PEEK grades. Bearing grade PEEK has an excellent combination of low friction, low wear, high limiting PV, low mating part wear, and easy machining. Bearing grade PEEK is black or dark grey in colour.Of the above grades of PEEK due to availability concerns in INDIA, 30% carbon filled grade was selected and purchased.

c. POLYTETRAFLUOROETHYLENE (PTFE)

Polytetra fluoroethylene (PTFE) is a synthetic fluoropolymer of tetra fluoroethylene that finds numerous applications. The best known brand name of PTFE is Teflon by DuPont Co.PTFE is a fluorocarbon solid, as it is a high-molecular- weight compound consisting wholly of carbon and fluorine. PTFE is hydrophobic: neither water nor water-containing substances wet PTFE, as fluorocarbons demonstrate mitigated London dispersion forces due to the high electro negativity of fluorine. PTFE has one of the lowest coefficients of friction against any solid.PTFE is used as a non-stick coating for pans and other cookware. It is very non-reactive, partly because of the strength of carbon–fluorine bonds, and so it is often used in containers and pipe work for reactive and corrosive chemicals. Where used as a lubricant, PTFE reduces friction, wear, and energy consumption of machinery.

d. CALCULATION OF GEAR TOOTH PARAMETERS

Number of teeth	Z1	=	50			
Total height of a gear tooth,			h	=	3.25m	= 3.3 mm
Module,			m	=	4/2.25	= 1.43 mm
Pitch circle diameter			d1	=	m.Z1	= 1.43*12
d1 = 15.96 mm						
Addendum,			ha	=	m	
ha = 1.33 mm						

Dedendum, hf =1.35* m
Hf = 1.77 mm

3. ANALYSIS OF MESH GEAR USING ANSYS

Step 1:- Import the solid model from pro e:-File-import-IGES
Step 2:-Preference →Structural→ OK.
Step 3:- Preprocessor selecting the element type for the gear
Preprocessor → Element type →Add/Edit/Delete→ click on Add in the dialogue box that appears → In Library of Element Types select Solid-Tet 10node 187→Ok
Step 4:- Specifying the material properties
Choose preprocessor→ Material props→ Material Models→ Double click on Structural→ Linear→ Elastic→ Isotropic. The Young's modulus of plain carbon steel is 2.1 E5 and the poisson ratio (PRXY) is 0.3. Choose preprocessor→ Material props→ Material Models→ Double click on Structural→ Density. Density of plain carbon steel is 6.8e-6
Step 5:-Meshing the geometry Decretive the model into finite elements. Set the element edge length to 30.
a) Meshing→ Size control→ Manual → Global→ Size→ Enter Element Edge Length as 30 → OK b) Now mesh all the volumes in the geometry
Step 6:-Applying load and constraints
Loads→ Define Loads→ Apply → Structural→ Displacement→ On Areas→ Select the inner surfaces of the key hole→ OK
Step 7:- Solution
Solution→ Solve→ Current LS→ In the prompting that appears on the screen click YES
Step 8:-General Postprocessor
General Post procedure → Plot Results→ in the Plot Deformed Shape dialogue box select Def + un-deformed → General Post procedure→ Plot Results→ Contour Plot→ Nodal Solu→ Stress→ Von mises Stress→ OK

e. ANALYSIS OF INJECTION MOULDING PROCESS

Injection molding may be a simple process but care has to be taken when it comes to die design and manufacture to make sure that the component produced from it has minimal defects. In the case of injection molding, location of spruce is very important. It determines the number of defects such as air traps, weld lines etc. In olden days the location of spruce was finalized either by trial and error method or out of shear experience in the field. Nowadays with the development of technology many software are available to roughly predict the process out comes by properly feeding the data of the problem or process under study.

The software "MOLDFLOW PLASTICS INSIGHT V 3.1" is used to analysis the injection molding process and using the results obtained the optimum location of the sprue can be got.

4. STEPS INVOLVED IN ANALYSIS

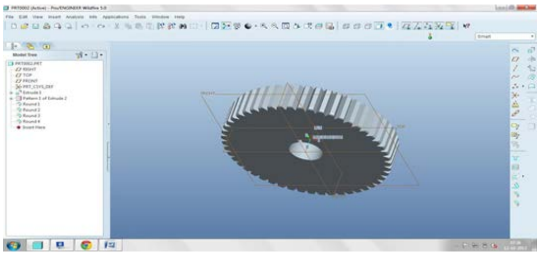

FIG 1 CAD 3D MODEL OF GEAR USING PRO E

The following steps are to be followed to analyze the injection molding process using "MOLDFLOW PLASTICS INSIGHT V 3.1".

- Development of the CAD model of the component using a 3D CAD software. So PRO E is used to model the CAD model of the gear as shown in fig 5.1.
- After completing the modeling it has to be saved in .stl file format because the MOLDFLOW software cannot access .cat or .prt files.
- Then the MOLD FLOW software is opened and new project directory is created in the name "Gear analysis".
- Then the gear's 3D model is imported to the MOLD FLOW software and meshed using standard 3D fusion elements as shown in fig 5.2.

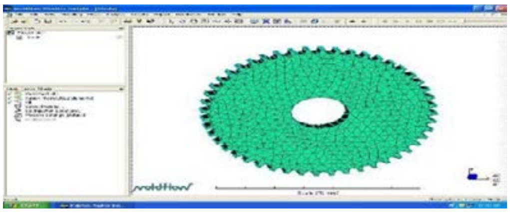

FIG 2 MESHED GEAR MODEL IN MOLD FLOW PLASTICS

Next the gear material is selected. Here one of the study materials VICTREX PEEK supplied by DuPont polymers is used.

f. MACHINE PARAMETERS

Maximum machine clamp force = 8.0000 x 103 tone
Maximum injection volume = 3.0000 x 104 cm3
Maximum injection pressure = 2.0000 x 102 MPa
Maximum machine injection rate = 6.0000 x 103 cm3/s

g. PROCESS PARAMETERS

Fill time = 50.0000 s
Cooling time = 30.0000 s
Packing/holding time = 20.0000 s

Next the injection location is marked using the injection point selection option. Here two positions were considered,

1. On the GEAR TOOTH
2. On the GEAR FACE.

Since the component is asymmetrical any two locations will serve the purpose.

Once all the settings are finished and parameters are given the analysis is made to run and the software runs the simulation and produces the results in few minutes

I. ANALYSIS OF THE RESULTS

From the results produced few important factors like the weld lines air traps fill time pressure required etc were considered to decide on the final location of the spruce out of the two suggested locations The fill time is a very important factor because it is not only related to the sprue location but also determines the productivity of the component. The figures7 and 8 shows the time required to fill the die cavity. Location 1 takes about 41.76 seconds to fill the cavity while location 2 takes only 36.33 seconds to fill the cavity. Again location 2 which is on the gear tooth seems to be a perfect location for the sprue as it produces gear in a quick time hence will be better productive than the location 1.

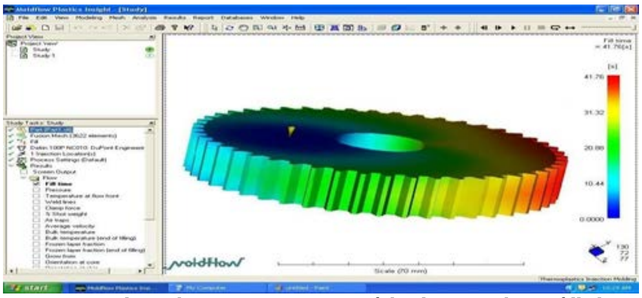

Fig 7 Analysis showing various parts of the die cavity being filled gradually in 41.76 sec at location 1

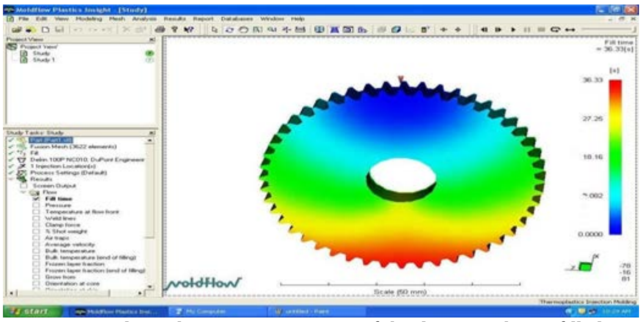

Fig 8 Analysis showing various parts of the die cavity being filled gradually in 36.33 sec at location 2 Inference from the results

From the above discussed results of the simulation it is clear that location 2 i.e. on the tooth will be ideal location for placing the sprue. Hence it was decided to keep the sprue location on the tooth of the gear during the die manufacturing.

h. GEAR COMPOSITION

MATERIAL= VICTREX PEEK POLYETHERETHERKETONE

These materials are mixed with Sic and PTFE (POLYTETRAFLUROETHYLENE) which is an internal lubricant in the following ratios. Hence here the polymer is the matrix and Sic is the reinforcement.

1. Virgin polymer
2. Polymer + 20% Sic + 10% PTFE
3. Polymer + 25% Sic + 10% PTFE
4. Polymer + 30% Sic + 10% PTFE

i. PROCESS PARAMATERS

The process parameters used for the manufacture of the above gears through injection molding process in a hydraulically operated injection molding machine are listed below,

Nozzle temperature : 450° C for VICTREX PEEK
Maximum machine clamp force : 8x103 tones
Maximum injection volume : 2x104 cm3
Maximum injection pressure : 1x102MPa
Fill time : 45-40 s
Cooling time : 19-20 s
Packing/holding time : 4-10

5. CONCLUSION

Engineering components made of composite materials find increasing applications ranging from spacecraft to small instruments. Many types of gear pump use composite gears, however little literature is available on their use. In this project, the results are obtained by static stress analysis of composite gears using a three-dimensional finite element approach are presented. From the results it is concluded that composite material such as PEEK can be thought of as a material for power transmission gears. Internationally patented Composite Structural Members provides slightly different engineering solution for bonding of structural inserts into composite plastic material. If Snap-on invention utilizes oriented and randomly oriented reinforced fibers for constructing the ring gear housing, the Composite Structural Members patent offers a solution for using filament winding material.

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