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Paper Authors

KUMMETHA MAHESWARAREDDY, K. MANOHAR REDDY, L.BALASUBRAMANYAM

PVKK INSTITUTE OF TECHNOLOGY, ANANTAPUR.

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DESIGNING, MODELING AND STRUCTURAL ANALYSIS OF SPUR GEAR SYSTEM BY USING POLYMERS.

[1]KUMMETHA MAHESWARAREDDY, [2]K. MANOHAR REDDY, [3]L.BALASUBRAMANYAM
[1]M.TECH STUDENT, PVKK INSTITUTE OF TECHNOLOGY, ANANTAPUR.
[2]ASSOCIATE PROFESSOR, PVKK INSTITUTE OF TECHNOLOGY, ANANTAPUR.
[3]ASSOCIATE PROFESSOR & HOD, PVKK INSTITUTE OF TECHNOLOGY, ANANTAPUR.

Abstract

This project elaborates more on the creep nature of metallic spur gear results in the deficiency because of the deformation of teeth when pressure angle of 20° acting on it.At the replacing points of tooth between driving and driven the disturbances such as in-evitable random noise, elastic deformation and manufacturing error, alignment error in assembly all these together causes the high level of gear vibration and noise and leads to loss in efficiency. The main motto is to reduce the deformation of teeth, by replacing the metallic cast iron gear with Nylon gear and proved that the deformation of Nylon gear is less compared to metallic and polycarbonate.Since the deformation is less the loss in efficiency is also less compared to metallic gear.The modeling of spur gear has been done in PRO-E and the structural and modal analysis of spur gear analyzed through ANSYS software.

1.INTRODUCTION TO GEAR

A gear or cogwheel is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit torque, in most cases with teeth on the one gear of identical shape, and often also with that shape (or at least width) on the other gear. Two or more gears working in tandem are called a transmission and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, torque, and direction of a power source. The most common situation is for a gear to mesh with another gear; however, a gear can also mesh with a non-rotating toothed part, called a rack, thereby producing translation instead of rotation.The gears in a transmission are analogous to the wheels in a crossed belt pulley system. An advantage of gears is that the teeth of a gear prevent slipping.When two gears of unequal number of teeth are combined, a mechanical advantage is produced, with the rotational speeds and the torques of the two gears differing in a simple inverse relationship

1.1 Tooth profile

A profile is one side of a tooth in a cross section between the outside circle and the root circle. Usually a profile is the curve of intersection of a tooth surface and a plane or surface normal to the pitch surface, such as the transverse, normal, or axial plane.The fillet curve (root fillet) is the concave portion of the tooth profile where it joins the bottom of the tooth space.

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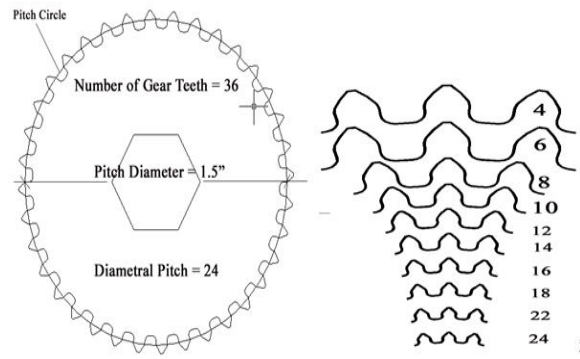
1.2Gear materials

Numerous nonferrous alloys, cast irons, powder-metallurgy and plastics are used in the manufacture of gears. However, steels are most commonly used because of their high strength-to-weight ratio and low cost. Plastic is commonly used where cost or weight is a concern. A properly designed plastic gear can replace steel in many cases because it has many desirable properties, including dirt tolerance, low speed meshing, the ability to "skip" quite well and the ability to be made with materials not needing additional lubrication. Manufacturers have employed plastic gears to reduce costs in consumer items including copy machines, optical storage devices, cheap dynamos, consumer audio equipment, servo motors, and printers.

1.3 Gear Terms And Concepts

Spur Gears**:**Are cogged wheels whose cogs or teeth project radially and stand parallel to the axis.

Diametric Pitch (DP):The Diametric Pitch describes the gear tooth size. The Diametric Pitch is expressed as the
number of teeth per inch of Pitch Diameter. Larger gears have fewer teeth per inch of
Diametric Pitch. Another way of saying this; Gear teeth size varies inversely with Diametric
Pitch.



Pitch Diameter (D)

The Pitch Diameter refers to the diameter of the pitchcircle. If the gear pitch is known then the Pitch Diameteris easily calculated using the following formula;

PD = N/P

PD = Pitch diameter

N= No.ofteeths on the gear

P= Pitch diameter

PD= N/P= 36/24= 1.5"

2.LITERATURE SURVEY

The gear stress analysis, the transmission errors, and the prediction of gear dynamic loads, gear noise, and the optimal design for gear sets are always major concerns in gear design. The polymer gear wear rate will be increased, when the load reaches a critical value for a specific geometry. The gear surface will wear slowly with a low specific wear rate if the gear is loaded below the critical one. The possible reason of the sudden increase in wear rate is due to the gear operating temperature reaching the material melting point under the critical load condition. Actual gear performance was found to be entirely dependent on load. A sudden transition to high wear rates was noted as the transmitted torque was increased to a critical value. This is to be associated with the gear surface temperature of the material reaching its melting point.

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That is for a given geometry of actual gear, a critical torque can be decided from its surface temperature calculation. [K. Mao, 2006] The detailed analysis of the flash temperature for polymer composite gears and the heat partition between gear teeth problem is treated as an unsteady one where the intensity distribution and velocity of heat source changes as meshing proceeds.

A numerical approximation is adopted using finite different method and the results are shown to be close to those found using semi-analytical method assuming no internal hysteresis and the material properties are constant. Blok's solution can be used to provide a quasisteady approximation that is for mean flash temperature estimation. A numerical method has been developed in the current paper for polymer composite gear fl ash temperature prediction. [K. Mao, 2007] Load carrying capacity and occurring damages of gears which are made of PC/ABS blends were investigated. PC is hard material and ABS is soft material. The usage of materials limits these drawbacks.

However PC and ABS polymers combine each other, the PC/ABS blends have suitable mechanical properties for gear applications in the industrial areas. In this study, usability of PC/ABS composite plastic materials as spur gear was investigated. PC/ABS gears were tested by applying three different loading at two different numbers of revolutions on the FZG experiment set. [R. Yakut, 2009]

3.TERMINOLOGY - SPUR GEARS

3.1 Terminology And Defnitions

- Dietral Pitch (D P) - The Number Of Teeth Per One Inch Of Pitch Circle Diameter.
- Module. (M) - The Length In Mm Of The Pitch Circle Diameter Per Tooth.
- Circular Pitch (P) - The Distance Between Adjacent Teeth Measured Along The Arc At The Pitch Circle Diameter
- Addendum (H A) - The Height Of The Tooth Above The Pitch Circle Diameter.
- Centre Distance (A) - The Distance Between The Axes Oftwo Gears In Mesh.
- Circular Tooth Thickness (Ctt) - The Width Of A Tooth Measured Along The Arc At The Pitch Circle Diameter.
- Dedendum (H F)-The Depth Of The Tooth Below The Pitch Circle Diameter.
- Outside Diameter (D O) - The Outside Diameter Of The Gear.
- Base Circle Diameter (D B) - The Diameter On Which The Involutes Teeth Profile Is Based.
- Pitch Circle Dia (P)- The Diameter Of The Pitch Circle.
- Pitch Point-The Point At Which The Pitch Circle Diameters Of Two Gears In Mesh Coincide.
- Pitch To Back - The Distance On A Rack Between The Pitch Circle Diameter Line And The Rear Face Of The Rack.
- Pressure Angle - The Angle Between The Tooth Profile At The Pitch Circle Diameter And A Radial Line Passing Through The Same Point.
- Whole Depth -The Total Depth Of The Space Between Adjacent Teeth.

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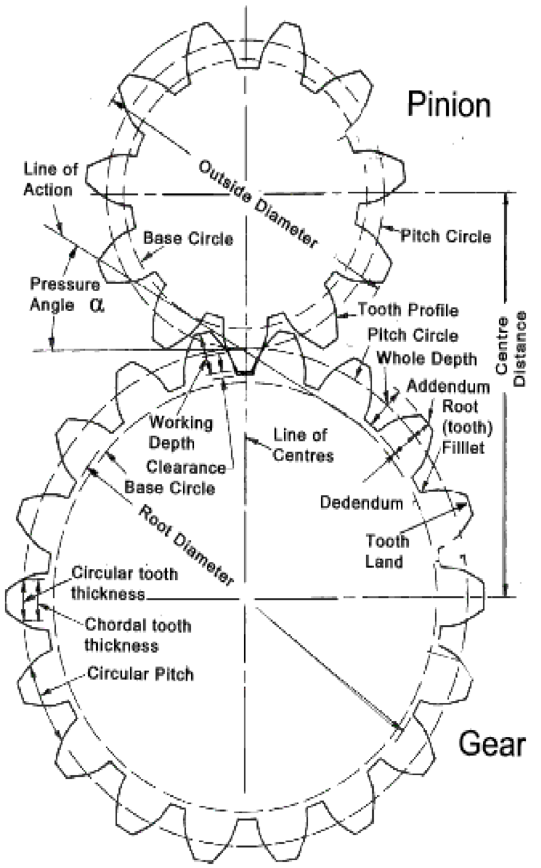

3.2 Contact Ratio The gear design is such that when in mesh the rotating gears have more than one gear in contact and transferring the torque for some of the time. This property is called the contact ratio. This is a ratio of the length of the line-of-action to the base pitch. The higher the contact ratio the more the load is shared between teeth. It is good practice to maintain a contact ratio of 1.2 or greater. Under no circumstances should the ratio drop below 1.1.
A contact ratio between 1 and 2 means that part of the time two pairs of teeth are in contact and during the remaining time one pair is in contact. A ratio between 2 and 3 means 2 or 3 pairs of teeth are always in contact. Such as high contact ratio generally is not obtained with external spur gears, but can be developed in the meshing of an internal and external spur gear pair or specially designed non-standard external spur gears.

$$(R_{go}^2 - R_{gb}^2)^{1/2} + (R_{po}^2 - R_{pb}^2)^{1/2} - a \sin \alpha$$

Contact ratio
m = p cos α
R go = D go / 2.Radius of Outside Dia of Gear
R gb = D gb / 2.Radius of Base Dia of Gear
R po = D po / 2.Radius of Outside Dia of Pinion
R pb = D pb / 2.Radius of Base Dia of Pinion
p = circular pitch.
a = (d g+ d p)/2 = center distance

3.3 Spur Gear Strength And Durability Calculations

Designing spur gears is normally done in accordance with standards the two most popular series are listed under standards above

Bending

The basic bending stress for gear teeth is obtained by using the Lewis formula

$\sigma = F_t / (b_a . m . Y)$

- F_t = Tangential force on tooth
- σ = Tooth Bending stress (MPa)
- b_a = Face width (mm)
- Y = Lewis Form Factor
- m = Module (mm)

Note: The Lewis formula is often expressed as $\sigma = F_t / (b_a . p . y)$
Where y = Y/π and p = circular pitch

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Material Propertiesof Cast Iron, Nylon And Polycarbonate

Material property	Cast Iron	Nylon	polycarbonate
Young's modules	1.65e5	2.1e5	2.75e5
Poisions Ratio	0.25	0.39	0.38
Density (kg/mm)	7.2e-6	1.13e-6	1.1e-6
Co-efficient of friction	1.1	0.15-0.25	0.31
Ultimate Tensile strength	320-350	55-83	55-70

4.INTRODUCTION TO CAD

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.

CADD environments often involve more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) objects. CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry. The design of geometric models for object shapes, in particular, is often called *computer-aided geometric design* (*CAGD*). Current computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surface modellers. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Some CAD software is capable of dynamic mathematic modeling, in which case it may be marketed as CADD — *computer-aided design and drafting*.

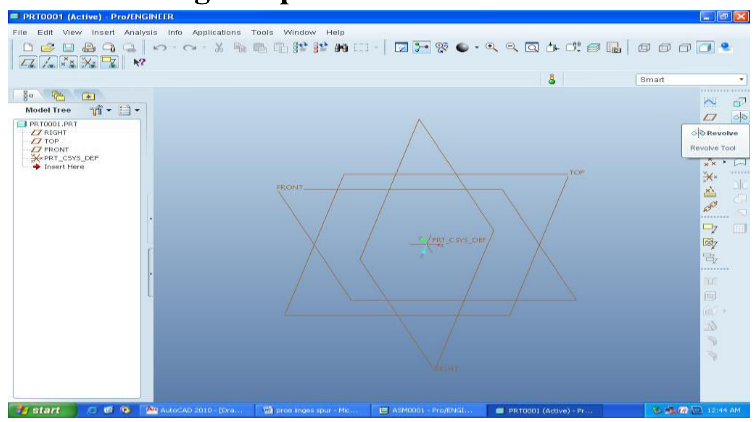
CAD is used in the design of tools and machinery and in the drafting and design of all types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories).

4.1IntroductionToPro-E

PTC was founded in 1985, by Samuel Peisakhovich Ginsberg, who previously worked at Prime Computer, Computer vision (CV) and Applicant. Pro/ENGINEER (a.k.a. Pro/E) the company's first product, shipped in 1988.

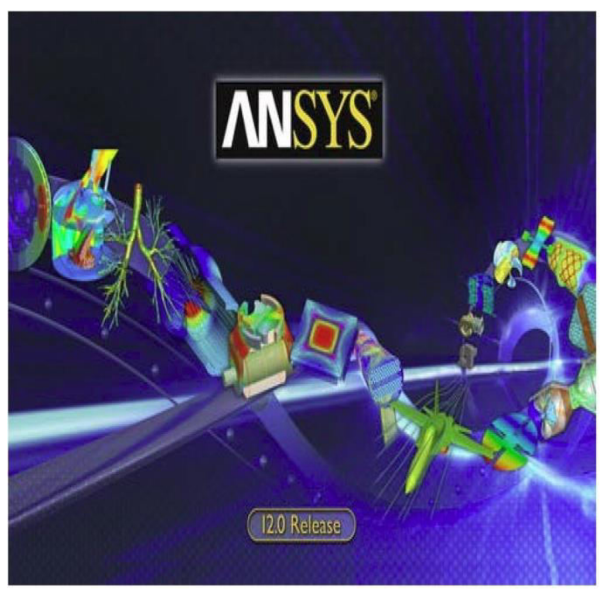
John Deere became PTC's first customer. Once an initial version of Pro/ENGINEER was developed, the company received venture capital funding from Charles River Associates and Steve Walske became the CEO. Pro/ENGINEER was the first commercially successful parametric feature based solid modeler. Through a combination of innovative technology, and no-holds-barred sales tactics, PTC quickly became a major force in the CAD industry. Its strong ascent continued unabated until the mid-1990s, when the introduction of Microsoft Windows NT, and the availability of commercial geometric modeling libraries opened the door to a new generation of low-cost competitors and PTC's reputation for overly aggressive sales tactics alienated many of its customers.

4.2.Modelling Of Spur Gear In Pro-E



Opening Pro/E 5.0 application and take a new file for designing the Gear .The sketch plane shown in above fig represents 3D view (Top,Front,Right) of the plane.

5.INTRODUCTION TO ANSYS



For all engineers and students coming to finite element analysis or to ANSYS software for the first time, this powerful hands-on guide develops a detailed and confident understanding of using ANSYS's powerful engineering analysis tools. The best way to learn complex systems is by means of hands-on experience. With an innovative and clear tutorial based approach, this powerful book provides readers with a comprehensive introduction to all of the fundamental areas of engineering analysis they are likely to require either as part of their studies or in getting up to speed fast with the use of ANSYS software in working life.

Steps involved in ANSYS:
In general, a finite element solution can be broken into the following these categories.

1. Preprocessing module: Defining the problem

The major steps in preprocessing are given below

- defining key points /lines/areas/volumes
- define element type and material /geometric /properties
- mesh lines/areas/volumes/are required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axis, symmetric)

2. Solution processor module: assigning the loads ,constraints and solving. Here we specify the loads (point or pressure), constraints (translation, rotational) and finally solve the resulting set of equations.
3. Post processing module: further processing and viewing of results

In this stage we can see:
List of nodal displacement
Elements forces and moments
Deflection plots
Stress contour diagrams

5.1 Analysis Of Spur Gear

Converting The Pro-E Model Into Iges Format

After the completion of modeling of Spur gear we need to convert it into the IGES format in which ANSYS recognizes our model and can be imported easily in the suggested way.

GO TO FILE---- CLICK SAVE COPY---- Change files type to IGES ---CLICK SOLID MODEL and give File Name --- SAVE in PRO-E SATIC ANALYSIS HAS BEEN DONE TO FIND OUT THE DEFORMATION OF TEETHS

We have to follow certain procedure to analyze the results in ANSYS.

Procedure Steps

1) Import The Model
2) Meshing
3) Constraining The Degress Of Freedom
4) Apply Loads
5) Solve

Importing The Model

Click File--- click on Import---IGES--- Browse---OK

Spur Gears will be displayed on the ANSYS working Window

Meshing

MESH---MESH TOOL--- CHANGE TO VOLUMES---CLICK--- FREE MESH--- CLICK THEE SPUR GEARS VOLUMES---OK and then CLICK ON MESH.

A very fine mesh view of spur gear is displayed below.

(MESHED USING TET10NODE187-ELEMENT USED)

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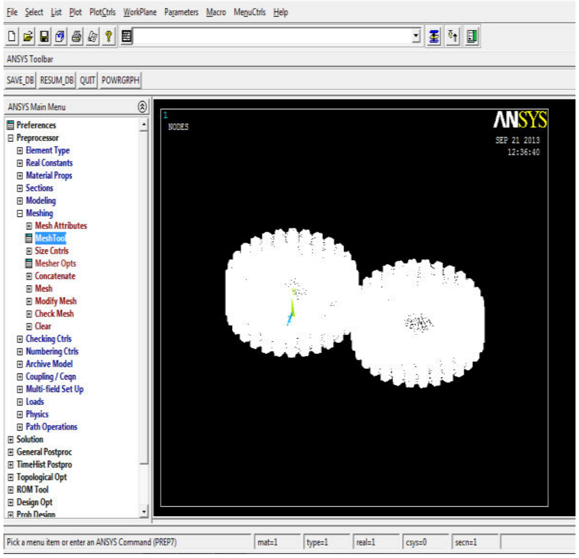

(Mesh View Of Spur Gear)

6.RESULTS

From the static analysis using ANSYS the deflections and Vonmises stress and strain values for the cast iron, Nylon and polycarbonate are obtained as following below tables.

FOR CAST IRON SPUR GEAR

Pressure (N/mm2)	Vonmise Stress (N/mm2)	Deflection (mm)	Strain
1	3.832	0.002905	2.21e-4
2	7.665	0.005811	4.41e-4
3	11.497	0.008716	6.62e-4
4	15.33	0.011622	8.82e-4
5	19.078	0.014488	1.14e-3

FOR NYLON SPUR GEAR

For Nylon Spur gear: Pressure (N/mm2)	Vonmise Stress (N/mm2)	Deflection (mm)	Strain
1	3.582	0.002381	2.19e-4
2	7.163	0.004762	4.37e-4
3	10.745	0.007143	6.56e-4
4	14.327	0.009524	8.74e-4
5	17.82	0.011867	1.29e-3

FOR POLYCARBONATE SPUR GEAR

Pressure (N/mm2)	Vonmise Stress (N/mm2)	Deflection (mm)	Strain
1	3.615	0.001817	2.20e-4
2	7.863	0.003635	4.45e-4
3	10.846	0.005452	6.61e-4
4	14.462	0.007274	8.82e-4
5	17.989	0.009059	1.38e-3

7.CONCLUSION

As per results given by ANSYS the deflections of nylon gear is less, Since the deflections are less the efficiency of nylon spur gear is more than the cast iron spur gear, results in less noise and long life, The metallic gear results is more deflection compared to nylon and polycarbonate, the cost price and life of nylon is also good. When we replace the metallic spur gear with nylon gear there would be better results we can find in the automobile, robotic and in medical fields where the need of nylon gear is there.

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