

Investigation of Wear and Load Carrying Capacity of Composite Gears

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ABSTRACT

Engineering plastics are widely use as material for gears. Plastic gears often require no lubrication or can be compounded with internal lubricants such as PTFE. Plastic gear are widely used in most mechanical devices such as photocopier machines, printers, automatic teller machines under oil-less conditions. Plastic gear materials undergo degradation from high temperature caused by accumulated heat which results in severe wear or early fracture. This wear can be reduced by using different composites of polymer material or by modifying geometry of existing gear. Generally thermoplastic polymers like acetal polymer and nylon polymer are used for gear applications. But acetal and nylon gears have low load carrying capacity. To improve the performance of gears, geometry modifications like tooth width modification and cooling holes on tooth surface has been attempted. For high power transmission these material shows poor performance. Therefore, it is necessary to select the polymer which has good load carrying capacity and also wear resistance. Poly-ether-Ketone-Ketone (PEKK) has comparatively good mechanical properties and thermal stability than other materials. The performance of spur gear with different compositions of glass fiber and carbon fiber will be evaluated. Specially developed test apparatus will be used to test the performance of gear at different speeds and torques. Based on the results, most suitable gear for a particular application will be recommended.

Keywords— PEKK, PTFE, Carbon Fiber, Glass Fiber, Wear, Plastic Gear Performance

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I. INTRODUCTION

In various applications plastic gear became an alternative to traditional metal gears. For the plastic gears it is required to transmit high power. Plastic gears have been used from low power transmission into more demanding power transmission applications. As designers learned about the behavior of plastics and their unique characteristics in gearing. There are number of advantage of plastic gears over metal gears. They have lower inertia, less weight and produce less noise while running. Plastic gears do not require lubrication or can be compounded with internal lubricants such as silicon or PTFE. Plastic gears have a less unit cost than metal gears, and can be designed to

incorporate other features needed in the assembly. These gears can resist many corrosive environments. Mostly light weight high strength composites are made with glass or carbon fibers and base material which gives excellent mechanical properties but these composites cannot be used in high temperature applications. In the applications such as aerospace and naval structure high temperature produces in accidents which reduce the mechanical properties. Polymer composites are mostly used in the tribo situations where resistance to abrasive wear is an extremely important criterion. Typical examples are vanes, conveyor aids, gears for pumps which are used in handling industrial fluids, abrasive contaminated water and sewage etc. The polyamide gears have a many disadvantages. These gear having low

load carrying capacity, poor heat resistance, less running life respectively. These disadvantages limit the application of polyamide gears, especially in high speed, heavy load and high ambient temperature conditions [9]. Over the past few decades, a considerable number of studies were conducted on the performance of polyamide gears. Plastic gear materials experience degradation from high temperature caused by accumulated heat, which results in severe wear and/or early fracture [7]. It was shown that the drilled cooling holes on the tooth body decreased the tooth surface temperature and led to an increase in the load carry capacity and improved wear resistance. Geometrically modified gears have showed an improved service life and a decreased surface temperature [10]. Proposed method was proven to be practically applicable to plastic gears made from soft polymers that show visco-elastic properties such as nylon [7]. Cooling operation must be applied or driver gear materials which have high heat transfer coefficient must be used for lessening the temperature and heat distribution of gear tooth surface during running time of plastic gears [13]. It is not possible to increase running life ever time by this solution. So it is necessary to select new material having good thermal and mechanical properties for critical conditions.

II. METHODOLOGY

The literatures are available on polymer gears for improving the capacity of torque transmission has been studied. There are two ways to improve the load carrying capacity of polymer gears. The first method is geometry modification. The second method is to improve strength of material either by adding fillers into base material or selecting new material having better mechanical and thermal properties. From the literature it is observed that the load carrying capacity of polymer gear depends upon the temperature of gear tooth. Selection of material for gear is depend on requirement of application. Therefore, for transmission of high power the second method is convenient. After selecting the material, material must be tested for desired running conditions depends on application. The design of experimentation has done to decide the combination of test parameters and number of tests using Taguchi approach. In the experimentation the tooth temperature will be recorded at different torque and rotational speeds at certain intervals. The specific wear rates will calculate for all the gear samples with the help of wear loss. The SEM analysis of gear tooth will do before and after the experimentation for gear samples which shows high specific wear rate. Then results will be compare based on tooth temperature, specific wear rate and the SEM analysis for all the composite materials. Based on result comparison conclusions will be made and suggest which material shows high load carrying capacity of gear tooth and ultimately high power transmission capacity of gears and at the end comment on future work will be done.

A. Tools

1) Test rig.

To perform Wear test of spur gear FZG test rig will be. This test rig works on the principle of closed loop power circulation. Gear loading was generated by FZG closed loop geared system.

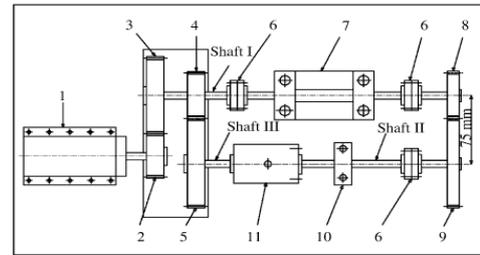


Fig. 1 Gear test apparatus

1:DC Motor, 2,3,4,5: Circulating gears Gear box, 6: Coupling Shaft, 7:Torque detector,8,9:Test gears,10:Bearing, 11: Load coupling

2) Infrared Thermometer

Infrared thermometer is noncontact type temperature sensor and it is used to measure temperature of teeth.

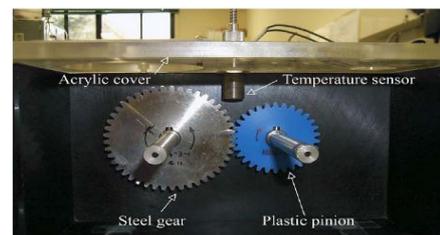


Fig. 2 Measurement of tooth surface temperature

3) Digital Tachometer

The digital tachometer is used to measure the speed of input shaft of gear box in RPM.



Fig. 3 Digital tachometer

4) Scanning Electron Microscope

In case of gears, the SEM images were taken on the pitch surface. Pitch surface is highly stress area where the wear or failure is occurred. In the SEM analysis, the images of gear teeth are taken before the experimentation as well as after the experimentation. The images with different magnifications are helpful for analyzing the wear mechanism or tooth failure mechanism.

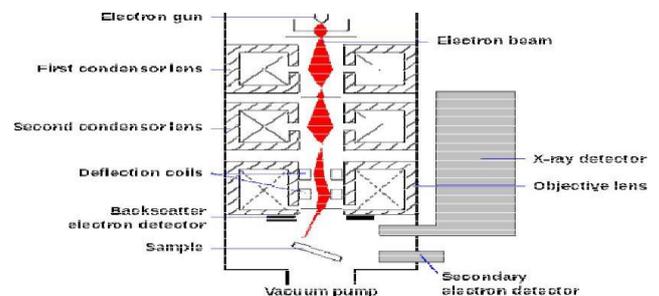


Fig. 4 scanning electron microscope

III. DESIGN OF EXPERIMENTATION BY TAGUCHI

I. A. Selection of material

There are some basic requirements while selecting the gear material. The materials must be strong enough to handle the

gear tooth loading and also have good wear and friction characteristics against the material of the mating gear. The gear designer must carefully evaluate the requirements, both environmentally and mechanically, that the gear demands, and compare these to the properties associated with the intended materials. Therefore, new base material must be suggested having good mechanical and thermal properties for critical severe conditions.

TABLE I
MATERIAL PROPERTIES

Parameter	PEEK	PEKK	PAI
Density(gm/cm ³)	1.26-1.32	1.31	1.42-1.46
Tensile modulus of Elasticity(GPa)	3.7-4.0	4.5	4.5-6.8
Tensile yield strength (Mpa)	70-100	110	110-190
Melting Point (Tm)	250	260	200-260
Thermal Conductivity (W/mk)	0.25@23c	0.25	0.25-0.54@23c
Water Absorption, 24 Hrs (%)	0.1-0.3	<0.20	0.3

B. Probability in material selection

Generally in the printer machines polyamide 66 with 30% glass fibre gears were used. From the literature comparative study have done on the material and their composites which have used earlier in manufacturing of gears. From Table 1 it is easy to select the material which have better property that is high tensile strength, greater load carrying capacity and wear resistance. It was seen that PEKK (Poly-Ether-Ketone-Ketone) have better mechanical and thermal property than other material. The experimentation was not done on PEKK polymer as a gear material. The data was available for unfilled PEKK as well as PEKK composite with different fillers like carbon fibre, glass fibre. As the glass fibre and carbon fibre both are used for increase the strength of base material, therefore we select PEKK with 30% glass fibre and PEKK with 60% carbon fibre. Polymer gears are used in dry lubricated conditions. Therefore additional additives will be added as an internal lubricant.

TABLE III
PROPERTIES OF TEST GEAR

Properties	PA 66GF 30	PE KKGf 30	PE KkCF 60
Density(gm/cc)	1.15	1.51	1.31
Tensile strength(Mpa)	80	186	102
Tensile elongation (%)	2	1.8	4

Water absorption (%)	3	0.04	
Melting point(Tm) ⁰ C	248	360	337

Table 3 shows specification of test gears for experimentation.

- i) 1- 70% wt. PA66+30%wt. of Glass Fibres (PA66GF30)
- ii) 2-70% wt. PEKK+30%wt. of Glass Fibres (PEKKGF30)
- iii) 3-30%wt. PEKK+60%wt. of Glass Fibres (PEKKCF60)

C. Specification of Test Gears and Test Condition

The HP printers were considered for this dissertation work. The HP Laser –Jet printer can have problem of wearing the gear on the fuser and in the printer. It had been necessary to replace the entire main drive assembly. But now we can save the money by replacing just an affected gear. In this work the comparison of PA66GF30, PEKKCF30, PEKKGF60 spur gears were done for the specific wear rate and load carrying capacity. All the tests will be conducted at dry lubricated condition as it requires for selected application. To improve load carrying capacity carbon fibre, glass fibres will reinforce into PEKK polymer.

TABLE IIIII
SPECIFICATION OF TEST GEARS

S r.n o.	Parameters of gears	Test gears			Mat ing gear
		PE KKG F30	PE KkCF 30	PA 66GF 30	
1	Module, mm	1.25	1.25	1.25	1
2	No. of Teeth(Z)	29	29	29	45
3	Pressure Angle(Degree)	20	20	20	20
4	Pitch circle diameter, mm	36	36	36	45
5	Face width(b),mm	12.5	12.5	12.5	12
6	Center distance	30	30	30	45

TABLE IVV
TEST CONDITIONS

S r.n o.	Parameter	Conditions
1	Applied Torque Nm (S)	0.066, 0.724, 0.796N-m
2	Rotational Speed in RPM (N)	3000,3300,3600 RPM
3	Temperature of Environment	Room Temperature, 25°C

4	Environment	Air
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D. Experimentation using Taguchi approach

The design of Experiment(DOE) was used to plan the experimentation for different torque and speeds. DOE tool was helpful for deciding the number of samples and number of tests. In this experimentation, DOE was done by using Taguchi approach. As the number of composite material were 3, the number of torque levels were 3, the number of speeds were 3.

Following specifications were used for three different parameters in DOE

- 1) Gear materials :PA66CF30, PEKKG30, PEKKCF60
 - 2) Applied torques :0.066, 0.724, 0.796mm
 - 3) Rotational speeds :3000, 3300, 3600 RPM
- For above mentioned condition Taguchi were suggesting the L9 array.

TABLE VV
L9 ARRAY OF TAGUCHI APPROACH

Test no.	Gear material	Torque	Speed
1	1	0.796	3000
2	1	0.724	3300
3	1	0.066	3600
4	2	0.796	3300
5	2	0.724	3600
6	2	0.066	3000
7	3	0.796	3600
8	3	0.724	3000
9	3	0.066	3300

It is clear that the number of test required to complete the experimentation was 9 and each gear material should have 03 samples.

IV. PROBABLE OUTCOMES

- 1) The whole test will conduct on FZG test rig at different applied torques and rotational speeds.
- 2) Specific wear rates of gear specimen will calculate and Find the minimum specific wear rate.
- 3) The SEM analysis of all the gears will show the correlation with the Specific wear rate results.
- 4) The test gear which has less Specific wear rate will have high load carrying capacity than other gears.

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REFERENCES

- 1]A manual for guide of plastic gear, SABIC innovation plastic, pp 2-17.
- [2] N.A. Wright and S.N. Kukureka, "Wear testing and measurement techniques for polymer composite gears" Wear, 251, pp

1567-1578,2001.

- [3] S.Apichartpattanasiri, J.N.Hay, S.N. Kukureka, "A study of the Tribological behavior of polyamide 66 with varying injection-moulding parameters", Wear, 251, 1557–1566,2001.
- [4] J.Bijwe, J.Indumathi, A.K Ghosh, "On the abrasive wear behavior of fabric reinforced polyetherimide composites", Wear, 253,768-777,2002.
- [5] Masaya Kurokawa, Yoshitaka Uchiyama, Iwai Tomoaki, Susumu Nagai "Performance of plastic gear made of carbon fiber reinforced polyamide 12", Wear, 254, 468–473,2003.
- [6] E.C Botelho., Figiela, M.C.Rezendeb, B.Laukea, "Mechanical behavior of carbon fiber reinforced polyamide composites", Composites Science and Technology, 63, 1843–1855, 2003.
- [7] Choong Hyun Kim, "Durability improvement method for plastic spur gears" Tribology International, 39, 1454–1461,2006.
- [8] K.Mao, "A Numerical method for polymer composite gear flash temperature prediction" Wear, 262, pp 1321-1329,2007.
- [9] A.D Lina, J.H.Kuang, "Dynamic interaction between contact loads and tooth wear of engaged polyamide gear pairs", International Journal of Mechanical Sciences 50 205-213, 2008.
- [10] Du zcukoglu Hayrettin, "Study on development of polyamide gears for Improvement of load-carrying capacity", Tribology International, 42, 1146 – 1153, 2009.
- [11] T. J.Hoskins, K. D Dearn, Y.K Chen, S.N. Kukureka, "The wear of PEEK in Rolling–sliding contact– Simulation of polymer gear applications", wear, 309, 35-42,2014.
- [12] Pratibha M. Karandikar, R.R. Kharde, S.B. Bhoiyar and R. L. Kadu, "A study the tribological properties of PEEK/PTFE reinforced with glass fibers and solid lubricants at room temperature", International Journal of Current Engineering and Technology, 2347 – 5161, 2014.
- [13] A. D Dighe, A. K.Mishra, V. D.Wakchaure, "Investigation of Wear Resistance and Torque Transmission Capacity of Glass Filled Polyamide and PEEK Composite Spur Gears" International Journal of Engineering and Advanced Technology, 2249 – 8958, 2014.
- [14]Donald R. Askeland, Pradeep P. Phule, 2003, 'The Science and Engineering of Materials', Fourth Edition, Thomson's Book/Cole Publication.