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A Comparative Study Based on ANSYS Analysis of Existing Sprocket's Material with High Performance Engineering Plastic Materials

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***Abstract* - In this dissertation work, we are trying to replace the material of sprockets of motorcycle by plastic material. I have been searching perfect and suitable plastic material which can replace the existing material of sprockets. For this, I have deeply studied about some high performance plastic materials termed as POLYETHER-ETHERKETON (PEEK), POLYIMIDE (PI), POLYPHENYLENESULFIDE(PPS), regarding the existing sprocket material STAINLESS STEEL 304(SS304).**

These are the toughest and hardest plastic material and also capable to bare the temperature generally up to 350^{0}C that is more enough than the temperature is produced while chain rotates over sprocket. Selection of material has done based on keeping in mind the physical and chemical properties of sprocket.

We are using two softwares named CATIA and ANSYS for designing and analyzing the result respectively. The main purpose of our work is to determine the equivalent stress and strain using base material like SS304 then change the material and take tests on PEEK, PI and PPS material then compare all the results. For this, after designing of sprocket model in CATIA then converted it into STEP file and after that surf it into ANSYS for structural analysis.

We applied varying pressures on the some tooth faces therefore we got the equivalent stress and equivalent strain at different pressures and hence we can compare the results of sprocket made by SS304 with PEEK, PI and PPS.

I. INTRODUCTION

Sprockets are most widely used in automobile sector and in machinery. These are used in two wheelers and four wheelers such as bikes, cycles, cars and other mechanism either to transmit revolving motion between two shafts wherever gears are incompatible or to communicate undeviating motion to a pathway etc. Generally it seems that most common sprocket is used in cycle, in which a large sprocket-wheel is mounted on pedal shaft which drives the chain and because of this, small sprocket runs which is mounted on axle of the rear wheel and hence cycle moves toward. Initially automobiles were also generally driven by sprocket and chain mechanism, this rehearsal mainly copied from cycles.

There are numerous types of sprocket's design, a maximum proficiency being appealed for each by its designer. Mainly sprockets have not any flange but some of sprockets are used with timing belts have flanges to possess the timing belt centered. Sprockets and chains are also used to transmit the power from one shaft to another shaft where slippage is not tolerable, sprocket's chains are used in the place of belts or wires and sprocket-wheels are used in the place of pulleys.

These can be rotate at high speed and some types of chain are so assembled as to be soundless even at higher speed.

USES AND APPLICATIONS

The sprockets are mainly used in cycles or bikes in which chain rotates between two sprockets. It is broadly used in automobiles and other matching machines.

MATERIALS

The materials used to manufacture the sprocket gears are aluminum, cast iron, plastic, steel, other metals, brass, copper, powdered metal, wood, etc.

ADVANTAGES

- High bulk density
- Corrosion resistance
- Easy for construction
- Longer service life
- Special surface treatment notrequired
- Competitive price

PEEK

It is also known as poly (ether-ether ketone) and is frequently abbreviated as PEEK. It is a thermoplastic polymer resin of the polyester family and is used in synthetic fibers, Beverage, Food and other liquid containers; thermoforming applications, and engineering resins often in combination with glass fiber carbon fiber. On the basis of its processing and thermal historical background, polyether-Ether ketone may be both as an amorphous that means transparent and as a semi-crystalline polymer. In the textile industries, It is known as, "polyester," whereas the acronyms “PEEK" is mostly used in packing resistant. Bearing-grade PEEK has enhanced bearing and wears properties. PEEK is commonly recycled, and has the number "1" as its recycling symbol. PEEK is a heavy-duty and inflexible plastic material that is habitually used in applications where performance at elevated temperatures is necessary. PEEK has outstanding chemical resistance as well as resistance to steam and hot water. Virgin PEEK is naturally abrasion. It works up to the temperature of 343^0c.

POLYIMIDE (PI)

It is a thermosetting kind of plastic. Thermosetting polyimides are well known for their thermal strength, blameless chemical resistance, superb mechanical properties, and its color may be of two types either orange or yellow. It is compounded with graphite or glass fiberreinforcements which have flexural strengths up to 340 MPaand flexural moduli of 21,000 MPa. These polyimides have very low creep as well as high tensile strength. These properties of Polyimides are sustained during nonstop use to temperatures up to 452 °Cand for short period of time, it is up to 704 °C.

POLYPHENYLENE SULFIDE (PPS)

It is a crystalline polymer which has a symmetrical, stiff spine chain that contains of repetitive p-substituted benzene rings and sulfur atoms. There is a variety of grades appropriate for slurry and Fluidized bed coating, electrostatic spraying as well as injection and compression molding are offered. It has unresolved chemical resistance, thermal solidity, dimensional stability and fire resistance. Its extreme inertness to organic solvents and inorganic salts and bases that make for outstanding performance as a corrosion- resistant coating. The first marketable grades of PPS were introduced by Phillips petroleum under a trade name that is Ryton in 1968.

STAINLESS STEEL 304 (SS 304)

There is so many grades of stainless steel available in the market. SS 304 is one of the best grades of among them. SS 304 is most commonly and broadly used. It is also known by other name 18/8 SS. It is most versatile grade among all grades of stainless steel. It has great chemical composition, mechanical properties machinability, weld ability, corrosion resistance which provides the best all-round characteristics of SS 304 comparatively at lower cost. Since the SS 304 having low temperature properties therefore it is hardened perfectly and quickly by cold working process. In some cases, if intergranular corrosion may occur in the heat affected zone then SS 304 material is preferred to use in such type of zone. Its strength is very high like ultimate tensile strength, tensile yield strength and compressive yield strength are 505MPa, 215MPa and 210MPa respectively. Also it can be operated up to very high temperature.

II. LITERATURE SURVEY

YousukeKawahito, KoujiNishimoto, Seiji Katayama et al. (2011) [2]. Joining of two or more dissimilar metals is needed and important from a manufacturing viewpoint. Therefore, the authors have established a novel laser direct joining method between a metal and a plastic which is named as Laser Assisted Metal and Plastic (abbreviated as LAMP) joining method. In this research, LAMP joining has applied to join silicon nitride Si3N4 ceramic and Polyether-Ether ketone(PEEK) engineering plastic, although metal was replaced by

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ceramic. The tensile shear strength of obtained joints was 3100 N at the maximum, which was strong enough to elongate a PEEK base plate of 2 mm in thickness and 30 mm in width. Furthermore, the observation of transmission electron microscopes (abbreviated as TEM) exhibits that the ceramic and the plastic are strongly bonded on atomic or molecular sized level.

Wilhelm Rust (2003) [3]. In this he describes after debating common properties of implicit finite element analysis using ANSYS and explicit analysis using LS-DYNA it is shown when and how quasi-static limit load analyses can be performed by a transient analysis using explicit time integration. Then we focus on the remaining benefits of implicit analysis and how a proper combination of ANSYS and LS-DYNA can be used to prepare the transient analysis by common preprocessing and static analysis steps. Aspects of discretization, solution control and consideration of imperfections and methods of checking the results are outlined

III. OBJECTIVE

My main objective of this work is to minimize the cost of sprocket. For this I have to search low cost materials but their mechanical properties and physical properties must be either equivalent or near to the properties of SS 304. So that either they can replace the existing material or can be used as alternate to existing material SS 304. For this I am studying comparatively high performance engineering plastic materials in reference of sprocket existing material SS 304.

IV. METHODOLOGY

In my thesis work, a three dimensional model of sprocket have been analyzed for additional research. The results obtained by actual experimentation of PEEK,PI and PPS material have been compared with numerical simulation results by using ANSYS. For modeling purpose chain sprocket is extensively used, since the sprocket was made of SS 304. The following figure shows the chain sprocket of motorcycle which has to be modeled to perform static analysis and compare the numerical simulations with the existing data.

At power (P)= 9kw and Speed(N)=4500rpm, I got the working stress of sprocket having 41 teeth is 36.93 N/mm^2.We know that F.O.S for sprocket must be greater than 1.5 and also we know that
F.O.S= ultimate tensile strength/working strength.

Ultimate tensile strength of PEEK is 100N/mm^2,Ultimate tensile strength of SS 304 is 505N/mm^2,Ultimate tensile strength of PI is 231N/mm^2 and Ultimate tensile strength of PPS is 145N/mm^2.After calculation I found that F.O.S of PEEK, SS 304, PI and PPS are 2.70, 13.67, 6.25 and 3.93 respectively. From these results observed that design in case of all the materials is safe.

COST ANALYSIS

Prices of materials on which I am studying comparatively are taken as per market rate and showing below-

FOR STAINLESS STEEL 304

Price of SS 304 / ton = USD (1200 to 5000) / ton.
Since 1 USD = 60 Rupees (approx)
Therefore,
Price of SS 304 / ton = Rs (72,000 to 3,00,000) / ton
Price of SS 304 / kg = Rs (72 to 300)
Mass of material SS 304 used for one sprocket = 0.53429kg
Therefore, Price of material SS 304 per sprocket = Rs (38.46 to 160.29)
Taking maximum price in round figure, we have
Price of material SS 304 per sprocket = Rs 161

FOR PEEK

Price of PEEK / kg = USD (150 to 260)
Since, 1USD = 60 Rupees (approx)
Therefore,
Price of PEEK / kg = Rs (9000 to 15600)
Weight of material PEEK used for one sprocket = 0.087829kg
Therefore, Price of material PEEK per sprocket = Rs (790.46 to 1370.13)
Taking maximum price in round figure, we have
Price of material PEEK per sprocket = Rs 1371.

FOR POLYIMIDE

Price of POLYIMIDE / kg = USD (20 to 100)
Since, 1USD = 60 Rupees (approx)
Therefore,
Price of POLYIMIDE / kg = Rs (1200 to 6000)
Weight of material POLYIMIDE used for one sprocket = 0.093152kg
Therefore, Price of material POLYIMIDE per sprocket = Rs (111.78 to 558.91)
Taking maximum price in round figure, we have
Price of material POLYIMIDE per sprocket = Rs 559.

FOR PPS

Price of PPS / ton = USD (500 to 2650) / ton.
Since 1 USD = 60 Rupees (approx), so the
Price of PPS / ton = Rs (30000 to 159000) / ton
Price of PPS / kg = Rs (30 to 159)
Weight of material PPS used for one sprocket = 0.10979kg
Therefore, Price of material PPS per sprocket = Rs (3.29 to 17.45)
Taking maximum price in round figure, we have
Price of material PPS per sprocket = Rs 18.

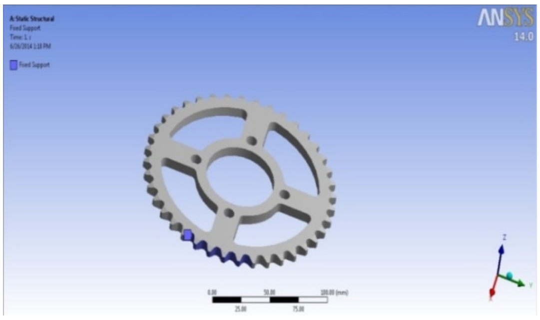

Fig 4.1 - Fixed tooth faces of sprocket

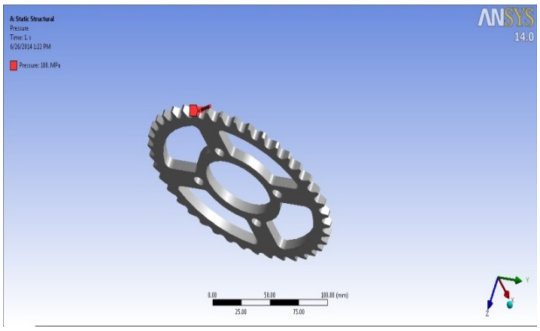

Fig 4.2 - Pressure applied on tooth face

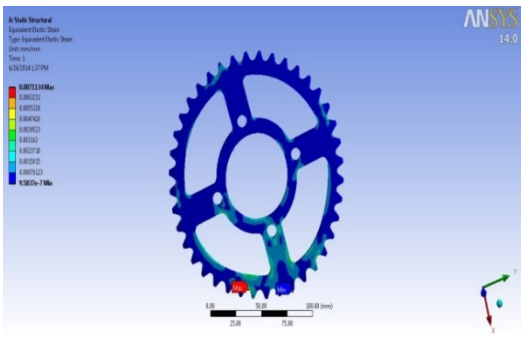

Fig. 4.3 - Meshed view of Sprocket

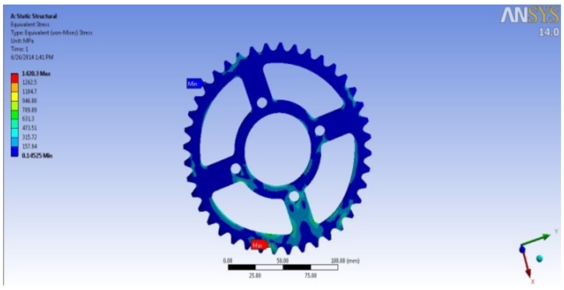

Fig. 4.4 - Equivalent stress at 200MPa of SS 304

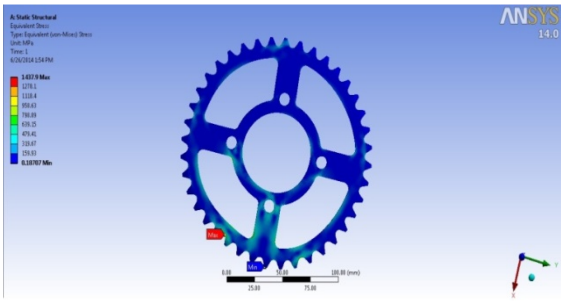

Fig 4.5 - Equivalent elastic strain at 200MPa of SS 304

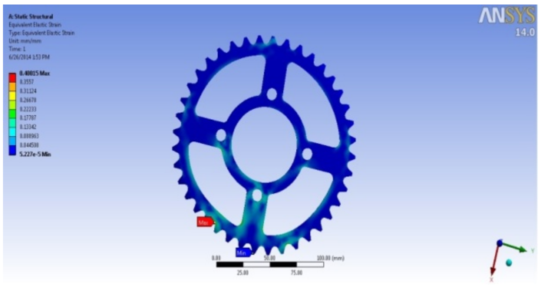

Fig 4.6 - Equivalent stress at 200MPa of PEEK

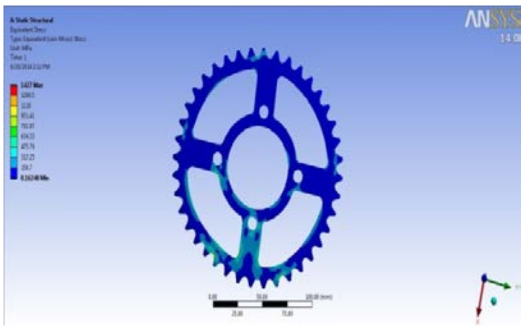

Fig 4.7 - Equivalent elastic strain at 200MPa of PEEK

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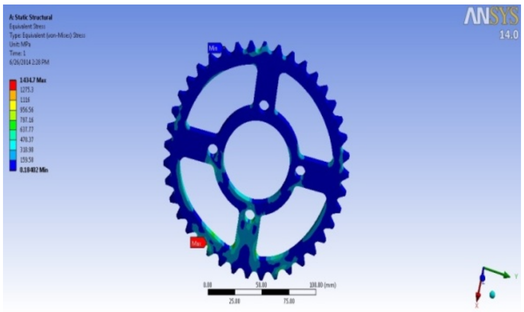

Fig 4.8 - Equivalent stress at 200MPa of PI

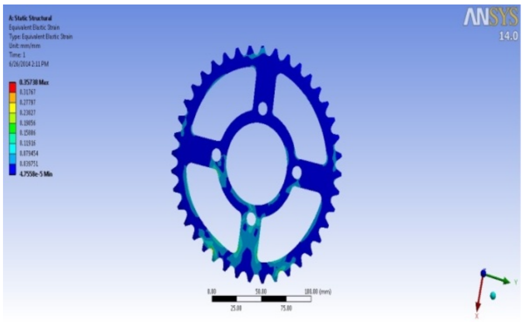

Fig 4.9 - Equivalent elastic strain at 200MPa of PI

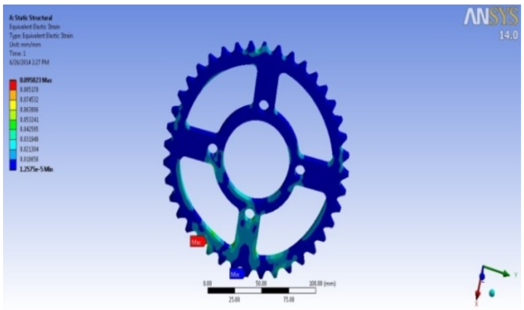

Fig 4.10 - Equivalent stress at 200MPa of PPS

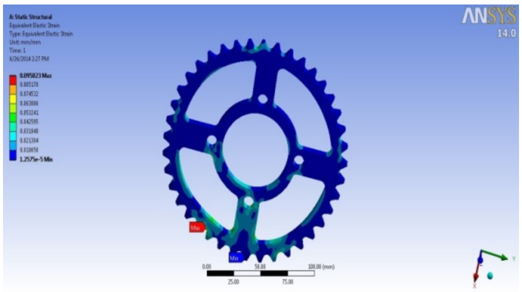

Fig 4.11- Equivalent elastic strain at 200MPa of PPS

Figure 4.1 shows the sprocket design in which few faces are fixed for the purpose of structural analysis, figure 4.2 shows that pressure is applied on a single face of tooth and figure 4.3 shows the meshed view of sprocket design.

In this work, we have done the structural analysis on different pressures like 100MPa, 150MPa and 200MPa but because of limited pages I am just showing structural analysis of sprocket on maximum pressure 200MPa.

V. RESULTS AND DISCUSSION

S. NO.	MATERIAL	MASS (In kg)	PRESSURE (In MPa)	MAX.EQUIVALENT STRESS (In MPa)	MAX. EQUIVALNT ELASTIC STRAIN
1.	SS 304	0.53429	100	710.13	3.5567e-003
			150	1065.2	5.335e-003
			200	1420.3	7.1134e-003
2.	PEEK	0.087829	100	718.93	0.20008
			150	1078.4	0.30011
			200	1437.9	0.40015
3.	PI	0.093152	100	713.52	0.17869
			150	1070.3	0.26803
			200	1427	0.35738
5.	PPS	0.10979	100	717.37	4.7912e-002
			150	1076.1	7.1867e-002
			200	1434.7	9.5823e-002

Table 5.1

The mass of the PEEK is lowest and mass of SS 304 and mass of PI is greater than mass of PEEK while mass of PPS is smaller than mass of SS 304. Overall view is that masses of all the plastic material is smaller than mass of SS 304.

From above table, in all the cases at all the pressures, orders of the Equivalent stresses are same. Equivalent Stress of SS 304 smallest and Stress of PEEK is largest among all but there is short gap.

From above table, in all the conditions at all the pressures, orders of the Equivalent elastic Strain are similar. Equivalent Elastic Strain of SS 304 is smallest and Equivalent Elastic Strain of PPS is largest among all but there is short gap.

COST COMPARISON

S. NO.	MATERIAL	MASS (In kg)	NO. OF SPROCKET	COST (In Rupees)
1.	SS 304	0.53429	1	161
2.	PEEK	0.087829	1	1371
3.	PI	0.093152	1	559
4.	PPS	0.10979	1	18

Table 5.2

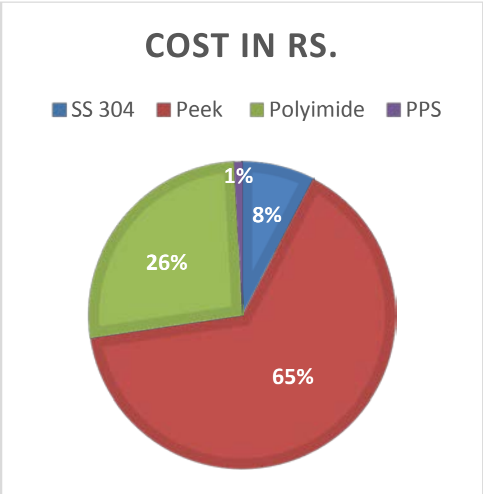

Fig 5.1 - Pie chart for cost comparison

Table 5.1 and Fig 5.1 are showing comparison of cost of all the materials per Sprocket material. The order of cost is-

PPS < SS 304 < PI < PEEK

i.e. Rs18 < Rs161 < Rs559 < Rs1371.

It is also showing cost comparison in percentage. In this cost of PPS is only 1%, cost of SS 304 is 8%, cost of PI is 26% and cost of PEEK is 65%. PPS is of lowest cost material and PEEK is the highest cost material among all.

VI. CONCLUSION

At all the pressures, values of stresses are increasing with the increase in pressure. The equivalent stress of all the materials varies but the variation's values of equivalent stresses are lesser. At all the pressures, values of strain are increasing with the increase in pressure. The equivalent elastic strain of all the materials varies but the values of variation of equivalent elastic strain are lesser.

Therefore we can use these high performance engineering plastic materials in the manufacturing of Sprocket in the viewpoint of equivalent Stress and Equivalent Elastic Strain.

The main thing is cost, and here we found that the cost of PPS is very lesser than other Plastic Material even much lesser than the cost of SS 304.

Therefore, PPS is one of the best Alternate material for SS 304.

- Cost of Sprocket can be reduced
- Design for all the high performance engineering plastic materials is safe
- Mass of the Sprocket material does not affect the Cost
- Equivalent Stresses of all the high performance engineering plastic material is found near about the existing Sprocket material
- Also Equivalent Elastic Strain of all the high performance engineering plastic material is found near about the existing Sprocket material.

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