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Prediction of Force Convergence and Stresses on a Gear using Coefficient of Friction from Wear test developed in Finite Element Method

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Abstract: Gear is a transmission element and is used in different machinery parts and automobile gear boxes. The main objective of this paper is to conduct analysis on spur gear in dynamic conditions by taking the values of coefficient of friction from Tribological experiments conducted for hybrid composite withAl6351.And this base metal is reinforced with SiC and Graphite ranging from 2-8% of equal compositions. In this paper based on the revolute joints as boundary conditions and coefficient of friction as input for different Modulu's of Elasticity for 2-8% of compositions, maximum force with force convergence, equivalent stresses and total deformation are estimated with respective time.

Key words: spur gear, wear, ANSYS, dynamic analysis, force;

I. INTRODUCTION

Gears are of different types and are used to transmit power from one shaft to the other shaft by mating with each other. In rotating machines Meshing gears are one of the most critical mechanisms [1].Gears are power transmitting elements and transmit power between two shafts without any loss of power. So these drives are called positive drives. Drive consists of two gears at any size one gear is driver and other is pinion [2].The effect of aluminium metal in manufacturing field plays major role because of its properties. Aluminium is reinforced with different reinforcement materials to enhance its properties which are suitable for different applications in manufacturing, industrial, aeronautical fields etc. The study of Aluminium Metal Matrix composites for their tribological behaviour in automotive applications [3].The minimum requirement of manufacturing gears is strength and low coefficient of friction. Depending on this requirement the proposed hybrid composites are suitable for manufacturing of gears [4].Gears are of three types 1. Spur gear 2.Helical gear3.Worm gear etc.Of all these gears spur gear produces 98-99% operating efficiency [5].

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The major problem of gear is often identified at the mating surfaces of gear tooth, and the stress is considered as the problematic element. High strength and superior wear resistance is required to reduce this stress. Analysis of spur gear through ANSYS was examined at mating surfaces of teeth [6]. Gear Modeling and analysis was carried out for different nonmetals[7, 8, 9, and 10].Spur gears have wide range of applications in various fields possibly in metal cutting machines, clocks and watches, Washing machines, Fuel pumps, Gear motor pumps, Material handling equipment's, Steel mills, Automobile gearboxes, Rolling mills. etc. [11].There is number of national standards and design methods for the design of gears. For evaluating the strength of gear, [12, 138, 9] root stress and tooth deformation will be analyzed by finite element method with 2-D single tooth model. The dynamic contact effects between rotating spur gears were studied by FEM with multi-body dynamic techniques [14]. The contact and bending strength of spur gears with tooth modifications were studied by FEM [15].

II. MATERIAL PROPERTIES

A. Al 6351

Among all 6XXX series Al6351alloyhaslightweight, superior oxidization, and excellent surface finish. Its electrical and thermal conductivity properties are four times greater than steel.Al6351 is called as structural alloy and is more commonly used for manufacturing purpose. Al6351 have properties like Yield strength, Tensile strength, Fatigue strength, Elastic modulus, Hardness, Poisons ratio, Elongation etc.Al6351 has wide applications in construction of ship, rail & road transport, vehicle, pipe, , bridge, tube, crane roof. It is also applied in aerospace, manufacturing in pipes, tubes and pressure vessels etc.

Properties of Al6351

Table2.1 Chemical Composition of Al6351

Al	Fe	Mn	Si	Cu	Mg	Ti	Zr	Pb	Ca	Sn
95.51	0.12	0.52	0.8	0.051	0.75	0.017	0.003	0.012	0.051	0.004

Table2.2 Physical Properties Al6351

Density (Kg/m^3)	Hardness (Brinell) (BHN)	Elastic Modulus (Gpa)	Poisson's ratio	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)
2710	95	75	0.033	250	150

B. Silicon Carbide (SiC):

The covalently bonded hard Silicon carbide material is manufactured with carbo thermal reduction of silica. The subsequent SiC is a fine powder that needs processing to generate a compatible feedstock maintaining the precise reaction conditions.

Table 2.3Physical properties of SiC

Size (µm)	Density (kg/ m^3)	Hardness (kg/mm^2)	Tensile Strength (Mpa)	Elastic Modulus (Gpa)	Poisson ratio
50	3100	2800	390	410.47	0.14

SiC has the features such as high melting point, outrageous thermal conductivity, low thermal expansion and exhibits good thermal shock resistance. Furthermore, superior corrosion resistance and high stiffness make the SiC to suit in different applications.

C. Graphite (Gr):

Graphite features in low density and is a soft allotrope of carbon. Carbon content in graphite usually ranges from dark gray to black color. The graphite particles are united together by weak Vander Waal forces. Graphite structure with layers allows sliding motion of the parallel graphene plates. The self-lubricating and softness properties are due to weak bonding between the plates.

Size (µm)	Density (kg/m3)	Hardness (HB500)	Tensile Strength(Mpa)	Elastic Modulus (Gpa)	Poisson Ratio
30	2230	1.7 mohrs scale	34.4738	27.6	0.2

I. MODELING AND ANALYSIS OF SPUR GEAR

A. Modeling: Modeling was conducted on Spur gear, designed in CATIA is as shown in **Fig.1.** The rotation for joints is conducted on driver and driven wheels are observed as in **Fig.2**.

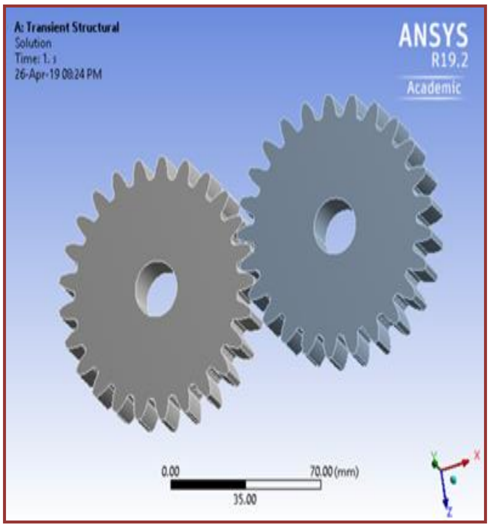

Fig.1

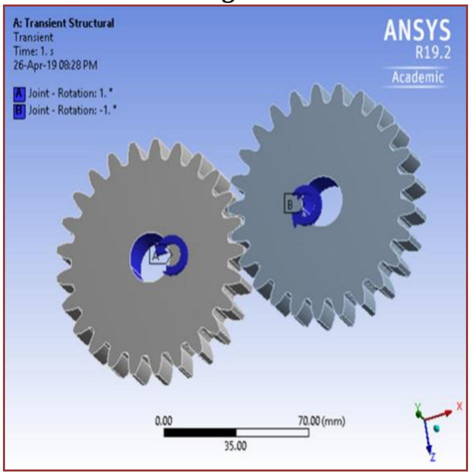

Fig.2

B.Analysis: The model of the spur gear was prepared by CATIA software according to basic dimensions as shown in **Fig.3**and the force distribution will be calculated by force convergence during 60 sec of time period shown in **Fig.4** and the total deformation calculated during the period of 60 Seconds are observed in **Fig.5.**

able 1. Specifications of pinion and gear used in the study.

No	Parameters	Pinion/Gear
1	Centre Distance, a	101.6 mm
2	Normal Pressure angle, ϕ	20°
3	Module, m	5 mm
4	Base Diameter, d_b	98.36 mm
5	Number of Teeth, N	20
6	Face Width, b	25.4 mm
7	Pitch Diameter, P_d	101.6 mm
8	Outside Diameter, d_o	111.76 mm
9	Addendum radius, a	5.08 mm
10	Dedendum radius, b	5.87 mm
11	Working Depth, D	10.16 mm
12	Angular thickness, t_a	9 mm

Fig.3

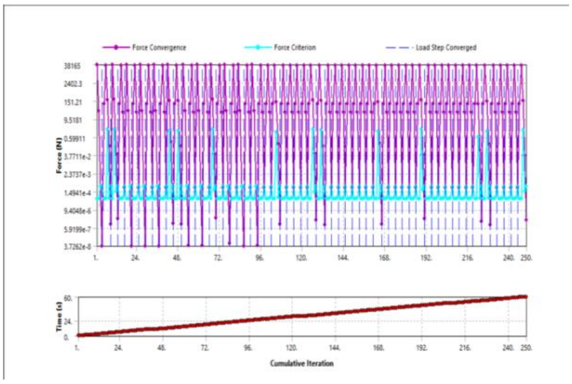

Fig.4

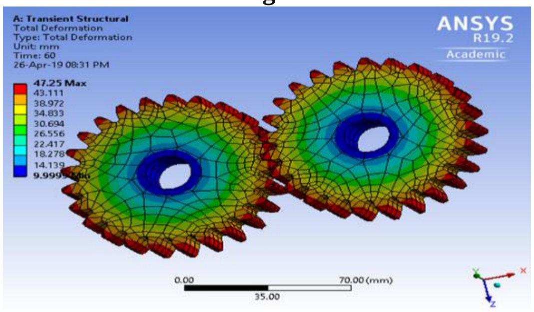

Fig.5

II. RESULTS AND DISCUSSION

According to Experimental results6% of Al6351 reinforced with 6%SiC and 6%Graphite shows better wear resistance and low coefficient of friction when compared with other percentages of reinforcements. Simulation is conducted for spur gear wheels with different coefficient of frictions (C.O.F) which is obtained experimentally. In consequence the coefficient of frictions as input as well as force distribution is considered during 60seconds from force convergence resulting in Equivalent stresses.

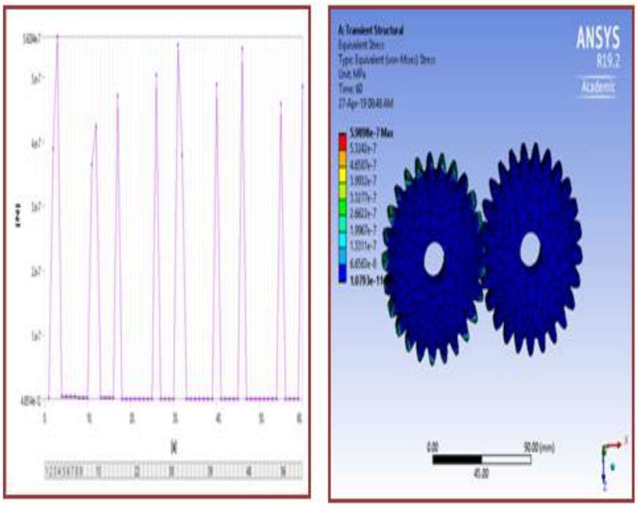

Fig.6 (a) Force convergence Fig.6 (b) Equivalent Stress with c.o.f (0.01)

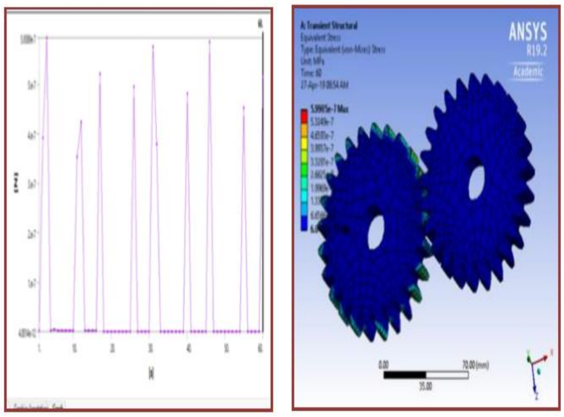

Fig.7 (a) Force convergence Fig.7(b)Equivalent Stress with c.o.f (0.03)

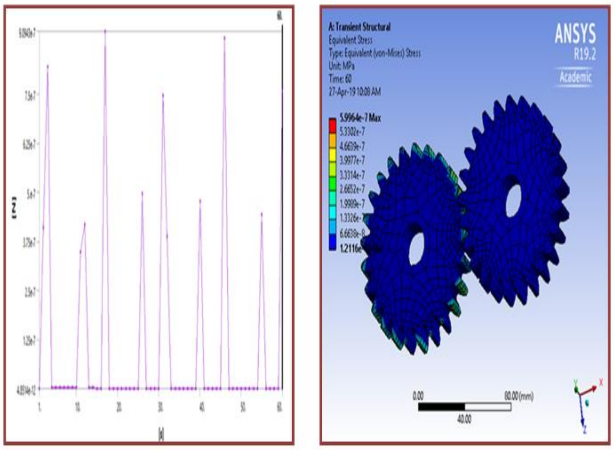

Fig.8 (a) Force convergence Fig.8(b) Equivalent Stress with c.o.f (0.11)

The force convergence graph and equivalent stresses for different COF are shown in the figures from Fig6 (a) to 10(b). From the fig 6(b) it is evident that the maximum Equivalent stresses are obtained at the contact region of the gears. It is also observed that when the coefficient of friction increases the force distribution from the force convergence also increases. The same phenomenon regarding stresses and forces was obtained for all percentage of reinforcements and coefficient of friction values and the plots COF vs stress and force are shown in figures 11(a) - 11(e).

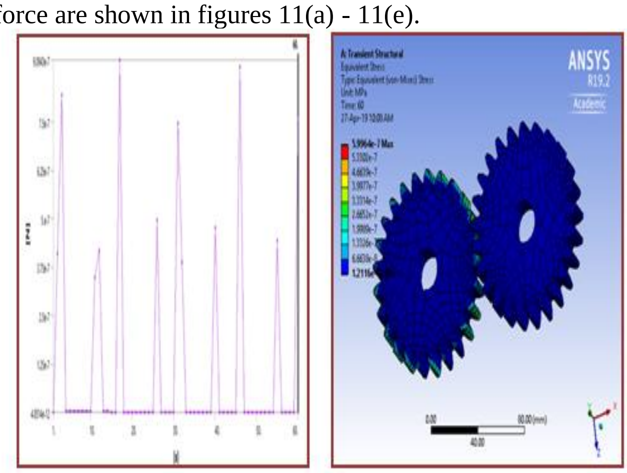

Fig.9 (a) Force convergence Fig.9(b) Equivalent Stress with c.o.f (0.14)

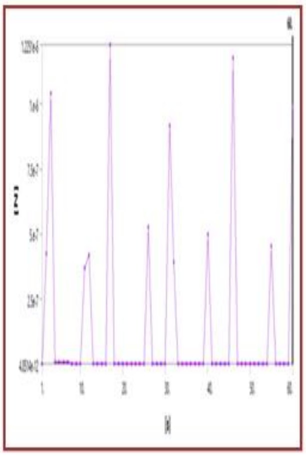
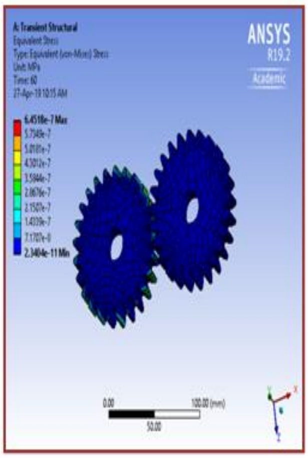

Fig.10(a) Force convergence Fig.10 (b) Equivalent Stress with c.o.f (0.16)

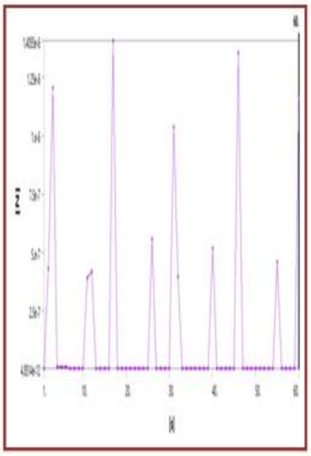
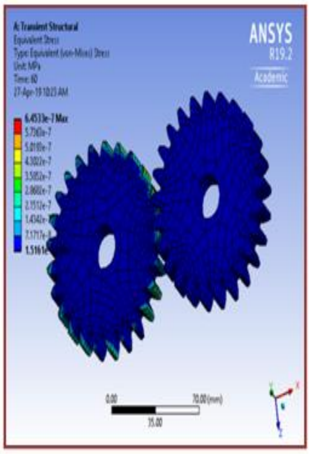

Fig.11(a)Force convergence Fig.11 (b)Equivalent Stress with c.o.f (0.19)

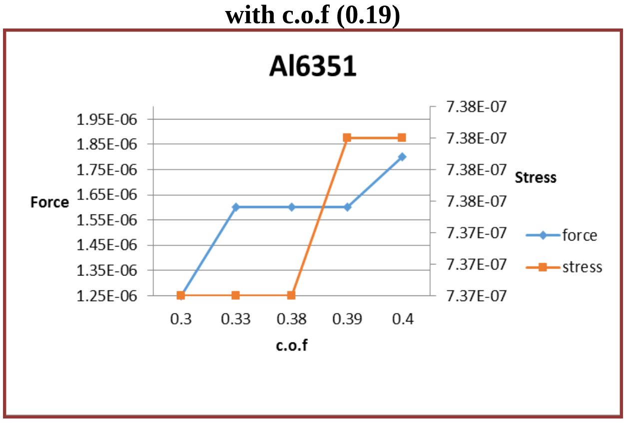

Fig.12 (a)

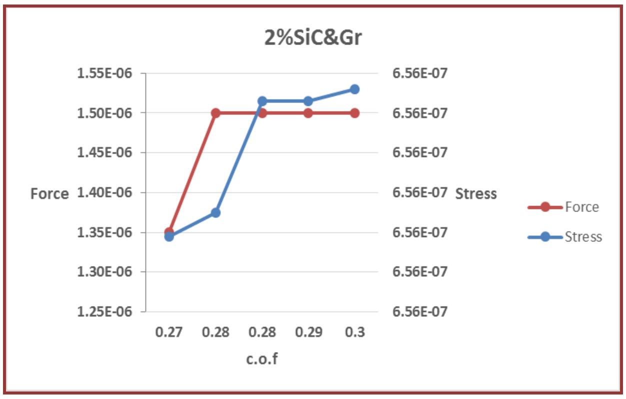

Fig.12 (b)

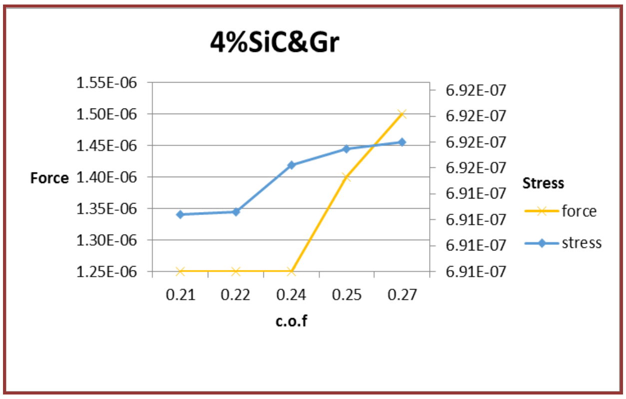

Fig.12(c)

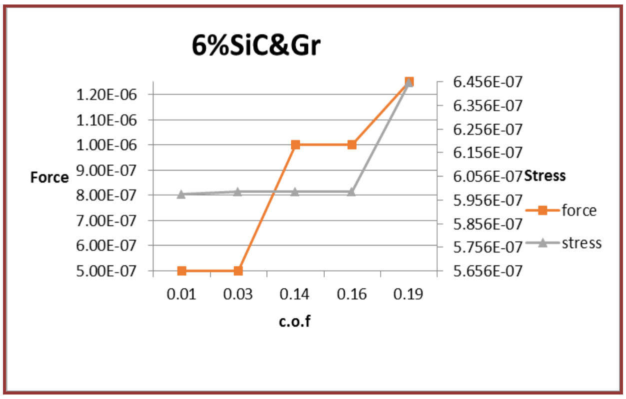

Fig. 12(d)

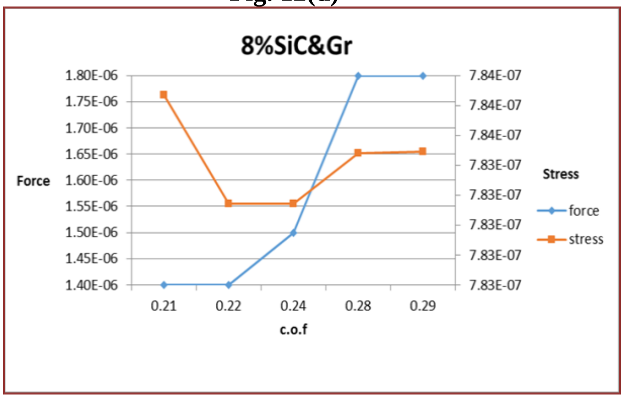

Fig.12 (e)

III. CONCLUSIONS

1. Finite element simulation of gears was performed by applying different COF values and material by varying the reinforcement of hybrid composite.
2. It was observed for all reinforcements that the dynamic forces values increases with increase in COF.
3. By comparing with experimental results, 6% reinforcement is considered as the best composite. Using FEM for this validation effects the dynamic forces gradually decrease as the COF value is minimum.
4. For all reinforcements based on the force convergence with respective time the Equivalent Stresses are flexible and keeps varying with respect to coefficient of friction.

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