Investigation of Tribological Behavior of PEEK Composite with Glass Fiber Filled under Harsh Operating Condition

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ABSTRACT

The polymer matrix composites are widely used in various mechanical applications. Aim of this project to study of the wear, Coefficient of friction & frictional force polyether-ether-keton (PEEK) matrix composites with Glass Fibers (GF). Also, under dry and wet friction conditions the wear, Coefficient of friction & frictional force of PEEK matrix composites was studied at temperatures 50^0C, 100^0C & 150^0C. Pure PEEK is having low friction coefficient and high wear rate, so its applications are limited. At room temperature the friction and wear of PEEK can be improved by adding different fillers such as Glass Fiber, Carbon fiber, metallic fibers etc. It is found that PEEK with 30 percent by weight GF at 150^0C having good wear resistance. Also at 80 N load under dry condition wear performance of PEEK with 30 percent by weight GF was improved.

Keyword : *-PEEK, glass fibers, wear properties, mechanical properties, temperature etc.*

1. INTRODUCTION

The development of composite materials and related design and manufacturing technologies is one of the most important advances in the history of materials. Composites are multifunctional materials having unprecedented mechanical and physical properties that can be tailored to meet the requirements of a particular application. Many composites also exhibit great resistance to high-temperature corrosion and oxidation and wear. These unique characteristics provide the mechanical engineer with design opportunities not possible with conventional monolithic (unreinforced) materials. Composites technology also makes possible the use of an entire class of solid materials, ceramics, in applications for which monolithic versions are unsuited because of their great strength scatter and poor resistance to mechanical and thermal shock. Further, many manufacturing processes for composites are well adapted to the fabrication of large, complex structures which allows consolidation of parts, reducing manufacturing costs.

1.1 Polyether Ether Ketone (PEEK)

PEEK is a semi-crystalline colorless organic polymer. It is a thermoplastic that has desirably very good mechanical and chemical resistance properties that are retained to high temperatures. It is highly resistant to thermal degradation as well as attack by both organic and aqueous environments. It has superior resistance to wear and dynamic fatigue PEEK (polyether ether ketone) is a high performance engineered polymer with amazing strength and heat resistant properties. PEEK polymer is a very rigid plastic with excellent lubricity. PEEK is naturally tan in color; however it can be pigmented with a wide range of colors for part identification. Thin wall PEEK is more flexible and can be cut to length with a razor blade. PEEK is a linear aromatic polymer which is semi-crystalline and is widely regarded as the highest performance thermoplastic material. PEEK polymers are obtained by step-growth polymerization by the dialkylation of bi-phenolate salts. Typical is the reaction of 4,4'-difluorobenzophenone with the disodium salt hydroquinone, which is generated in situ by deprotonating with sodium carbonate. The reaction is conducted around 300°C in polar aprotic solvents such as diphenyl sulphone

1.2 Advantages and Disadvantages PEEK

Advantages	Disadvantages
Excellent high temperature for all mechanical properties	Extremely high cost but the properties can justify this when it becomes almost the only polymer capable of being used
Excellent electrical performance at high temperature	Limited supplier base
Excellent wear and abrasion resistance at high temperature	Limited range of colors
Excellent chemical resistance at high temperature	
Excellent gamma radiation resistance	

2. MATERIALS AND METHODS

The details of processing of the composites and the experimental procedures followed for their characterization and tribological evaluation. The raw materials used in this work are Unfilled PEEK and PEEK with 30% GF. Commercially available Polyetheretherketone (PEEK) of grade 450 G fine powder with the average diameter of 100µm. The composite is prepared by injection molding. PEEK with 30% glass fiber are mixed for various batches with batch size100gm for injunction molding.

Table 2.1 Designation of Composites

Specimen	Compositions
S1	PEEK (100%wt)
S2	PEEK (70%WT) +30% GF

3. EXPERIMENTAL

Observations

Table.3.1 Wear of Neat PEEK and PEEK 30% GF

Temperature in ºC	V (m/s)	WEAR (µm)					
		PEEK			PEEK+30%GF		
		2kg	4kg	8kg	2kg	4kg	8kg
50 ºC	1.4	56.70	66.93	352.05	41.35	60.51	117.61
100 ºC	1.4	273.93	38.56	100.77	52.37	69.15	18.69
150 ºC	1.4	586.86	333.09	502.67	165.70	168.57	126.01

Table 3.2 Coefficient of friction of Neat PEEK and PEEK 30% GF

Temperature in ºC	V (m/s)	Coefficient of friction(μ)					
		PEEK			PEEK+30%GF		
		2kg	4kg	8kg	2kg	4kg	8kg
50 ºC	1.4	0.650	0.160	0.090	0.670	0.170	0.140
100 ºC	1.4	0.190	0.230	0.200	0.180	0.000	0.220
150 ºC	1.4	0.190	0.320	0.170	0.100	0.320	0.230

Table 3.3 Frictional force of Neat PEEK and PEEK 30% GF

Temperature in ºC	V (m/s)	Frictional force(N)					
		PEEK			PEEK+30%GF		
		2kg	4kg	2kg	2kg	4kg	8kg
50 ºC	1.4	13.08	5.82	5.58	13.29	10.75	10.96
100 ºC	1.4	3.53	5.41	15028	3.17	3.17	17.46
150 ºC	1.4	0.190	12.47	0.170	3.08	4.32	6.57

4. RESULT AND DISCUSSION

The comparative study of PEEK and PEEK with 30% GF were studied from Table 3.1 TO 3.3 It was observer that wear rate at 50ºC and at 150ºC for pure PEEK was found to be $3.65\times10^{-3}mm^3/m$ to $5.21\times10^{-3}mm^3/m$. This indicates that for pure PEEK due to increasing the temperature it thermo mechanical properties decrease which leads to increase the wear rate because of softening of material further increasing the temperature the wear rate falls down drastically and archived the value $5.21\times10^{-3}mm^3/m$ at. 150° C. But by reinforcement PEEK with 30% GF. It is found that ware rate fall down compare to pure PEEK. Wear value drastically enhanced by Glass fiber. It is also observed that transfer film formed very soon with increasing of temperature as compared to pure PEEK material. The negative values of wear till continued up to temperature 150°C with increasing temperature the value of wear increased when temperature goes beyond the 150 °C.

Form fig 4.1 to 4.3 It was also observed that with addition of GF in PEEK from table 3.1 and table 3.3 shows that GF is show more significant effects to enhance the mechanical properties. The addition of GF in PEEK make tough bounding due to the tough covalent bounding the surface asperities are hold firmly with its neighbor or adjacent asperities. Due to these bounding shows the resistance against the drag force created by machine torque and applied normal force. The wear rate due high load and high temperature is found to be $1.3085\times10^{-3}mm^3/m$. This indicate that the with addition of 30% GF with PEEK enhanced wear rate four times PEEK ie. with addition of GF with PEEK increase the wear resistance 75%.

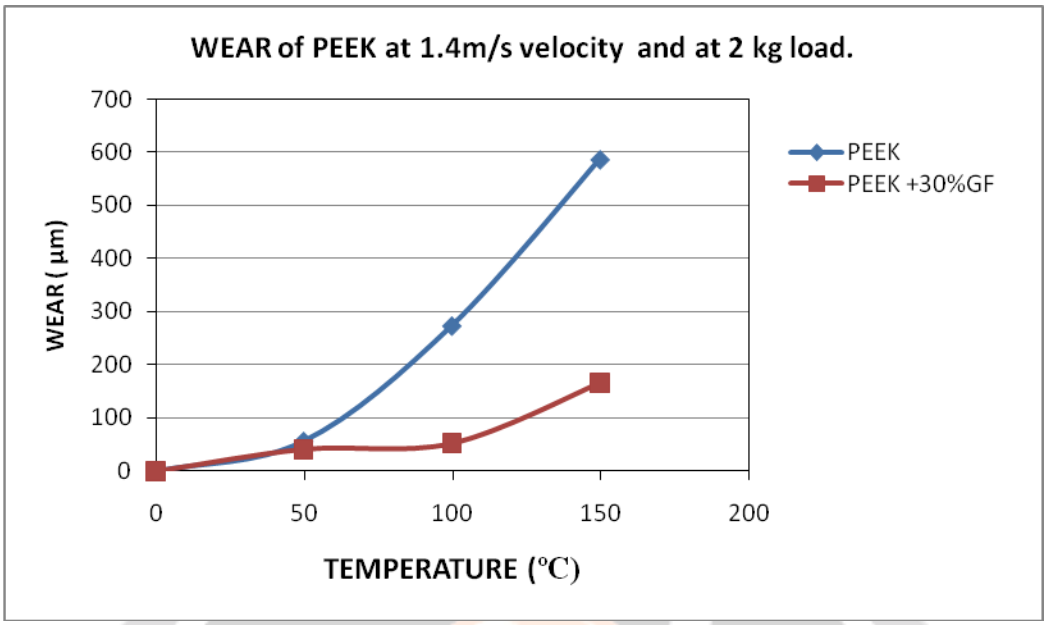

Fig. 4.1 Effects of load on wear PEEK and PEEK with 30% GF composites. at 2 kg

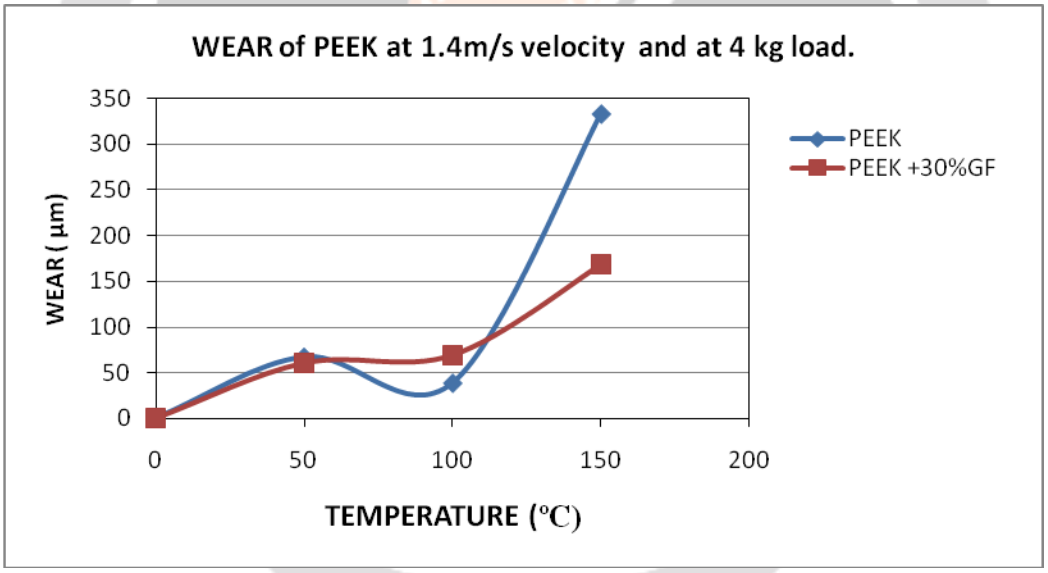

Fig. 4.2 Effects of load on wear PEEK and PEEK with 30% GF composites at 4 kg

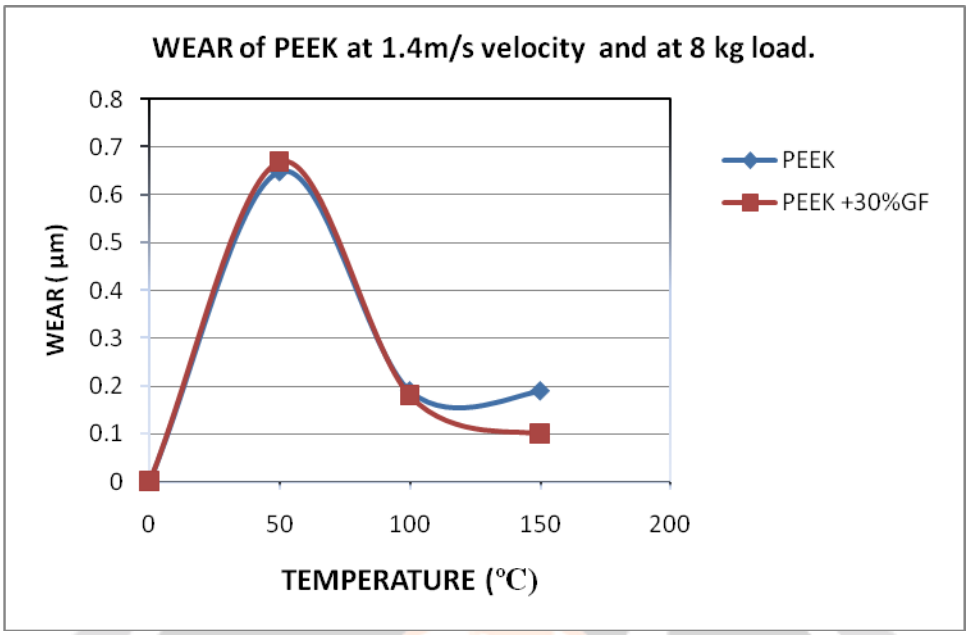

Fig. 4.3 Effects of load on wear PEEK and PEEK with 30% GF composites at 8 kg

Fig.4.1 to 4.4 shows the relationship about frictional force Vs temperature characteristic with same operating parameter for all three type of pin S1and S2.The value of frictional force of pin S1 (PEEK) was less as compared to the Pin S2 (PEEK+30% GF).The value of frictional force found to be lass in second trial at high loading condition as compare to low load due to which wear characteristics also enhanced. In the comparative study about the frictional force value for PEEK and PEEK with 30% GF. Initially it is observed that the value of frictional force is very high for PEEK as well as PEEK with 30% GF at normal temperature range this value reaches up to 13 N for both pin 1 and pin2 which is made up of Pure PEEK and pin 2 is made of PEEK with 30% GF. But with rising the temperature this value fall down at high temperature and high load. Tabulate in table 5.6

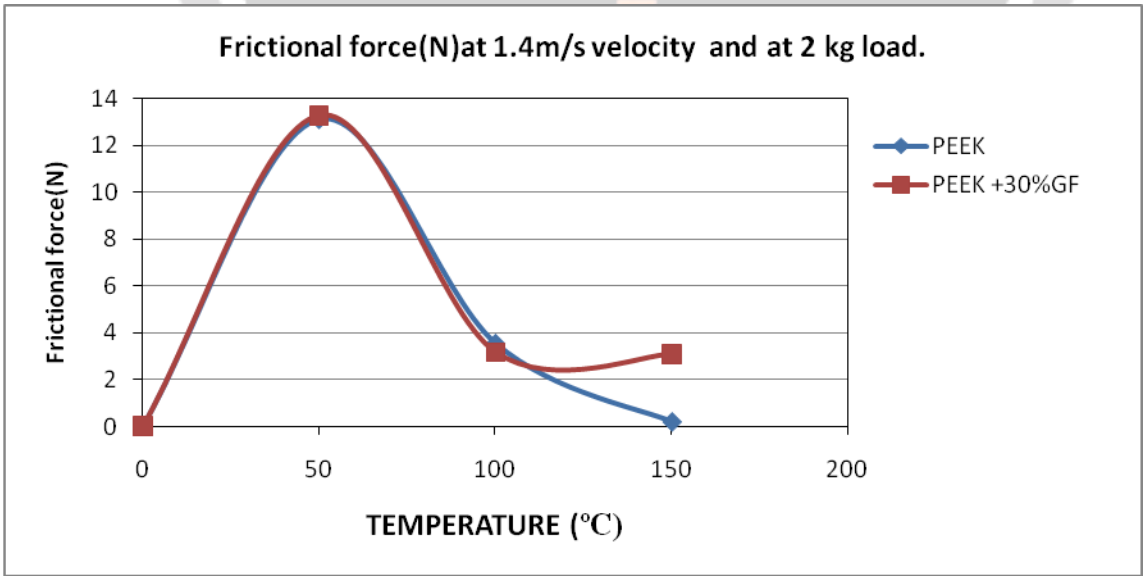

Fig. 4.4 Effects of load on frictional force PEEK and PEEK with 30% GF composites at 2 kg

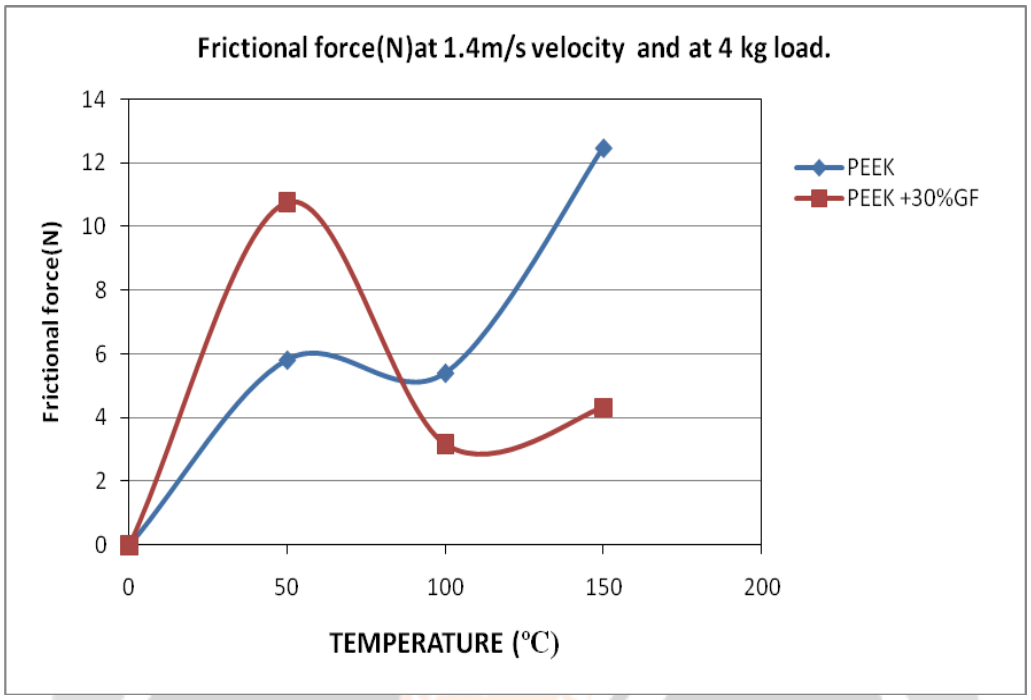

Fig. 4.5 Effects of load on frictional force PEEK and PEEK with 30% GF composites at 4 kg

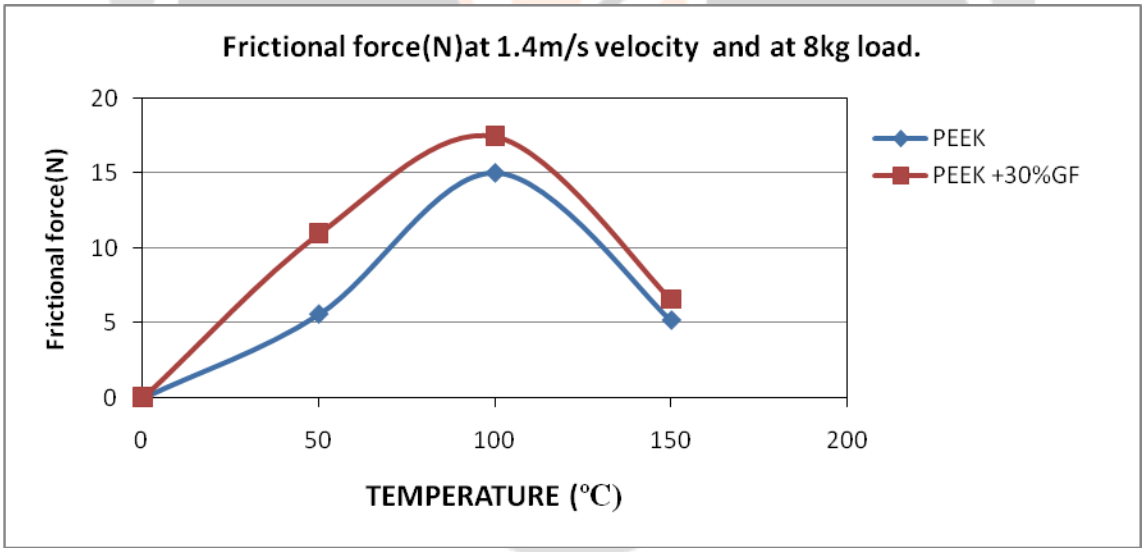

Fig. 4.6 Effects of load on frictional force PEEK and PEEK with 30% GF composites at 8kg

Fig.6.25 to fig 6.27 shows the effects varying temperature Vs coefficient of friction of Pin S1, S2 graph plotted from the observations gave idea about the coefficient of friction between the rubbing part of pin and disc. It was found that the Pin S1 of PEEK martial has less value of coefficient of friction as compared to the pin S2. This value was found satisfactory as per the references regarding the piston ring material selection. The standard value of coefficient of friction for steel alloy with sintered operation μ= 0.25at contact pressure 0.6mpa to 1.2 Map. In experimental analysis of brass composites this value obtained near about μ= 0.21.

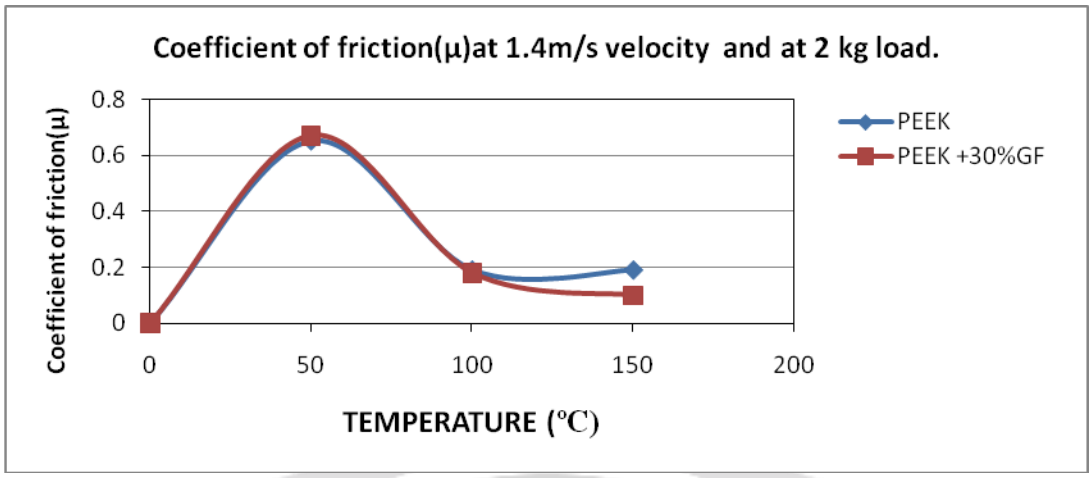

Fig. 4.7 Effects of load on frictional force PEEK and PEEK with 30% GF composites at 2 kg

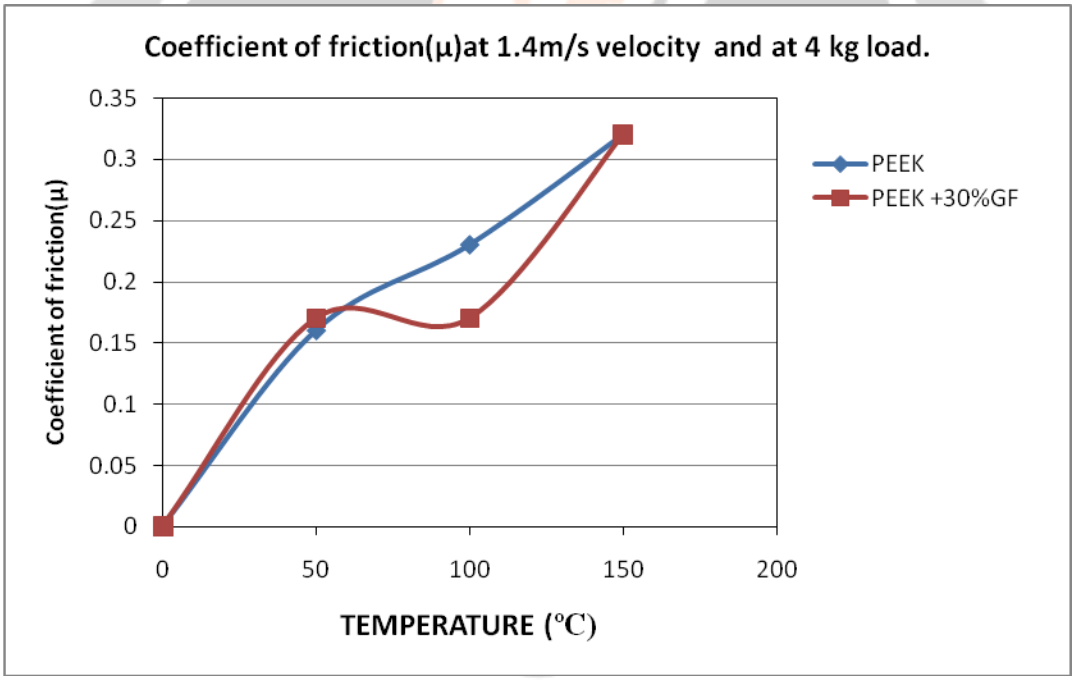

Fig. 4.8 Effects of load on coefficient of friction PEEK and PEEK with 30% GF composites at 4kg

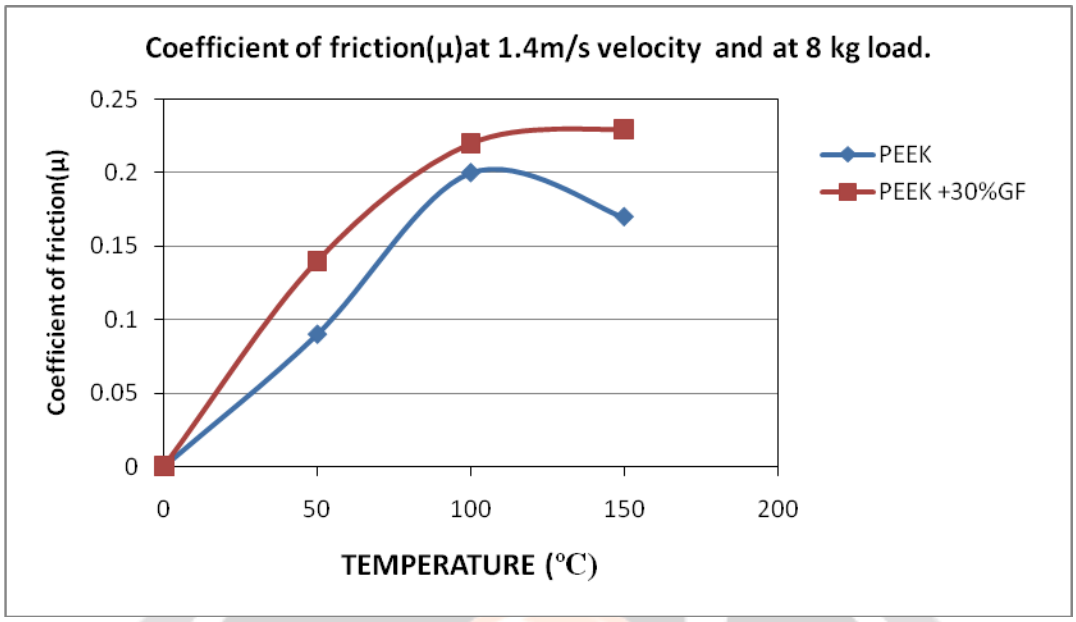

Fig. 4.9 Effects of load on coefficient of friction PEEK and PEEK with 30% GF composites at 8 kg

5. CONCLUSION

The tribological properties of PEEK and PEEK composites reinforced with 30% GF systematically studied under harsh operating condition ie at high load and at temperature. From the result the following conclusions are drawn.

- In comparative study of PEEK & PEEK with 30%GF. It was observer that wears resistance of PEEK enhanced with reinforcement of 30% GF.
- It has been observed that when Pure PEEK is tested at high load and high temperature, the pure PEEK show the higher wear value ($5.21\times10^{-3}mm^3/m$) as compare to PEEK with 30% GF ($1.3085\times10^{-3}mm^3/m$.) This clears that reinforcement of PEEK with GF there is desirable improvement in mechanical properties of PEEK.
- From result it was cleared that PEEK composite can be act as good solid lubricants at low as well as at high loading condition as compare to pure PEEK.
- PEEK composite is one of the few metals composite that can be considered for use as a true metal replacement for high temperature and heavy load applications.
- The outstanding mechanical properties of PEEK composites at high load made it suitable for the most emending applications, but the high cost sometimes limits applications to those where the properties are very necessary.

6. REFERENCES

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