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The Effect of Synthetic Diamond Powder on the Mechanical Properties of PEEK

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ABSTRACT

PEEK (Poly Ether Ether Ketone) composites reinforced with ceramic fillers result in the improved thermal, mechanical, electrical and wear resistance are useful to various applications. The exceptional hardness of synthetic diamond and its very low thermal degradation have inherent advantage in mechanical and thermal properties as making it suitable reinforcement for thermal applications specifically heat sinks. The present study deals with incorporating different proportion of synthetic diamond powder in PEEK and evaluating its mechanical properties. This composite manufactured through the powder metallurgy process. It was found that the synthetic diamond powder enhances the mechanical properties significantly and as filler is very effective in improving thermal properties of PEEK. Synthetic diamond dispersion and the microstructure of the fabricated composite were characterized using scanning electron microscope. The thermal decomposition and heat absorbing rate were characterized using thermo-gravimetric analysis. The results are discussed in detail.

Keywords: Mechanical and thermal properties, PEEK-synthetic diamond powder composite, powder metallurgy, SEM, TGA.

1. INTRODUCTION

Advent of high temperature polymers are replacing traditional materials are increasing such as poly ether ether ketone (PEEK) and poly tetra fluoro ethylene (PTFE). PEEK is a popular polymer matrix material for high performance composites due to its high mechanical strength and elastic modules, melting temperature, chemical inertness, toughness, easy processing and wear resistance. PEEK is widely accepted too in many applications for engineering and medicine because of its high strength and high melting point relative to other polymers, as well as its resistance to chemical and biological action [1,2]. Several research studies related to the tribological behaviour of PEEK and its composite have been reported. Thermoplastics based composites reinforced with carbon fillers are increasingly employed in many industries due to their attractive mechanical properties and relatively low manufacturing cost. Notably PEEK reinforced with carbon fibers showed a beneficial effect on its strength and tribological properties [3,4]. Exotic properties of nano particles addition in PEEK enhanced the thermal conductivity to great extent [5]. Due to high temperature working range of PEEK, the possible technology for the production of composites is powder metallurgy process [6]. It has been observed that presence of zirconia filler dispersed in polymer matrix enhances mechanical properties, thermal stability and physico-mechanical properties. Thermal analysis of the polymer composite showed an increase in the thermal stability with increase of nanofiller content [8]. Synthetic diamond has an increased thermal conductivity and higher moduls attracted the reinforcement of high temperature polymer.

In this work, mechanical properties of PEEK and PEEK containing with different weight percentage of synthetic diamond powder were studied. Thermogravimetric analysis was carried out in order to understand the thermal decomposition of pure and synthetic diamond reinforced PEEK.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

PEEK composite is fabricated by powder metallurgy method using varying the composition of synthetic diamond 0%-30% with step of 10%. PEEK grain size of 20μm and synthetic diamond size 0.5μm were mixed in

ball milling for 3 hours at room temperature under dry condition. The temperature ramp of 10°C was maintained during sintering process. The composites were sintered at 325°C and soaked for two hours. The specimen was fabricated in the form of cylindrical pellets of dimension; diameter 10mm and height 10mm as shown in Fig.1.

Fig. 1 Typical fabricated specimen

2.2 Micro-structural analysis

The microstructure of PEEK- synthetic diamond composites were analysed by Zeiss scanning electron microscope (SEM). An accelerating voltage of 15 kV was used for the image observation. Prior to SEM examination, the specimen was cleaned with alcohol. Gold sputtering over the specimen was done using Balzers SCD 050 sputter coater to make as a conductive sample surface. XRD of synthetic diamond powder also carried out to confirm the diamond structure.

3. RESULTS AND DISCUSSION

Typical SEM image of the fabricated composite is shown in Fig. 2. From the SEM image, synthetic diamond was fairly dispersed and also rarely observed agglomeration of synthetic diamond in PEEK matrix.

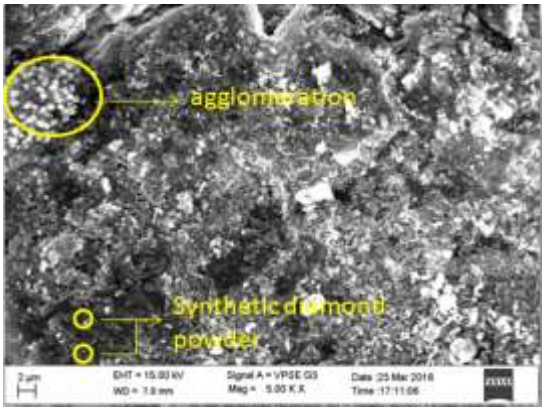

Fig. 2 SEM image of the fabricated sample

XRD profile of synthetic diamond is shown in Fig. 3. Peak seen in figure of 2θ value at 43 degree and 75 degree shows the presence of carbon. From the reference JCPDS code 96-900-8565, the compound name was found to be diamond. The crystal structure was found to be cubic crystal with the space group number of 227.

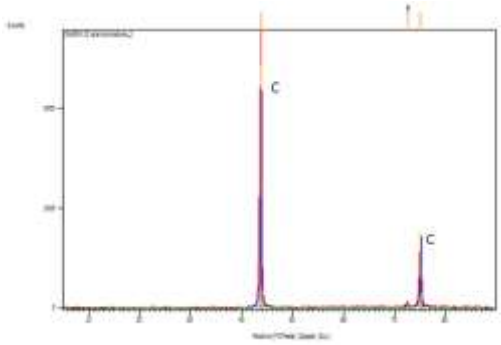

Fig. 3 XRD of synthetic diamond powder

3.1 Density

Fig. 4 shows the effect of synthetic diamond on density of PEEK. Density of the PEEK composite increased with the addition of synthetic diamond powder due to higher density of diamond. Density has been calculated using archimedes principle.

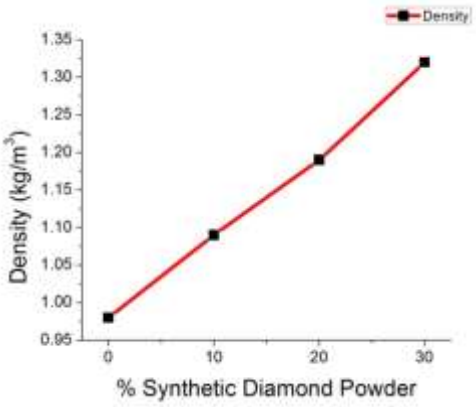

Fig. 4 Effect of synthetic diamond on density in PEEK

Fig. 4 shows the effect of synthetic diamond on density of PEEK. Density of the PEEK composite increased with the addition of synthetic diamond powder due to higher density of diamond. Density has been calculated using archimedes principle.

3.2 Mechanical testing

The hardness of the composite was tested as per ASTM D 785 standard using Rockwell hardness; m scale.

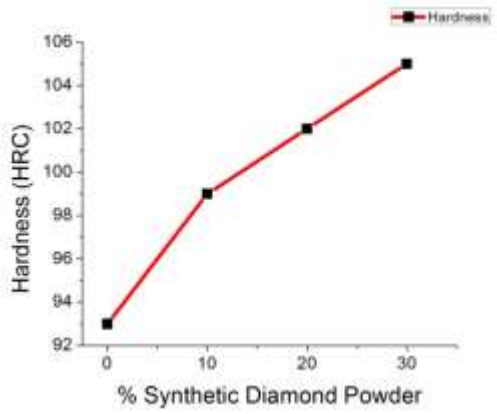

Fig. 5 Effect of synthetic diamond in hardness of PEEK

Fig. 5 shows the hardness of PEEK and synthetic diamond powder reinforced PEEK composites. It is clearly seen that the addition of reinforcement (synthetic diamond) clearly improves the hardness of PEEK due to high strength of diamond powder. In spite of low order of agglomeration of diamond particles beyond 10% the PEEK composites hardness observed to be slightly increased. This is because of the termination and pinning mechanism [6].

3.3 Thermal analysis

Fig. 6 shows the typical TG weight loss curves for PEEK-synthetic diamond composite. TGA was analysed using Perkin Elmer made. A ramp of 10˚C/ min was maintained during the heating. Nitrogen was used as purge gas and maintained at flow rate of 20ml/ min. The experiment was operated in room temperature. In general, introduction of the filler in polymer increases the thermal stability.

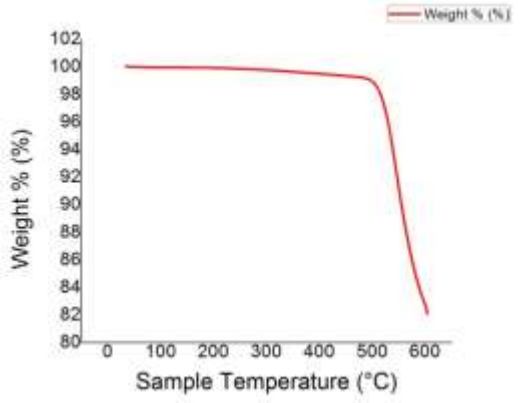

Fig. 6 TGA curves of the fabricated composite

As seen from the Fig. 6 the incorporation of synthetic diamond powder in the PEEK polymer matrix increased thermal stability. It is evident that the weight loss temperature of reinforced composites is about higher than that of pure PEEK [6]. The fabricated composite exhibits higher thermal stability as result of higher thermal conductivity of diamond powder and high order of densification of sintered PEEK composite.

4. CONCLUSIONS

The mechanical and thermal properties of PEEK with different composition of synthetic diamond powder have been studied in this paper. PEEK- synthetic diamond composite was fabricated successfully. The synthetic diamond was fairly dispersed and also rarely observed agglomeration of synthetic diamond in PEEK matrix. Density of the PEEK composite increased with the addition of synthetic diamond powder due to higher density of diamond. The hardness of the PEEK reinforced with synthetic diamond composite was higher than those of pure PEEK. The weight loss temperatures of synthetic diamond powder reinforced composites were higher than that of pure PEEK; the incorporation of synthetic diamond into the PEEK polymer matrix increased the thermal stability.

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