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Research on Mechanical Behaviors of Micro-crystal Muscovite/UHMWPE Composites to Impact Loading

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Abstract. UHMWPE composites were prepared by hot pressing process with micro-crystal muscovite as reinforced particulates. The mechanical behaviors of composites to impact loading was evaluated by split Hopkinson bar. The results demonstrated that dynamic yield stress and failure stress of UHMWPE composites were gradually increased when the filling amount was less than 20%; when the filling content of muscovite was around 15%, the energy absorption efficiency of the composite reaches maximum value. It was also found that when strain rate within 3200/s, the dynamic yield stress, failure stress and energy absorption efficiency of UHMWPE composites increased with the increase of strain rate and display strain rate enhancement effect.

Keywords: UHMWPE composites; impact loading; dynamic behavior

1 Introduction

Erosion wear cause streamline appearance damage in flow-passing surface, which has been always the Technical problems that impact a safe and stable operation in the field of hydropower and water conservancy engineering equipment[1, 2]. In the 80's of last century, the application of polymer materials in the erosion resistance test was carried out. The results show that Ultra high molecular weight polyethylene (UHMWPE) composites filled with particles exhibit better corrosion resistance than plain carbon steel under hyperconcentrated flow conditions of low head[3].

Erosion in essence is the result of the continuous impact damage on the material surface by the particle flow, including the conversion, transmission, absorption and release process of energy. According to the contact dynamic theory, the dynamic mechanical properties of the material have great influence on the impact damage of the material. In 1963, Bitter proposed the theory of deformation and wear and the material erosion phenomenon was explained from the viewpoint of energy balance, but all were based on the results of metal materials[4]. With the popularization and application of polymer composites in the erosion environment, to carry out the dynamic characteristic study of polymer composite materials, to reveal the mechanism of erosion damage of polymer materials, improve the component design of erosion resistant polymer composite, improving the preparation method of anti erosion polymer composite material, and further improve the anti erosion comprehensive performance has a important significance.

Hopkinson pressure bar technique can be used to test the dynamic strain rate of the material that is 102~104/s order of magnitude, and it is an effective experimental technique to test the mechanical response of material under high strain rate. Al Maliky et al has studied the dynamic impact characteristics of different polymers by using the Hopkinson's pressure bar technique and the expansion ring technique[5]. However, there are some problems in the process of expanding ring technology, such as high demand of sample preparation and complex testing process. And in recent years, the related researches are also few. The Hopkinson pressure bar test datas of metal, ceramic and plastic three engineering materials were summarized by YU Shuisheng who improved Johnson-Cook constitutive model and could well describe the stress-strain relationship of different materials in high speed impact load[6].

In this paper, The micro-crystal muscovite was selected as the reinforcing particle[7] and the UHMWPE composite materials were prepared by hot pressing method, and the mechanical properties of UHMWPE composites under dynamic impact load were investigated by using SHPB experimental technique[8].

2 Preparation of Microcrystalline Muscovite /UHMWPE Composite Materials

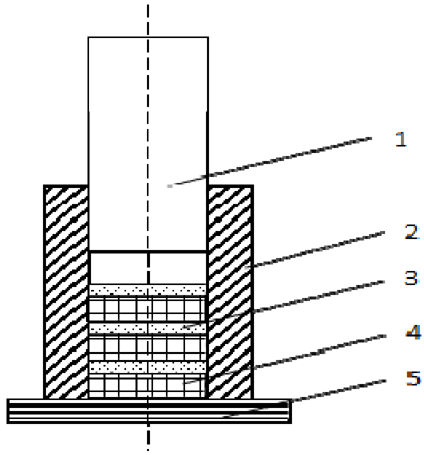
2.1 Main Experimental Raw Materials

UHMWPE of the molecular weight of more than 1.5 million (Mitsui Chemicals Inc products); microcrystal muscovite powder (Sichuan xinju mineral company products in China), the morphology of particles is fine flake, and the average thickness is 0.8μm; Silane coupling agent (Chinese medicine KH-550), Anhydrous ethanol (Tianjin Fuyu Fine Chemical Co., Ltd in China); Antioxidant (Chinese Zibo Xiangdong Chemical Co. Ltd. T501); Polyimide stripping paper (commercially available).

2.2 Composite Specimen Preparation.

The micro-crystal muscovite powder was placed in an oven at 110 for the removal of the surface of the mineral. Measuring the amount of 1.5% KH-550 silane coupling agent in microcrystalline dolomite powder and the KH-550/ Anhydrous ethanol mass ratio of 1:5 was mixed and ball milling, then the surface treatment.

After the processed micro-crystal muscovite powder drying, the mass ratio of the 5%, 10%, 15%, 25%, 20% were added to the UHMWPE powder, the ball milling mixed evenly. The mixed raw material was put in a mold as shown in Figure 1, and gave the mold pressure, pre 20MPa pressure of three times, each time 10min. After the pre press and the die together were put in the heating furnace, heated 2h at 200, and then pressurized to 40MPa, maintained pressure 1h. When cooling to room temperature, the composite materials would be prepared and processed into pieces.



1-male mold 2-female mold 3-blending material 4-septa 5-base

Fig.1 Mold assembly drawing

3 Impact Mechanical Properties of Composite Materials

The impact mechanical properties of composite materials was tested by Hopkinson pressure bar (SHPB) test. The experimental device was mainly composed of a compression chamber, the impact rod, the input rod ,the output rod , energy absorption device and analysis system of corresponding data acquisition. The experimental principle was shown in Figure 2. The material sample was sandwiched between the input rod and the output rod, and through the high pressure light gas push rod to impact the input bar, a shock compression load stress wave was generated. The stress wave through the input rod conduction to the specimen, a part of the stress wave in the specimen surface and between the input bar was reflected, the other through the specimen into the output rod; in the input and output rod respectively with a collection of strain gauge stress wave signal, data collected by the dynamic strain meter and oscilloscope storage processing and calculation, draw the dynamic stress-strain curves. The different impact strength is obtained by changing the driving pressure of the impact bar, respectively taking driving pressure of 0.2MPa, 0.3MPa, 0.4MPa and 0.5MPa.

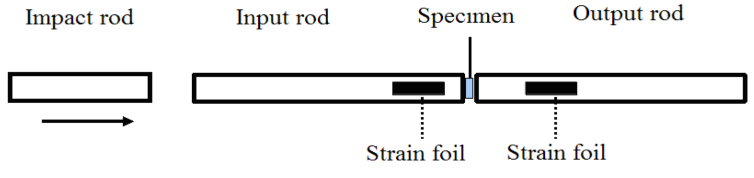


Fig.2 Schematic of SHPB setup

3.1 Stress-strain Curve

Figure 3 shows the corresponding stress-strain curve of the composite with different micro-crystal muscovite filling amount. It can be seen that under the dynamic impact load, the material undergoes elastic deformation, elastic-plastic deformation and failure unloading stage. The stress value（Dynamic yield stress）in the material elastic range and the failure stress value increase with the increase of the filler content, and then reflect the enhancement effect of particles. When the filling amount is more than 20% (up to 25%), the maximum value of the material elastic range is reduced.

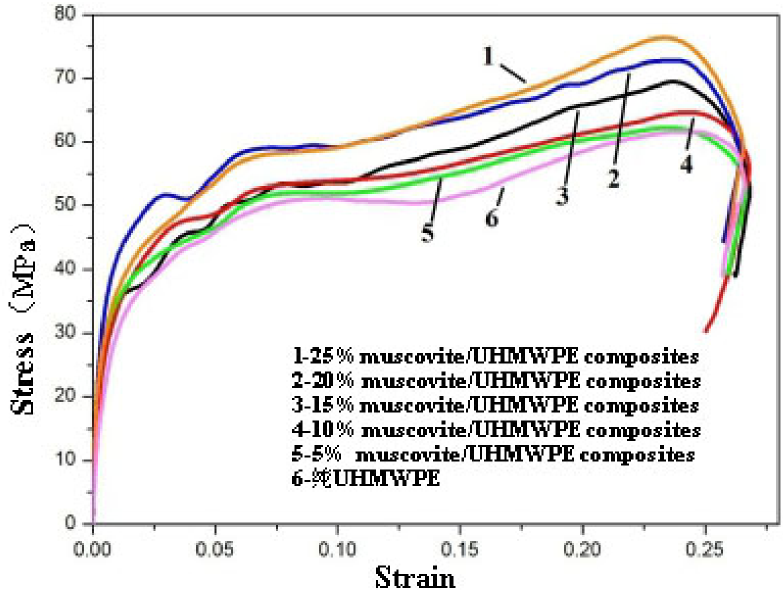


Fig.3 Stress-strain curves of micro-crystal muscovite/UHMWPE composite

3.2 Strain Rate and Its Strengthening Effect

Strain rate (Strain in the unit time) reflects the material impact sensitivity. The strain rate curves of composite materials under different shock bar driving pressure are shown in figure 4 when the content of filled with micro-crystal muscovite is 5%. By comparing the impact strain history of composite materials with different filling amounts , the filling amounts had little effect on the strain rate.

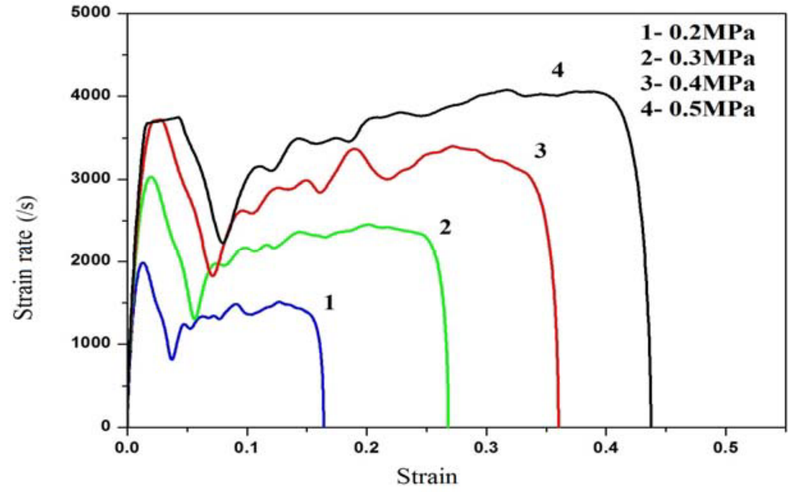


Fig.4 Strain rate curve of 5% micro-crystal muscovite/UHMWPE composites of different air chamber pressure

The stress strain curves of composites(The filling amount is 5%) with different strain rates (1400/s, 2300/s, 3200/s, 3800/s) are shown in Figure 5. The dynamic elastic modulus, dynamic yield stress and failure stress of the material were greatly improved with the increase of the strain rate, which indicated that the composite material had the strain rate strengthening effect. It reflected the characteristics of polymer materials that can effectively resist dynamic impact load. When the strain rate was over 3200/s, the strain rate strengthening effect was weakened.

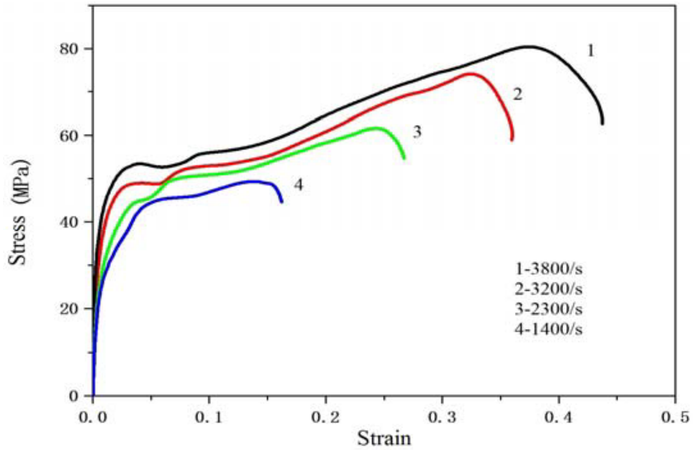


Fig.5 Dynamic stress-strain curves of 5% micro-crystal muscovite/UHMWPE

composite

3.3 Energy Absorption Characteristics

Material energy absorption characteristics can be used to evaluate the efficiency of energy absorption[9]. Energy absorption efficiency is the ratio of the energy absorbed by the composite materials in the process of deformation and the absorption of the ideal elastic material in the same condition. It should be the ratio of the area B surrounded under stress-strain curve and the σm×εm rectangle area A, as shown in figure 6. And the larger the ratio, the better the performance of the material is better.

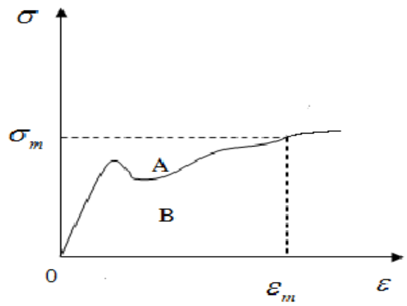


Fig.6 Diagram of the energy absorption efficiency

According to the results of the experiment data processing, drawing the composite energy absorption efficiency with the filling amount change curve as shown in Figure 7, figure shows that the filling amount of 15% can get a higher energy efficiency value that is about 15% higher than the pure UHMWPE(The value of the filling amount is 0).

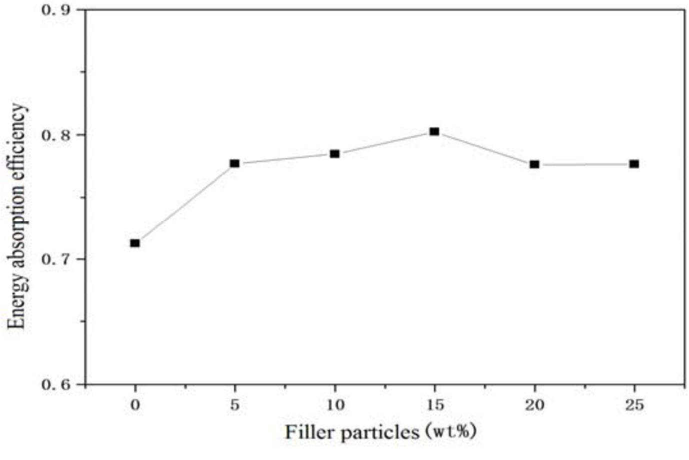


Fig.7 Effect of filling amount on energy absorption efficiency（Strain rate is 1400/s）

Fig. 8 shows the effect of strain rate on the energy absorption efficiency of the composite. From the figure, the strain rate has a significant influence on the energy absorption efficiency and the energy absorption efficiency is increased with the increase of strain rate. When the strain rate increases from 1400/s to 3200/s, the energy absorption efficiency of the composite is increased by about 20%.After the strain rate is more than 3200/s, the absorption energy efficiency tends to be stable.

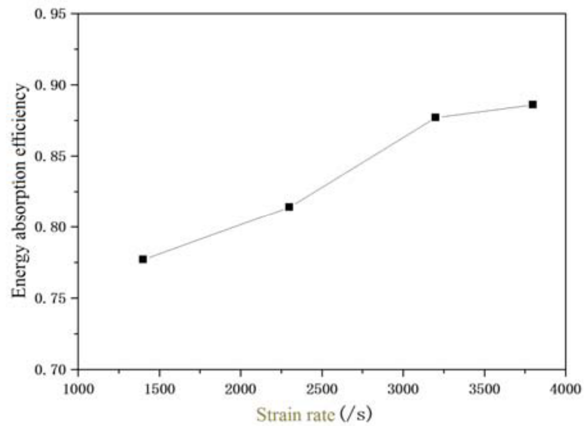


Fig.8 Effect of strain rate on energy absorption efficiency of UHMWPE composites（The filling amount is 5%）

4 Conclusions

（1）The modified UHMWPE by using the micro-crystal muscovite can effectively improve the dynamic performance of the material. When the filling amount is less than 20%, the dynamic yield stress and the failure stress value of UHMWPE composites will increase with the increase of the filler content.

（2）Energy absorption efficiency of the composites filled with micro-crystal muscovite is obviously improved compared with the pure UHMWPE under impact load. When the filling amount is about 15% , the composite material can get a higher energy efficiency value.

（3）The micro-crystal muscovite/UHMWPE composites exhibit strain rate strengthening effect, And the dynamic yield stress ,failure stress and energy absorption efficiency of the composite under impact load are improved with the increase of the strain rate. After the strain rate is more than 3200/s, the absorption energy efficiency tends to be stable.

（4）The above conclusions indicate that micro-crystal muscovite/UHMWPE composites have better impact resistance than pure UHMWPE; The ideal modification effect can be obtained when the filling amount is about 15%; The experimental results also show that the impact loading conditions of the composite material properties should be controlled in the range of the strain rate of 3200/s

Acknowledgements

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