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The failure of meteorites at impact tests

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Abstract

Meteoritic materials and ice instrumented impact testing results at room and liquid nitrogen temperatures as well as impact specimens fractographic data are presented. Analysis of experimental impact loading curves makes it possible to divide total fracture energy into crack initiation and crack propagation energy. The influence of meteorites chemical composition and microstructure on impact strength, crack propagation resistance and fracture mechanisms is discussed.

1. Introduction

There are very limited data about mechanical properties and behavior of meteorites under load while its chemistry and mineralogy have been studied extensively [1, 2]. The majority of strength data were obtained from compressive tests while only a few experimental results in this field were related to tensile tests [1, 3]. Meteoroids were subjected to dynamic loading during mutual impact actions and interaction with atmosphere. In this study we present the original numerical results on impact strength of both meteoritic materials including a number of extraterrestrial iron bearing minerals and ice.

2. Materials and Methods

Dynamic tests of meteoritic materials and ice were performed using instrumented Tinius Olsen IT542 impact test machine at 300 and 77 K. Samples were prepared from monocrystalline and polycrystalline fragments of octahedrite Sikhote-Alin, impact-reheated meteorite Dronino, ataxite Chinga, chondrite Tsarev and ice. Scanning electron microscopes JEOL JSM-66490LV and TESCAN VEGA were used for fracture surface analysis of studied meteorites.

3. Results and Discussion

Typical experimental impact loading curve of studied meteoritic materials for ductile failure process is shown in Fig 1.

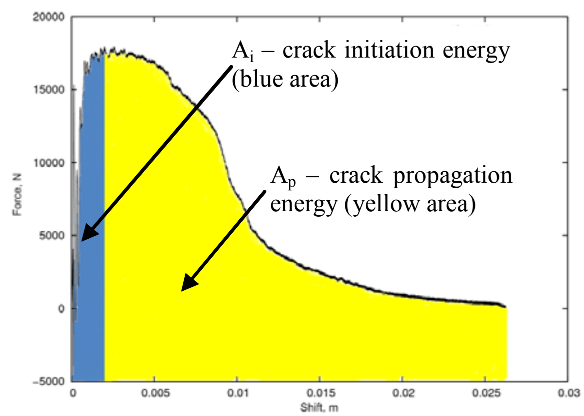

Figure 1: Experimental impact loading curve of Dronino iron meteorite obtained at 300 K.

The values of impact strength and ratio of crack initiation (A_i) and crack propagation (A_p) energies are shown in Figs. 2 and 3.

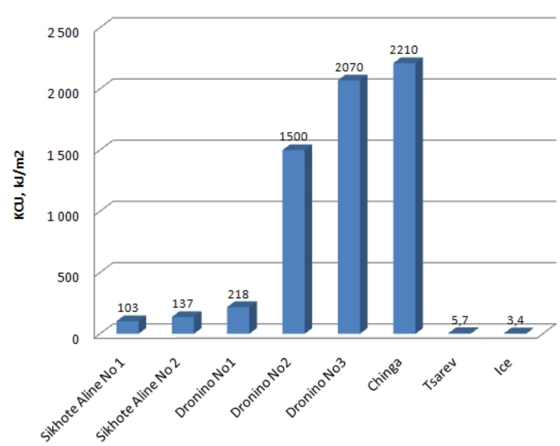

Figure 2: Values of impact strength for different meteorites at 300 K.

The highest values of impact strength and maximum of A_p/A_i ratio were obtained for Chinga and Dronino iron meteorites which had submicroscopic ($\alpha+\alpha_2+\gamma$) and duplex ($\alpha+\alpha_2$) structures, respectively. Decreasing of the test temperature down to 77 K led to decrease of impact strength values down to 47 kJ/m^2 for Dronino and 1170 kJ/m^2 for Chinga meteorites. Monocrystalline Sikhote-Alin meteorite samples demonstrated brittle transcrystalline fracture surface mode (Fig. 5) while polycrystalline Sikhote-Alin samples were characterized by intercrystalline fracture mechanism. In this case fracture energy was less than that for Tsarev L5 chondrite.

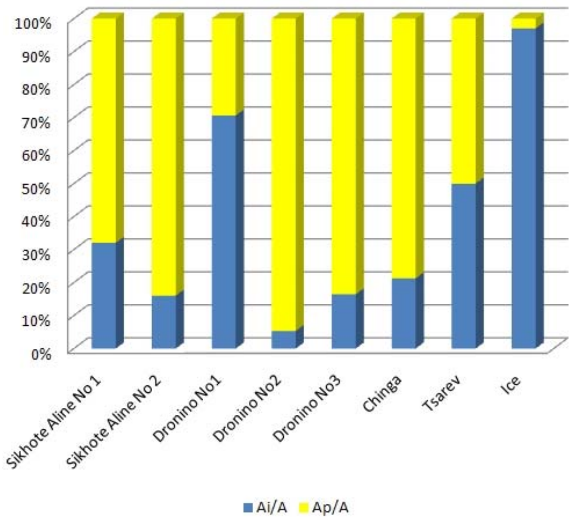

Figure 3: Ratio of crack initiation (A_i) and crack propagation (A_p) to the total impact fracture energy ($A_{total} = A_i+A_p$) of studied meteorites at 300 K.

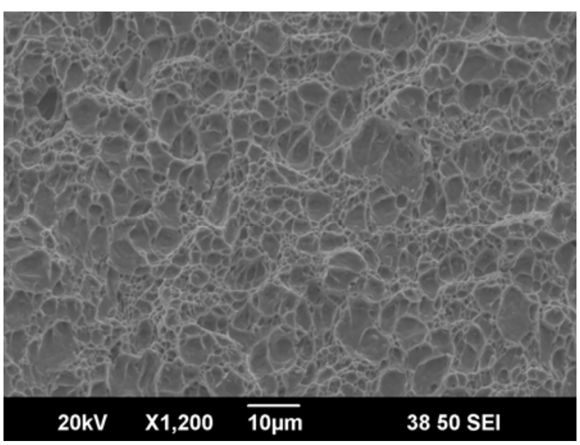

Figure 4: Ductile (dimple) mode of fracture surface after impact test of Chinga ataxite at 300 K.

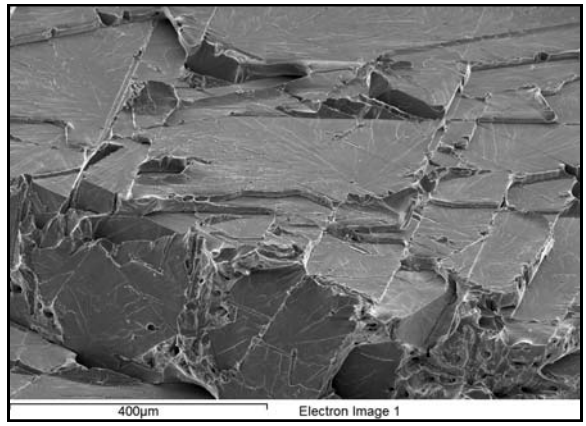

Figure 5: Brittle transcrystalline mode of fracture surface after impact test of octahedrite Sikhote-Alin at 300 K.

6. Summary and Conclusions

The performed study clears up that the process of meteoritic materials failure is strongly affected by their chemical composition, type of microstructure and test temperature. It may be a result of different values of impact strength, impact testing parameters (ratio of crack initiation, propagation and total fracture energy) along the side with fracture mechanism transfer from ductile to brittle transcrystalline mode.

Acknowledgements

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