Fracture Properties of Mode II Cracks in Ceramics and Metals†

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Abstract

The mechanical properties and fracture mechanism of cracking and failure for Si_3N_4 ceramics, Ni and Mo metals and $Ni_{20}Si_{10}Ti$ filler are presented and discussed in this research. The fracture toughness K_{II} of these materials was obtained from the fracture shear loading. Ductile nickel showed the highest value, and ductile-brittle molybdenum yielded the middle, and brittle $Ni_{20}Si_{10}Ti$ and Si_3N_4 presented the lowest. The fracture toughness of materials depends on their fracture characteristics.

KEY WORDS: **(Ceramics), (Fracture toughness), (Fracture direction), (Fracture mechanism), (Fracture load)**

1. Introduction

It is important to prevent cracks in ceramic/metal joints and also composites for practical engineering applications. The knowledge of fracture behavior of these materials and joints are necessary to control and prevent cracking. The fracture properties and fracture mechanism in these materials and joints have been studied in this work, the fracture process of Mo metal, $Ni_{20}Si_{10}Ti$ and Si_3N_4 ceramics which were used in the ceramic/metal joint are investigated under shear stress. The fracture behavior is analyzed by fracture techniques and theories [1-10].

The fracture load, fracture direction, and fracture toughness for the materials are investigated, and discussed from the point of views of fracture mechanism.

2. Experimental procedure

Mo as metal and $Ni_{20}Si_{10}Ti$ filler metal with the numbers designating atomic percent are used as metal materials. The $Ni_{20}Si_{10}Ti$ filler was used to braze Si_3N_4 ceramic [11]. Si_3N_4 is used as ceramic. The specimens of all materials were cylindrical in shape and about 6mm diameter and 4mm length. A typical example of Mo specimen is shown in Fig. 1. All specimens had a notch of 1mm depth and 0.5 thicknesses as shown in **Fig. 1**.

The materials are tested under shear loading with a jig shown in **Fig. 2** with a pulling speed of 1mm/min.

3. Results and Discussions

Two types of fracture behavior are observed in the fractured specimens. The nickel and molybdenum maintained the original shape after shear loading as shown in **Figs. 3** and **4**. The $Ni_{20}Si_{10}Ti$ showed crushed shapes after shear loading as shown in **Fig. 5**. The fracture toughness under shear stress (K_{II}) is obtained from the following equation.

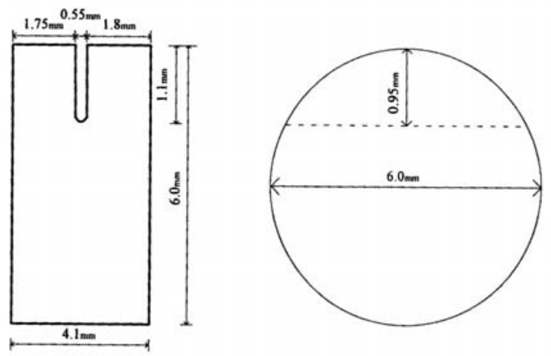

Fig. 1 Specimen size of Mo.

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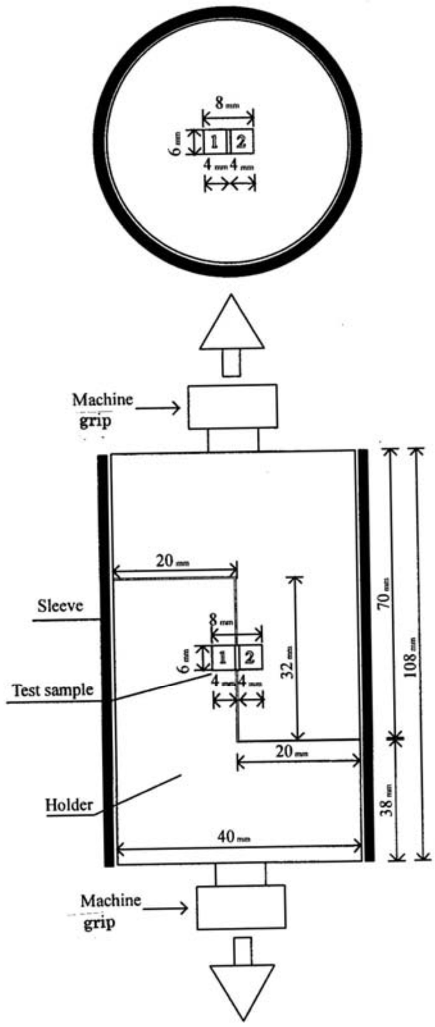

Fig. 2 Schematic figure of fracture shear jig.

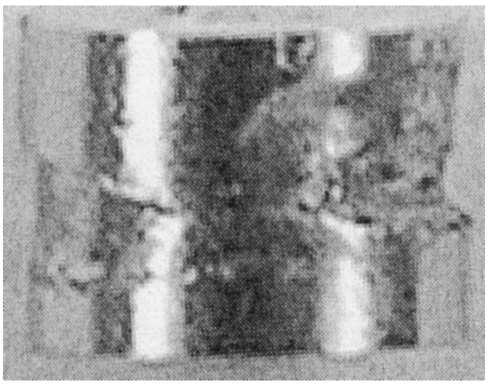

Fig. 3 Vie of nickel shear fractured.

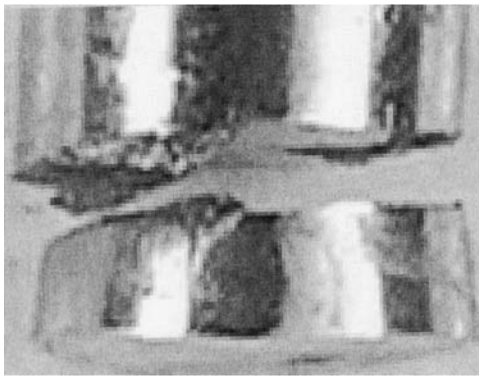

Fig. 4 View of molybdenum shear fractured.

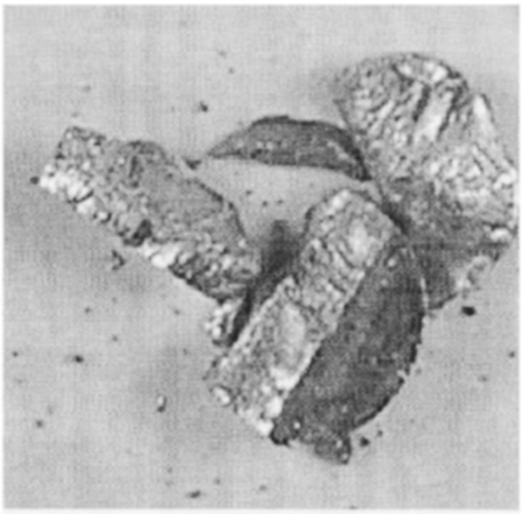

Fig. 5 View of Ni20Si10Ti alloy shear fractured.

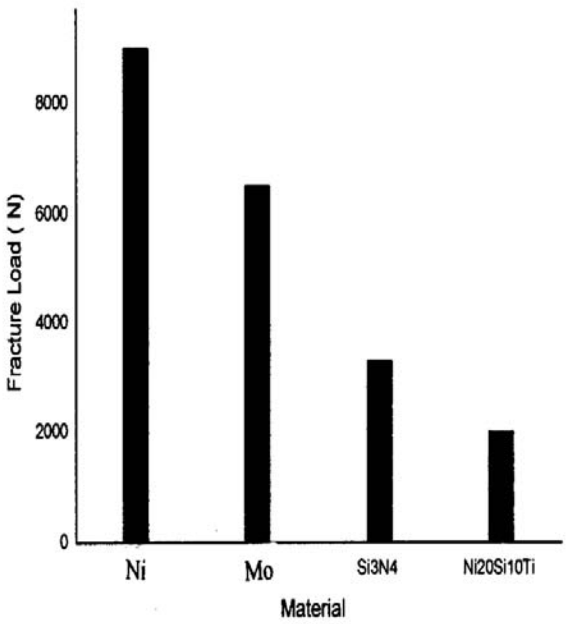

Fig. 6 Fracture loads of specimens.

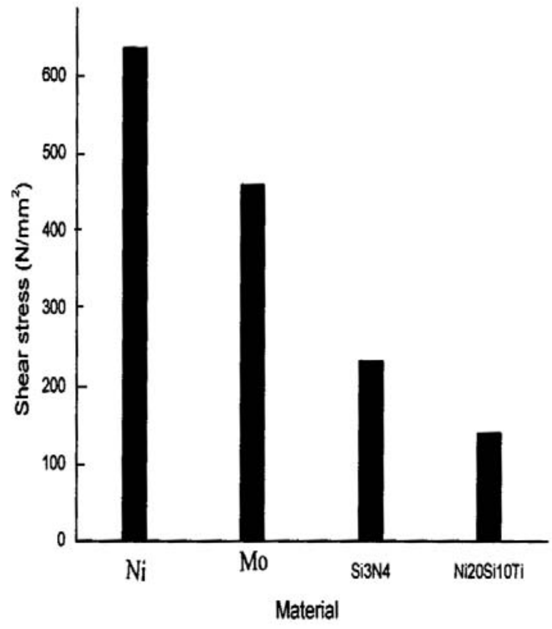

Fig. 8 Fracture stresses of specimens.

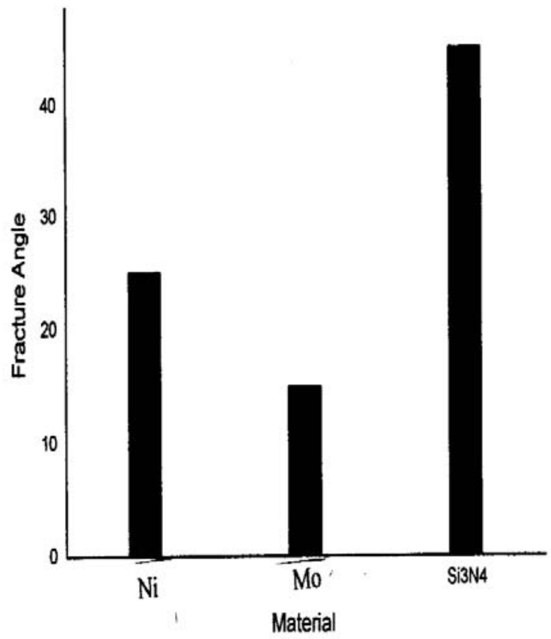

Fig. 7 Fracture angles of specimens.

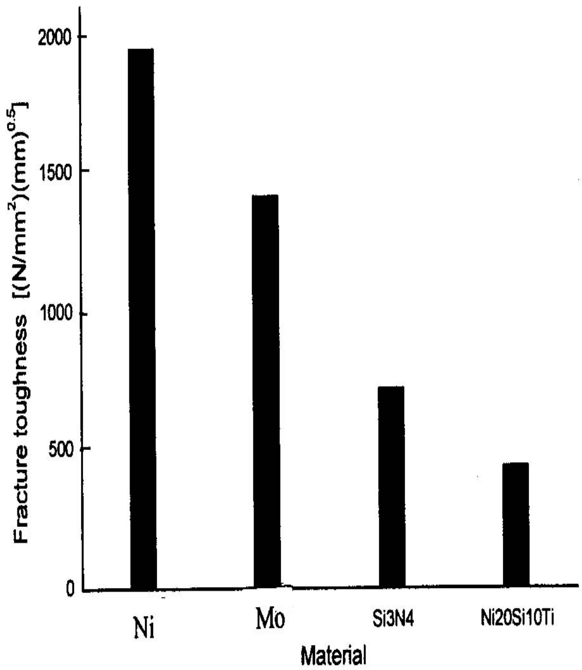

Fig. 9 Fracture toughness of specimens.

$$K_{II} = \tau_c (\pi a)^{0.5} \quad (1)$$

$$\tau_c = P_c / A \quad (2)$$

Where Pc and A are fracture load and fracture area, respectively. Further the dimensions of materials and crack are taken into consideration to estimate K_{II}. The fracture loads of the materials are shown in **Fig. 6**. The fracture angles are known to affect the fracture load [1-6] and the observed fracture angles of the materials are shown in **Fig. 7**. From the fracture loads and angles of the materials the fracture stresses and toughness of materials are caluculated in **Figs. 8 and 9**. The nickel shows the highest value of the fracture toughness among the materials, and Si_3N_4 and $Ni_{20}Si_{10}Ti$ alloy yield the lowest values.

Mo shows a middle value between the Ni and Si_3N_4 group.

These values for the materials correspond to the in fracture behavior. Nickel which possesses the highest value shows a ductile fracture mode, and Si_3N_4 and $Ni_{20}Si_{10}Ti$ alloy show a brittle fracture mode. Molybdenum which takes the middle value between nickel, and Si_3N_4 shown a brittle-ductile mixed mode.

4. Conclusions

In order to obtain the fundamental value of fracture toughness for shear mode. The fracture load, crack angle of nickel, molybdenum, $Ni_{20}Si_{10}Ti$ and Si_3N_4 were measured to estimate the fracture toughness K_{II} under shear load. Nickel shows the highest value and Mo shows the middle value between nickel and Si_3N_4. These values of the materials depend on their fracture behavior. Ductile nickel shows the highest value and molybdenum which is ductile-brittle yields the middle. Further, brittle Si_3N_4 and $Ni_{20}Si_{10}Ti$ alloy present the lowest values.

References

1) El-Sheikhy R. and Nishimura N., Proc. of NEF3&IMA, Korea, pp.98-103, (1999).

2) El-Sheikhy R. and Nishimura N., Proceedings of Int. Conf. of Space Steel Strucrures., pp. , Singapore, (1999).

3) El-Sheikhy R. and Naka M, Proceedings. of Int. Conf. ISEC-03, Shunan, Japan, (2005).

4) El-Sheikhy R. and Naka M, Proceedings. of Int. Conf. ISEC-03, Shunan, Japan, (2005).

5) El-Sheikhy R., Proceedings of Int. Conf. Dis'02, Kyoto, Japan, (2004).

6) El-Sheikhy R., Ph.D. theses, Cairo Univ., Egypt, (1995).

7) Theocaris, P.S., *Eng. Frac. Mech*., Vol. 30, No. 6, pp. 767-777, (1988).

8) Anderianopoulos, N.P. Theocaris P.S., *Eng. Frac. Mech*., Vol. 30, No. 1, pp. 5-12, (1988).

9) Zheng M., Luo, Z.J. and Zheng X., *Eng. Frac. Mech*., Vol. 41, No. 1, pp. 103-110, (1992).

10) Theocaris, P.S., *J.of Engineering Fracture Mechnics*, Vol. 24, (1986).