FRACTURE BEHAVIOUR OF COMPACT TENSION SPECIMEN IN HIGH VACUUM ATMOSPHERE UNDER PLANE STRAIN CONDITIONS

M.R. SABAYO

Department of Metallurgical Engineering,
Mehran University of Engineering and Technology,
Jamshoro, Sindh, Pakistan

ABSTRACT

An attempt has been made to discuss the design criteria of the materials for the use in high vacuum technology. The present work supports this and concludes that fracture behaviour of compact tension specimen with crack divider geometry made from 4340 steel in high vacuum atmosphere at different strain rates does not remain same under plane strain conditions. This is supported by the load-displacement graph by using Instron testing machine and the fractography which support the same modes of failure during fracture process. Thus confirming the higher KIc values at slower rates and suggesting the advanced materials in aero-space sector in order to fully optimise cost effective designs and to accomodate the requirements of automoted production environments.

KEY WORDS

Fracture toughness, vacuum Technology, environmental constraints, design and hardware, cost effective designs and automated production environments.

INTRODUCTION

Fracture toughness is the most significant and useful parameter defining the fracture behaviour of high strength materials especially steels. Alloys and composite materials are being developed to obtain maximum fracture toughness. In an engineering sense a material is said to be tough if its resistance is such that cracks would run catastropically only if the applied stresses are greater than that at which the structure suffers general plastic collapse,(Sabayo, (1), 1988). Vacuum technology is of considerable and increasing interest in metallurgy, because of many metallurgical processes involve heat, and most metal when heated react with atmospheric air. The principle interactions between the space or vacuum environments and metallic materials occur at the metal surfaces which results considerable changes in the bulk properties. Recent space exploration research work has shown numerous vacuum problems which still need solutions. This has ultimately created metallurgical problems and hence made the selection of materials for the design of equipment in such environments difficult, (Sabayo, (2), 1991). The automotive, aero-space and electronic industries are particularly involved in research that has led to the development of a range of advanced engineering and electronic ceramic materials, (Fernie, (3), 1992).

MATERIAL AND EXPERIMENTAL PROCEDURE

Material of the following composition in the form of a bar having dimensions 252mm x 151mm x 50mm was supplied: C:0.38%, Ni: 1.54% Cr: 1.12%, Mn: 0.5%. Before being machined smooth, they were hardened at 650°C and tempered at 200oC and then notched according to the specifications. Fig 1 shows such geometry. A Haigh machine was used for pre-cracking. All conditions satisfied for pre-cracking were fulfilled, (Brown, (4), 1970). The main feature of the rig were pull rods including pin loading grips to fit into the holder of an Instron testing machine in a chamber to provide environment around the specimen permiting a pressure of 0.5 x 10-5 torr. Fig 2 shows the details of the chamber.

FRACTURE TOUGHNESS TESTING

Fracture toughness tests were carried out on an Instron machine at a cross head-displacement rate of 0.02cm/min using such precracked specimens and specimen were mounted in pin type grips loaded in tension. A 1000 Ohm BISRA clips guage was located across the notch of the specimens by using brass saddless glued on the surface of the specimens. The plot on the X-Y recorder was subsequently used for analysis and measurement of fracture toughness. Fig 3 shown the load-displacement records, which fulfilled all conditions for valid KIc tests in high vacuum atmosphere. Such results are shown in Table 1.

TABLE 1. Fracture toughness tests results of CTS specimen made from 4340 steel tested in high vacuum atmosphere.

Specimen No.	Displacement rate cm/min	Tangent line	P 5 kg (v)	K = KIc Q(v) MNm -3/2
1.	0.02	53.0o	1025.42	53.5
2.	0.02	53.0o	1025.42	53.5
3.	0.02	53.0o	1025.42	53.5

Mean K = KIc = 53.5 MNm -3/2

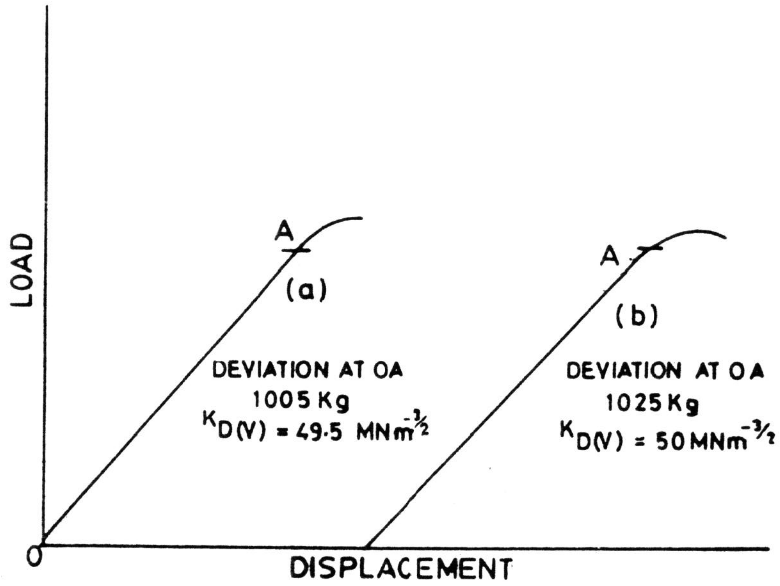
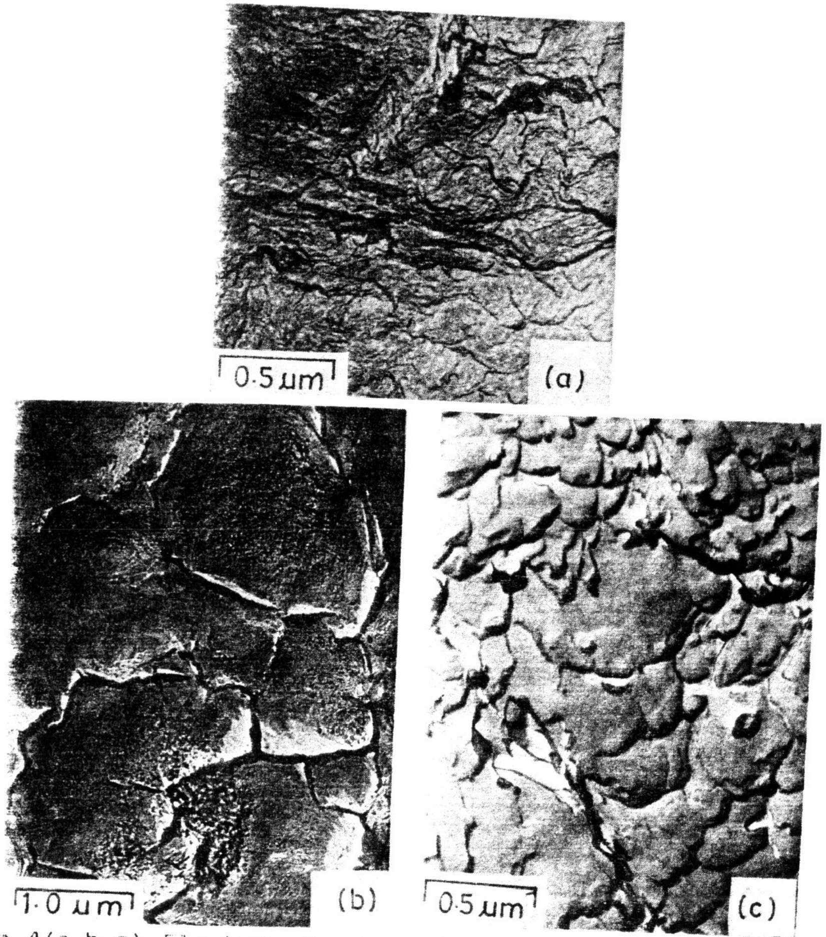


Fig 3. Load displacement graph for the CTS specimen made from 4340 steel tested in a high vacuum atmosphere at (a) 0.05cm/min-1 and (b) 0.02cm/min-1.

MICROSCOPY

To study the modes of failure during fracture process. Electron fractography was carried out by using Em6G microscope and Cambridge Scanning Electron Microscope. Such details are shown in Fig 4(a,b,c) for CTS specimen tested in high vacuum atmosphere. This includes surface cracking in the region of fatigue, intergranular in the region of slow crack growth and ductile dimples in the region of fast fracture.



Fiq 4(a,b,c) Electron fractography of CTS specimen made from 4340 steel tested in high vacuum atmosphere at 0.02cm/min under plane strain conditions.
(a)Cracking in the region of fatique (b)Interqranular in the region of slow crack growth and (c)Ductile dimples in the region of fast fracture.

DISCUSSION.

There exists in the world a large number of materials which could be used in space craft hardware. Each of them has several possible applications and they differ from each other by the amount of stress and environmental constraints they sustain. In space activities, as in all other industries,

materials and processes constitute the necessary link between design and hardware.(Dauphin, (5), 1991). The present work support this and concludes that the fracture behaviour of CTS composite laminates made from 4340 steel does not remain same in the high vacuum atmosphere with a cross head displacement rate of 0.02cm/min and 0.05cm/min during fracture under plane strain conditions. This is supported by the fractography which shows same modes of failure in either case during all stages of fracture tested under plane strain conditions and the Deviation stress intensity (KD(V) values as shown in Table 1, are less susceptible than the same specimens tested at the strain rate of 0.05cm/min in high vacuum atmosphere, (Sabayo, (6), 1983).

In-summary, confirming higher KIc values at slower rates and suggesting the advanced materials in aerospace sector in order to fully optimise cost effective designs to accomodate the requirements of automoted production environments, (Lee, (7), 1991)

ACKNOWLEDGEMENT

The author is grateful to the administration of Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan. for financial support.

REFERENCES

1. SABAYO, M.R. (1988), Proceedings of 5ICM, Perqamon press, pp-493-502, U.K.

2. SABAYO, M.R. (1988), Advances in Fracture Mechanics Research, vol.(6), Perqamon Press, U.K.

3. FERNIE J.A and etal (1992), Metals and Materials, A Jr. of the Institute of Materials, vol.8, No.4, p-212, London, U.K.

4. BROWN, H.F. (1970), A.S.T.M., S.T.P., 463, P-49.

5. DAUPHIN J. and etal (1991), Metals and Materials, A Jr. of the Institute of Materials, vol.7, No.7, p-422, London, U.K.

6. SABAYO, M.R. (1983), The fracture toughness of CTS specimen made from 4340 steel in high vacuum atmosphere,Proceedings of 4th National Conference on Engineering , Fracture Mechanics,p-50-56 Karachi, Pakistan.

7. LEE R.J and G.C. ECKOLD (1991), vol.7, No.10, p-614, London, U.K.

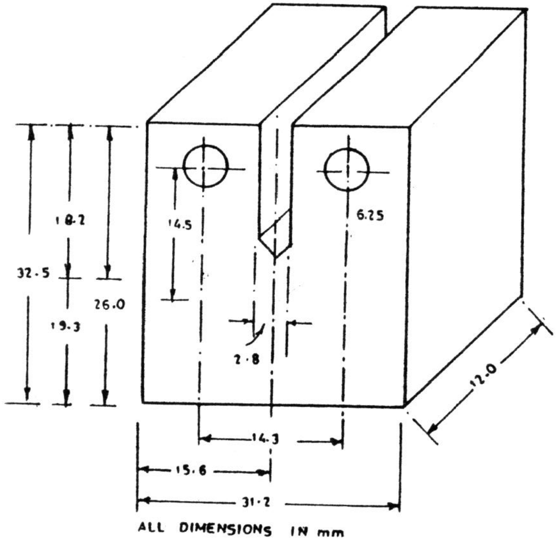


Fig-1. Compact Tension fracture toughness specimen.

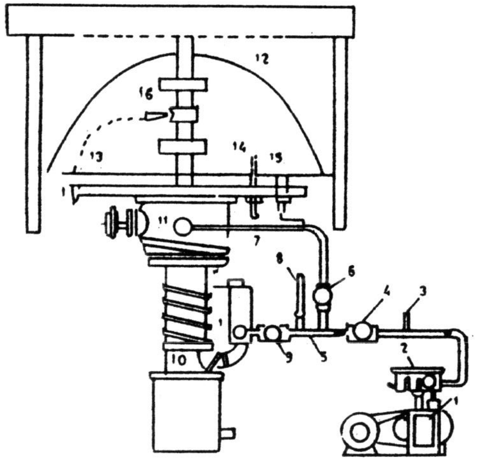


Fig-2. Environmental chamber.