New Test Method Measuring Crack Arrest Properties of Steel

K. Ishikawa and K. Tsuya
National Research Institute for Metals, Tokyo, Japan

1. Introduction

Various methods for directly measuring the crack arrest properties have been developed. These tests provide the critical stress and/or the critical temperature of unstable crack arrest, but requre large size specimens. On the other hand, Charpy impact test has been generally used for appreciation of crack arrest properties of steels, though from the test any direct information such as critical stress below which an unstable crack cannot propagate, can not be got without the aid of some correlations with the data by large size tests. The correlations are very useful for engineering but would not be applied in investigating materials newly developed. Consequently, the small size test is not powerful but it will be convenient that the result has physical meanings, even if they are qualitative.

In this paper, an interesting phenomenon in the propagation of an unstable crack in steel is mentioned through a quite simple bend test method made on the Charpy V-notch specimens with a hole. The behavior of a brittle crack was supposed to be associated with the crack arrest properties. In addition, these results had a good agreement with those obtained by a large size test (Robertson test).

2. Experimental Procedure

Specimens (a high tension structural steel, SM-50) tested were of standard Charpy geometory in cross-section (10mm square with a 45^{o} V-notch of depth 2mm and root radius 0.25mm). The specimens were tested in the range from room temperature to $-196^{o}C$ using a three point bend jig suspended beneath the cross-head of an Instron-type Testing Machine of 5ton capacity.

3. Experimental Results and Discussion

When a slow bend test was carried out on the specimen with a small drilled hole located at some distance from the tip of a notch, an interesting behavior was found on the load-deflection curve. These results are shown in Fig.1 compared with those of normal specimens without holes. Tested below $-40^{o}C$, an unstable brittle crack is initiated at the notch followed by the breaking of the specimen in two. On the other hand, above the temperature an unstable crack goes into the hole and stops just there. This critical temperature is expected to be characteristic of each steel. An apparent arrest load P_A is defined on the load-deflection curve as shown in Fig.2.

3-1. Effect of the Distance between a Hole and a Notch Tip

No big difference between the yield load of the specimens with a hole and that of normal ones is observed. The fracture load of the specimens with a hole at various distances from the notch tip are shown as a function of test temperature in Fig.3.
The temperature dependence of the fracture loads of normal

specimens is shown by a broken line together. It is noted that the loads for the specimens with a hole at a 2mm distance take the nearly same values as those of the normal specimens. A hole at a 2mm distance is assumed not to disturb the stress field in the specimen during bending since both P_Y and P_F are hardly affected by a hole. The effect of the position of a hole on an arrest load is shown in Fig.4. The specimens with a hole at a 2mm or 3mm distance yield the definite values above the critical temperature, but they are not essential themselves. Nevertheless, it should be noted that the definite value, not zero, lies above the critical temperature, which shifts with the test conditions. That corresponds to the phenomenon that a brittle crack is arrested in a hole. If the crack is not arrested in a hole and immediately another crack is initiated at the opposite side of a hole, the specimen is broken and the definite value of an arrest load can not be obtained.

In the case that a brittle crack is arrested in a hole, the arrest load is roughly half the general yield load of the same specimen at the critical temperature. When a similar consideration as in the case of a Robertson test is taken here, the temperature at which a brittle crack running in the specimen under a uniform transverse tensile stress of half an yield stress can be arrested, may well be defined as an apparent arrest temperature of the specimen. There is a good agreement between the apparent arrest temperature and an arrest one obtained for the same thick specimen by a large size test. Namely, for the steel tested both temperature are about -35°C. But it will be quite difficult to explain it convincingly from the viewpoint of crack arrest mechanism.

3-2. Effect of the Diameter of a Hole

The critical temperature is a little moved to higher as the diameter of a hole is smaller, and the arrest load to higher, too. These shifts can not be explained even qualitatively, either. But the critical temperature, which is a function of the diameter of a hole and the thickness of a specimen, satisfied the only unified relationship including all results in this small test and in a Robertson test as shown in Fig.5. Here the results in the Robertson test were obtained by Go-Arrest test for specimens with a small drilled hole at a 100mm distance from a starting notch tip.

4. Conclusion

For the present, there has been no explanation of a crack arrest mechanism in a small hole, but it is noted that there is found a good relationship between a critical arrest temperature obtained by this new bend test and one by a Robertson test. In addition, this new test is very simple, while the large size test is very expensive. It, however, is necessary to apply this test to other various specimens to concrete this relationship. Furthermore, light should be thrown to the clarification of the mechanism of a brittle crack arrest in a small hole.

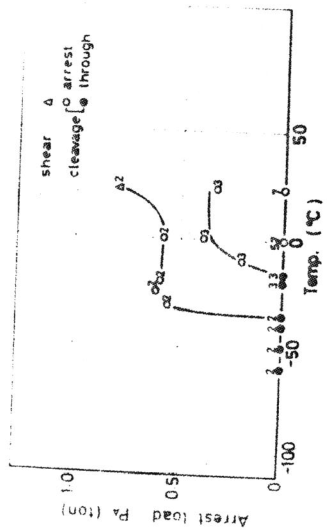

Fig.4 Effect of position of a hole on arrest load

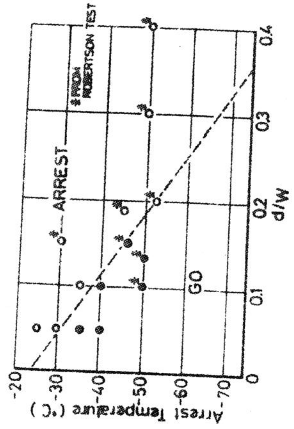

Fig.5 Go-Arrest relationship
d: diameter
W: thickness

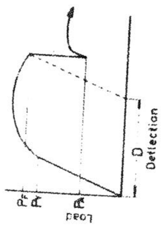

Fig.2 Difinition of P_Y, P_F, P_A & D on the curve

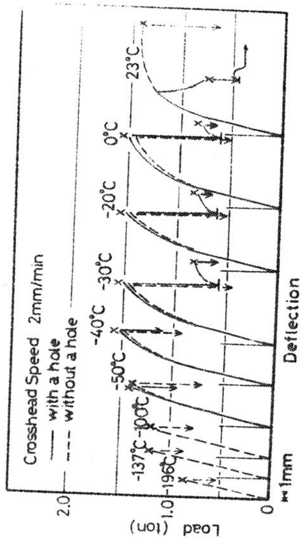

Fig.1 Load-Deflection curves

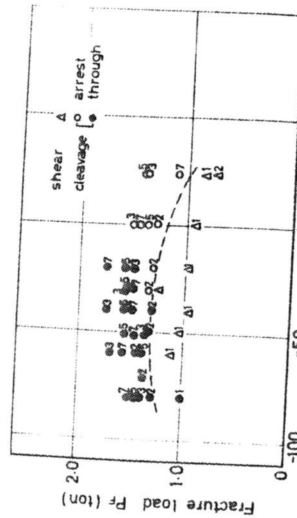

Fig.3 Effect of position of a hole on fracture load