AN ASSESSMENT OF THE FRACTURE RESISTANCE OF MISMATCHED WELD JOINTS IN PRECRACKED CHARPY V NOTCH IMPACT TEST

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The paper presents an assessment of the dynamic fracture toughness of heterogeneous weld joints of HSLA steel 14HNMBCu by impact bend test. There was made an assessment of the dynamic fracture parameters such as K_{Id}, J_{Id} total failure energy K and their parts K_z, K_r, K_h of the tested precracked Charpy V specimens. The calculation of K_{Id}, J_{Id} and K_z, K_r, K_h were performed by mean of a computer using a special program elaborated in the Technical University Bydgoszcz to interpret the test results. The investigation reveals that the scatter in Charpy date is among other factors dependent on the nonuniformity of structure in tested mismatched weld joints.

INTRODUCTION

The Charpy V test is considered by many standards and codes as a quick and relatively inexpensive quality control test. This Charpy V test procedure presents some difficulty when considered for quantitative toughness measurement. The rate at which energy is actually used to create dynamic fracture must be isolated from other forms of energy dissipation such as plastic deformation, acoustic emission, etc., in order to obtain a reliable assessment of the time - dependent failure process. Moreover the classical Charpy impact energy normally specified in J or J/cm^2 is not sufficient to describe dynamic fracture. The rate of energy used to initiate

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dynamic fracture as distinguished from that dissipated in plastic deformation and other forms is the relevant quantity. In this reason we used to our investigation the instrumented Charpy impact machine to determine significant dynamic material date such as loads, deflection and partial impact energies at the start of flow, at the beginning of stable and unstable crack propagation. In addition, precracked Charpy specimens have been employed to determine fracture mechanics properties such as K_{Id} an J_{Id}.

THE DYNAMIC FRACTURE TOUGHNESS IN ASPECT OF THE FRACTURE MECHANICS

The value of K_{Id} was calculated in according to the formula given in (1) as follows:

$$K_{Id} = \frac{F_m \cdot S}{BW^{\frac{3}{2}}}\left[2{,}9\left(\frac{a}{W}\right)^{\frac{1}{2}} - 4{,}6\left(\frac{a}{W}\right)^{\frac{3}{2}} + 21{,}8\left(\frac{a}{W}\right)^{\frac{5}{2}} - 37{,}6\left(\frac{a}{W}\right)^{\frac{7}{2}} + 37{,}7\left(\frac{a}{W}\right)^{\frac{9}{2}}\right] \quad (1)$$

In order to compute the critical value of J - integral the formula given in reference (2) was used:

$$J_{Id} = \frac{2U}{B(W-a)} \quad (2)$$

In order to proper an assessment of the fracture toughness it is indispensable to determine accurately the moment of the crack development initiation, i.e. the moment when the critical K_{Id}, J_{Id} - values are determined. To determine this moment we used a special program elaborated in the Technical University of Bydgoszcz.

THE DYNAMIC FRACTURE TOUGHNESS OF THE HETEROGENEOUS WELD JOINTS

There are presenting an example of the extend investigations of weld joints of the high - strength low - alloy (HSLA) steel 14HNMBCu.

The chemical composition of the material given in table 1

TABLE 1 - Chemical composition of used HSLA steel.

Symbol of steel	C %	Mn %	Si %	P %	S %	Al %	Cr %	Ni %	Mo %	Cu %	B %
14HNMBCu	0,16	0,89	0,23	0,018	0,025	0,017	0,55	0,84	0,46	0,39	0,03

Figure 1 presents the hardness penetration pattern at mismatched weld joint of HSLA steel 14HNMBCu with designation the positions of the notches in Charpy specimens. The results of an assessment of K_{Id}, J_{Id}, K and a_d have been presented in figure 2 and reveals the difference of K_{Id}, J_{Id} and K at weld and heat affected zones (HAZ).

In order to explain above situation the total energy K was divided into three parts: K_z, K_r, K_h - figure 3. By an apostrophe was designated the results of investigation of the precracked Charpy V notch samples. The dates in figure 3 reveals a considerable difference of K, K_z, K_r, K_h and K', K'_z, K'_r, K'_h respectively $\Delta K^o = K - K'$, $\Delta K^o_z = K_z - K'_z$ $\Delta K^o_r = K_r - K'_r$, $\Delta K^o_h = K_h - K'_h$. The differences ΔK^o, ΔK^o_z, ΔK^o_r, ΔK^o_h have been presented in figure 4. The values of J_{Id}, KCV, a_d as a function of temperature have been presented in figure 5. Furthermore more the values of J_{Id}, KCV = K/A (A - area of cross - section at notch) and characteristic of change of J_{Id} at weld and HAZ:

$$U_j = \frac{J^W_{Id} - J^B_{Id}}{J^B_{Id}} \quad \text{or} \quad U_j = \frac{J^{HAZ}_{Id} - J^B_{Id}}{J^B_{Id}} \tag{3}$$

as a function of the distance l on weld axis have been presented in figure 6.

There also were established, after statistic analysis for above situation, the following correlations between J_{Id} and KCV

- at weld as a function of temperature (fig.5)

$$J_{Id} = KCV\left(e^{-0{,}374+0{,}445\cdot 10^{-2}\,T}\right) \tag{4}$$

-at weld and HAZ as function of the distance l on weld axis (fig.6)

$$J_{Id} = 8{,}818KCV + \left(0{,}00209l^5 - 0{,}1055l^4 + 2{,}044l^3 - 17{,}07l^2 + 28{,}27l - 598{,}8\right) \tag{5}$$

CONCLUSIONS

The Charpy V test procedure presents some difficulty when considered for quantitative toughness measurement. One of the major shortcomings of the conventional approaches is that they failed to separate the fracture energy from other forms energy dissipation. The development of measuring equipment and computers has made the numerical treatment of experimental date convenient and the evaluation of physical quantities, such as $K_z, K_r, K_h, K_{Id}, J_{Id}$, which were difficult to measure directly, has become possible.This investigation also to confirmed that scatter in Charpy date is among other factors dependent on the non - uniformity of the structure in tested mismatched weld joints.

SYMBOL USED

F_m - maximum load (KN)
S - distance between the impact machine supports (m)
B - specimen thickness (m)
W - specimen width (m)
a - crack length in the specimen (m)
K - total failure energy (J)
K_z - crack initiation energy (J)
K_r - crack propagation energy (J)
K_h - crack slide energy (J)
U - strain energy (J)
a_d - flaw length (m)

REFERENCES

[1] ASTM E 24.03.03. Proposed standard method of test for instrumented impact testing of precracked Charpy specimens of metallic materials.

[2] ASTM Standard E 813-89. A measure of fracture toughness of metallic materials.

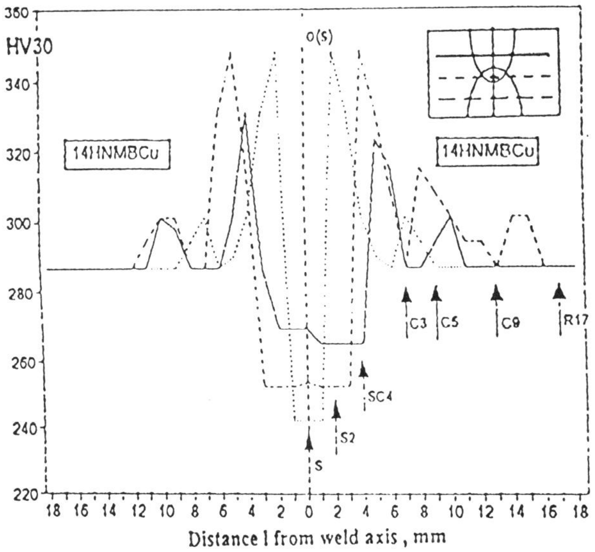


Figure 1. Hardness diagram of HSLA steel 14 HNMBCu weld joints
BM - base material, HAZ - heat affected zone, W - weld

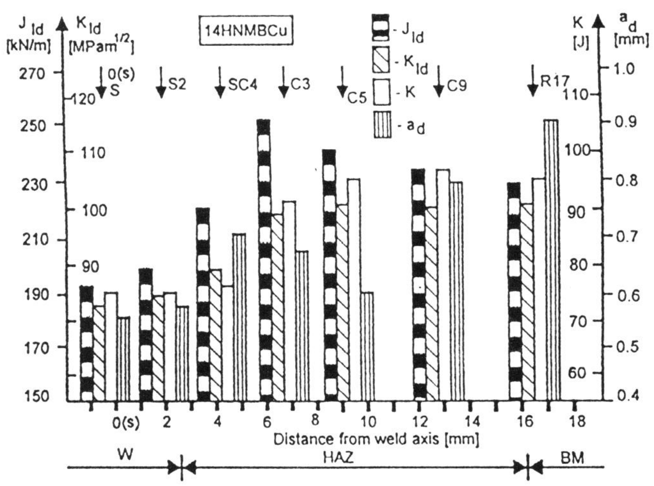
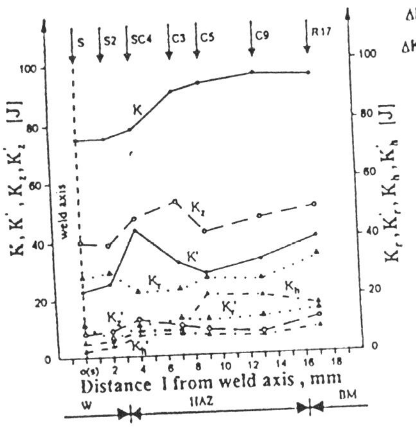


Figure 2. The Values of J_{Id}, K_{Id}, K, a_d for 14HNMBCu weld joints



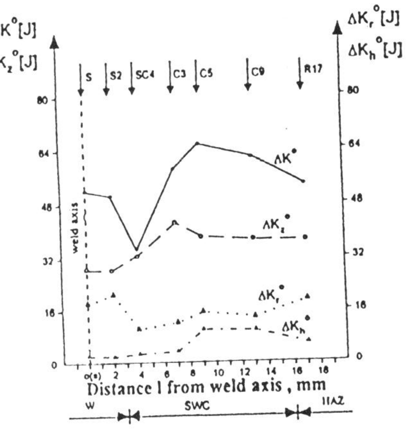
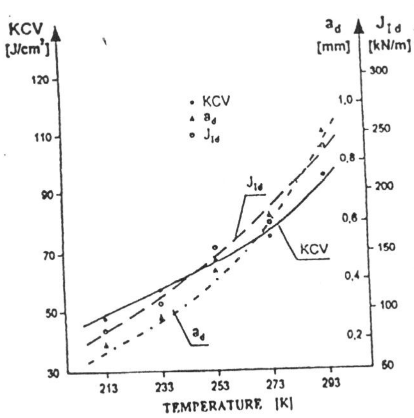


Figure 3. Change of K, K_Z, K_r, K_h for Charpy V specimens

Figure 4. Differences of $\Delta K^O, \Delta K_Z^O$, $\Delta K_r^O, \Delta K_h^O$ under investigation Charpy V specimens



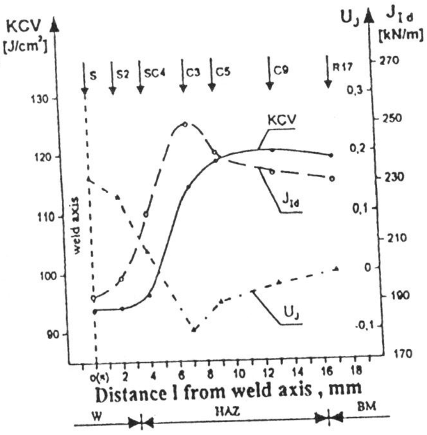


Figure 5. Diagram of KCV, J_{Id}, a_d for weld on T dependence

Figure 6. Diagram KCV, J_{Id}, U_j on the distance l dependance