Relationship between the Fracture Toughness and the Morphology of the Fracture Surface in Steels Resistant to Atmospheric Corrosion.

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Introduction

The welding heat flow has a considerable influence on the fracture toughness of structural steels. This effect is especially large in Cu-Cr-Ni-P steels /Cor-ten tipe steels/. We set ourselves the goal of determining the effect of the welding heat flow on the fracture toughness of Cu-Cr-Ni-P steels and establishing a relationship between the variation of fracture toughness and the morphology of the fracture surface.

Experimental

The welding heat flow was simulated by resistance heating. The specimen had a section of 12 x 12 mm; the heating rate was 250°C per second. The peak temperature of the heat process varied up to 1375°C. The COD tests were carried out on specimens with a section of 10 x 10 mm, bent at three points at 0°C temperature. The bending rate was 8 mm per minute. The fracture surfaces were examined with an ISM - U3 type JEOL scanning microscope. A JXA - 3 electron probe microanalyzator was used for phase analysis.

Our tests were carried out on the steel according to Table 1.

Figure 1 presents the results of COD tests on specimens heated to the peak temperature $T_{max} = 1375^{\circ}C$, as a function of cooling rate /expressed by cooling time from $850^{\circ}C$ to $500^{\circ}C$/. Figure 2 shows the effect of the peak temperature on COD in the case of single and repeated heating.

Evaluation

The following conclusions may be drawn from the COD tests:

- for the tested steels the COD value of the specimens heated up to $1375^{\circ}C$ is independent of the cooling rate,
- COD is reduced markedly under the influence of heat processes with peak temperatures in excess of $1100^{\circ}C$,
- the toughness of the steel heated once to $1375^{\circ}C$ will - on repeated heating - fall short of the value obtained after a single heating to the same temperature.

Figure 3 shows the characteristic fractographic image of the steel heated up to $1100^{\circ}C$ and Figure 4 the same for the steel heated to $1375^{\circ}C$. In the first case tough and brittle parts were found in proportions depending on the heating temperature and the photographs in Figure 4 show a lack of metallic contact in some parts of the material. Metallographic tests have also unamboguously shown traces of local melting /Figure 5/. This local melting did not occur on the austenite grain boundaries which had existed at $1375^{\circ}C$ but at the ferrite or pearlite grain boundaries which existed before heating. Local melting may be connected always with segregations with low melting points at the ferrite grain boundaries. Chemical

analysis at the spots of melting did not show any enrichment of Cu, Ni, Cr, P or S. After correlating the results of metallographic tests and chemical analysis we came to the conclusion that cavities were formed at the sites of melting. The formation of cavities may be explained as follows: in the welding heat flow a plastic deformation draws away a substantial part of the melted material. The presence of "cavities" can also explain the effect of repeated heating on COD. In the specimens heated up to $1375^{\circ}C$ the favourable effect of repeated heating on the microstructure increases the toughness without attaining the value which characterizes the state after a single heating process, because of the presence of the cavities.

Summary

The effect of the welding heat flow was studied in the case of Cu-Cr-Ni-P steels resistant to atmospheric corrosion. The welding heat flow was realized by resistance heating simulator, the COD value was determined by static bending. It was found that fracture toughness is considerably dependent on the peak temperature of the heat process and decreases rapidly under the influence of thermal processes with peak temperatures in excess of $1100^{\circ}C$. On the basis of the results of fractographic, metallographic tests and electron microprobe analysis this is due to local melting and cavity formation at the original grain boundaries.

Table 1.

	C	Si	Mn	S	P	Cu	Cr	Ni	Al
LK52	max. 0,18	0,2 - 0,5	0,6 - 1,0	max. 0,04	0,04-0,08	0,3-0,5	0,5-1,2	0,3-0,6	min. 0,02
Y8	0,09	0,27	0,46	0,013	0,082	0,42	0,68	0,35	0,023

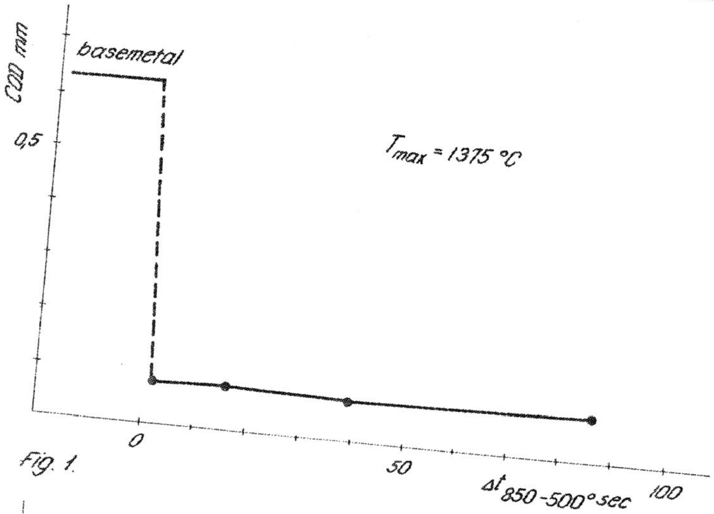

Fig. 1.

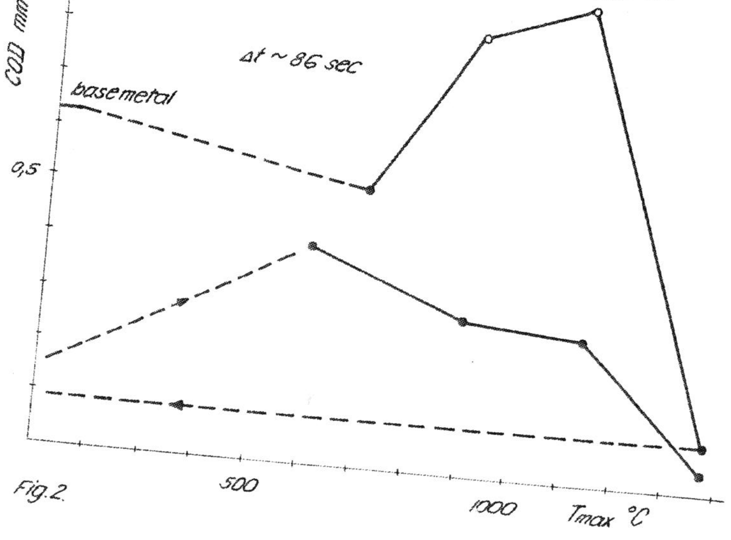

Fig. 2.

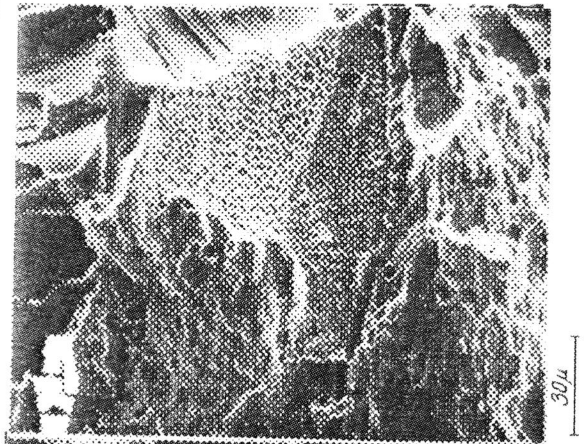

Figure 3

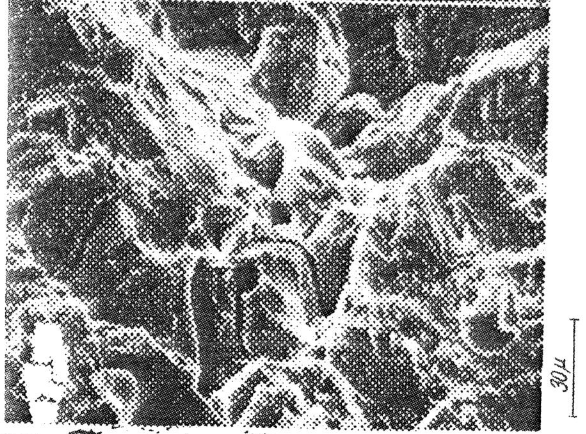

Figure 4

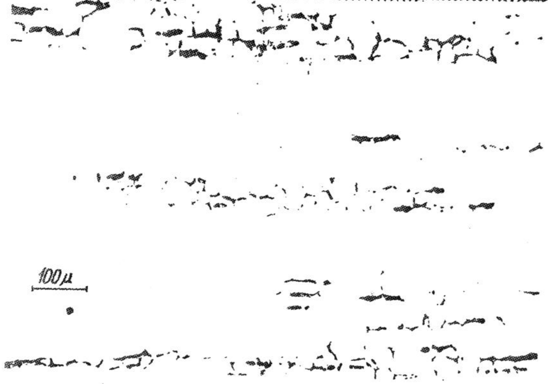

Figure 5