THROUGH THICKNESS FRACTURE PROPERTY VARIATION IN 50mm HSLA STEEL PLATE

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Variation in impact transition temperature through the thickness of a HSLA steel plate has been investigated. No significant variation in prior austenite grain size, hardness and tensile properties was found. Heat treatment and extensive metallographic studies have been carried out and the transition behaviour has been related to microstructural differences caused by differential cooling rates across the thickness. The implications of the findings are discussed.

INTRODUCTION

Submarine hull steels in the U.K. are, at present, covered by specifications Q1(N) and Q2(N). These steels are used in the quenched and tempered condition and Q2(N) has a higher yield strength due to a higher nickel content and other small variations in composition. A new high strength low alloy (HSLA) steel, RQT 701 (New) has been developed by BSC Swindon Laboratories as a possible replacement for the current materials. RQT 701 (New) is a low nickel, boron containing, quenched and tempered steel and is less expensive than the Q(N) steels because of its lower nickel content, the hardenability being maintained by the boron addition. Because of its lower carbon content fabrication costs are also likely to be reduced because of the lower welding preheat requirements. A comparison of the composition of the material with Q2(N) is given in Table 1 below.

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ELEMENT	Q2 (N)	RQT 701
C	.15	.11
Si	.19	.35
Mn	.42	.91
P	.008	.006
S	<.005	.002
Cr	1.58	.50
Mo	.51	.44
Ni	3.58	.84
Al	.045	.08
Cu	.08	.25
Nb	<.01	<.01
V	.07	.034
B	<.001	.0016
Ca	.0009	.0026
N	.013	.004
Pb	.00014	.0001
Sb	.0014	.0005
Zr	.009	.004
Ti	<.01	<.01
Sn	.014	.01
As		.01

TABLE 1

Preliminary testing of RQT 701 revealed a marked difference in the through thickness impact transition properties.⁽¹⁾ The naval requirement for impact properties is that at -85°C the charpy energy must be above 80 Joules. It was initially found that in thicknesses greater than 50mm the mid thickness of the plate conformed to this specification but that the sub surface regions did not. Accordingly a study was initiated at the University of Salford sponsored by the DRA to investigate this effect. This report describes the initial findings.

Experimental

Charpy specimens to BS131 were machined from the sub surface and mid thickness of a 50mm thick RQT (701) New plate. The specimens were longitudinal to the rolling direction with the notches parallel to the top and bottom surfaces. Fig 1 shows the results of Charpy tests compared with typical results for Q2(N).

It can be seen that a variation in properties through the thickness exists and that the sub surface regions do not conform to naval specifications. Fig 2 shows results for a 40mm plate taken from another work⁽¹⁾. Again a through thickness variation is evident but not as marked as in thicker sections.

Variation in fracture transition temperature can be caused by a variety of factors associated with microstructure and yield stress variations. Yield stress and hardness tests were carried out across the plate section and revealed no significant variation. These results will be produced in detail in a future publication. Extensive metallographic examination of the plate material has been carried out. The first factor to be studied was the prior austenite grain size. Specimens were taken from sub surface and mid thickness positions, polished to a 0.5μm finish and electrolytically etched in a solution of HCl in methanol to enhance the grain boundaries. No differences were found, the grain size in all cases was ASTM grain size no. 10.

The microstructure of the material across the section of the plate revealed slight differences. Fig 3 shows a sub surface region which shows a mixture of auto tempered and tempered martensite. In the central regions these features were still present but some areas of lower bainite (Fig 4) were evident.

The differences in microstructure would be caused by variation in cooling rate across the thickness. Slices 185 x 60 x 20mm were taken from sub surface and mid thickness positions and given the standard heat treatment of 925°C for 4 hours, water quench, followed by tempering at 645°C for three hours. Fig 5 shows the results of impact tests on these samples. The variation in properties seems to have been removed,but both mid thickness and sub surface fracture properties have become inferior to Q2 (N) steel.

It would seem from the above that the variation in fracture properties was a result of cooling rate effects. Accordingly, Jominy end quench tests were carried out on samples taken from sub surface and mid thickness positions. The austenitising treatment was 4 hours at 925°C in each case and the hardness readings are shown in Fig 6. The hardenability of the material through the thickness of the plate appears to be reasonably constant.

Discussions

The preliminary trials suggest that the variation in impact properties through the thickness of RQT (701) New plate is a cooling rate effect. The increased toughness of the central regions of the plate can be related to the presence of bainite and Tometa(2) amongst others has reported on the benefit of mixed martensite and bainite structures. Fig 5 shows that if the same cooling rate is applied there is no difference between material taken from different positions in the plate;this is supported by the Jominy results. The problem remains that the surface regions do not conform to specification and that further work should establish the reason for this and suggest means of improving the fracture characteristics of the material. An extensive transmission electron microscopy investigation is under way to study microstructural effect produced by a variety of heat treatments and their effects on the fracture properties of the material. It is hoped that this work will enable recommendations to be made for a heat treatment to produce optimum mechanical properties.

References

(1) Wrigley, N.S., University of Salford, Final Year Project Report, 1990.

(2) Tometa, Y., Mat Sci Tech v7, 1991, pp. 299-306.

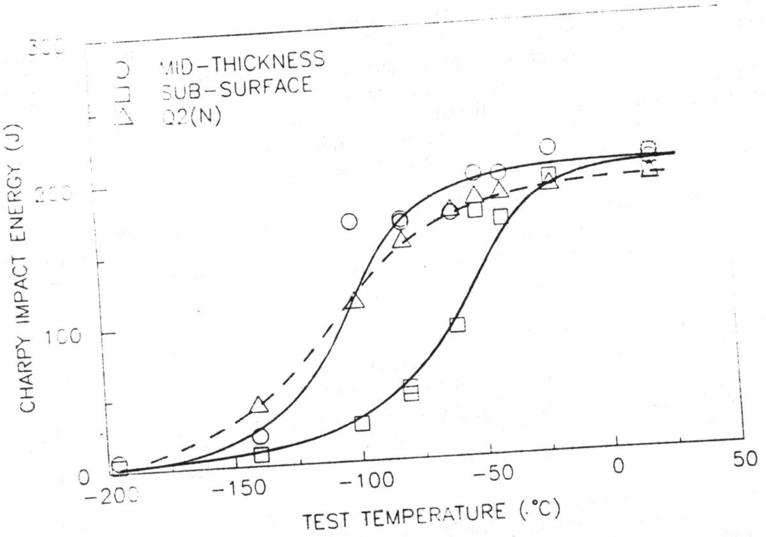

Figure 1

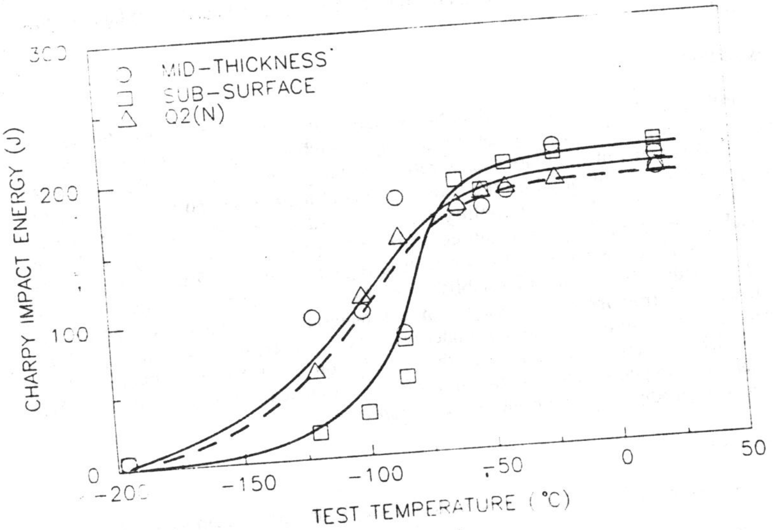

Figure 2

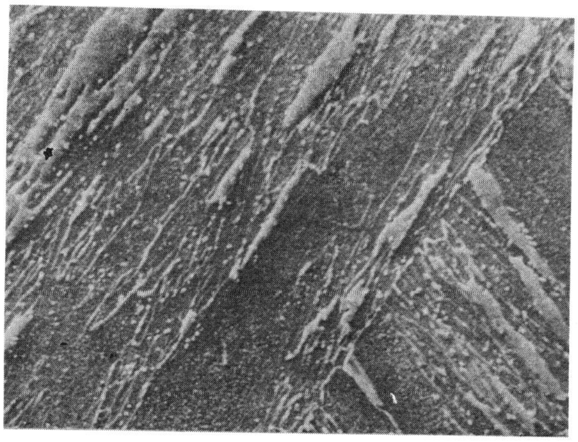

Figure 3 Magnification x5000

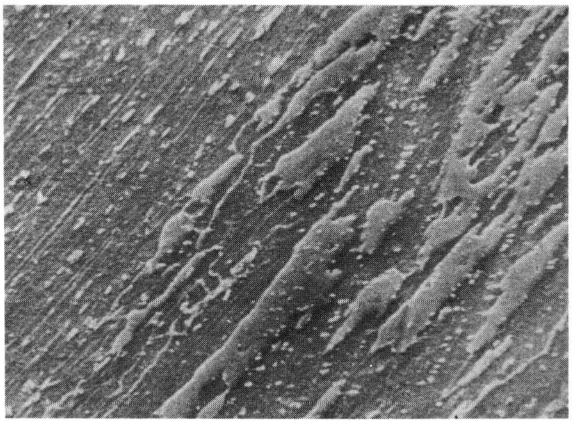

Figure 4 Magnification x5000

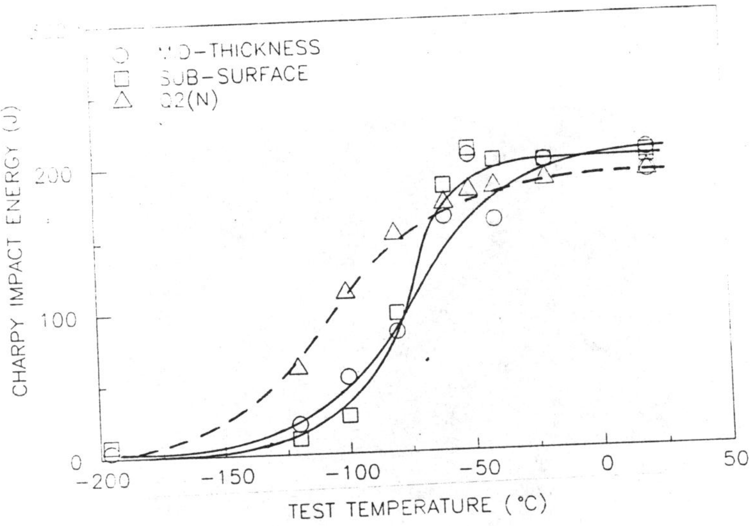

Figure 5

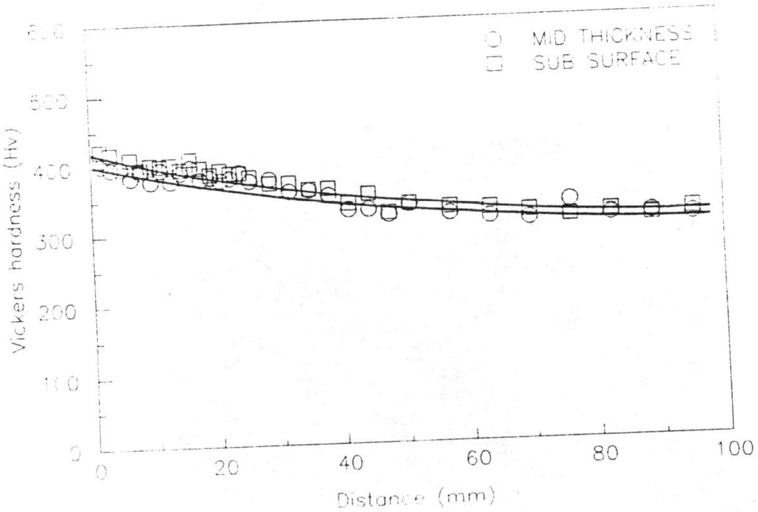

Figure 6