IMPACT TOUGHNESS OF STEELS FOR CRYOGENIC APPLICATION

T. Maguda,* A. Zaczyk*

INTRODUCTION

Cryogenic applications such as liquid gas storage require alloys having good toughness but also appreciable tensile characteristics. These cryogenic alloys,as the conventional 9% Ni steels, have the disadvantage, that they contain major additions of nickel, a particularly costly alloy addition. In view of the high and increasing cost of Ni, the economics of cryogenic steel may be improved either by minimizing the nickel content in commercial Fe-Ni steels or by developing Ni-free compositions with suitable properties. The first approach caused the development of the 5-6% Ni steels [1] with the three-step heat treatment designated the "QLT" treatment, which results in a combination of tensile characteristics and low temperature toughness equivalent to that of the 9% Ni steel. A promising way for the development of a Ni-free steels is to substitute Mn for Ni since Fe-Mn alloys have similar microstructure to Fe-Ni alloys in iron rich region [2-4]. Ferritic 6-9% Mn steels can also be toughened for cryogenic service by QLT treatment as the 5,5% Ni steels are in commercial practice. But as it has been shown [4,5] the steel properties or microstructure are strongly affected by heat treatment temperature and Fe-Mn steel has a complicated structure since the autenite reverts in relatively low temperature as in 5,5 and 9% Ni steel and either transforms to martensite or retains at -196°C. The retained austenite has a key role in determining the Fe-Mn steel properties as in Fe-Ni steels [4,5]. The present work reports the effect of QLT heat treatment on low temperature toughness and compares the properties of 6% Mn and 5,5% Ni steels.

MATERIAL AND METHODS

The 6% Mn and 5,5% Ni steels were induction melted in vacuum. The chemical compositions of the steels are shown in Table 1. The cast ingots (approx. 60 kg each) were forged, homogenized at 1150° C for 6h and finish rolled into plates of 13 mm thickness. The plates were cut into blanks and then heat treated. Heat treatment began with a treatment labeled Q, which involved austenitization at 850° C for one hour followed by quenching in water. After Q treatment the steels were either annealed in the upper region of the two-phase ($\alpha + \gamma$) field for 1h with following water quenching

* Institute of Materials Science, Cracow Technical University, Al.Planu 6-letniego 19A, 31-864 Cracow, Poland.

Table 1. Chemical composition of the 5,5% Ni and 6% Mn steels.

steel	C	Mn	Si	P	S	Ni	Mo	other
A	0.085	0.86	0.35	0.013	0.026	5.33	-	-
B	0.065	0.76	0.15	0.010	0.013	5.08	0.26	-
C	0.022	0.78	0.34	0.012	0.016	6.05	-	Ce
D	0.024	6.13	0.23	0.005	0.017	0.02	0.23	-

(L treatment) and then tempered (T) within a range 500-625°C or only tempered (T) within a range 500-650°C.The specimens were then subjected to Charpy impact and tensile tests.

RESULTS AND CONCLUSIONS

Charpy impact energies for QLT treated specimens of A,B and D steels as a function of T temperature are presented in Fig. 1 and 2 (compared in Fig. 1 with QT treated A steel). The QLT treatment greatly improved the toughness of all A,B,C and D steels. In case of 5,5% Ni steels further improving of the toughness was observed with lowering C content and Ce addition. The tensile properties at room temperature and Charpy transition curves are shown in Fig.3 and 4. The temperatures of QLT treatment were chosen in this case with regard to results of Charpy tests shown in Fig.1,2. As shown in Fig.3 all of the steels have good tensile properties and save good toughness even down to -196°C. The low temperature toughness and tensile properties of the QLT treated 6% Mn steel are relatively as good as that of the 5,5% Ni steel.

REFERENCES

(1) Yano, S. et al., Transactions ISIJ, Vol.13., 1973, pp.133-140.
(2) Murakami, M., Shibata, K. and Fujita, T., Tetsu-to-Hagane, 72, 1986, pp.69-76.
(3) Duchateau, D. and Guttmann, M., Met. Science, Vol.17., 1983, pp.229-240.
(4) Kim, J.I., Syn, C.K. and Morris, J.W., Metall. Trans., Vol.14A, 1983, pp.93-103.
(5) Murakami, M., Harada, M., Shibata, K. and Fujita, T., Transactions ISIJ, Vol.23., 1983, pp. B-255.

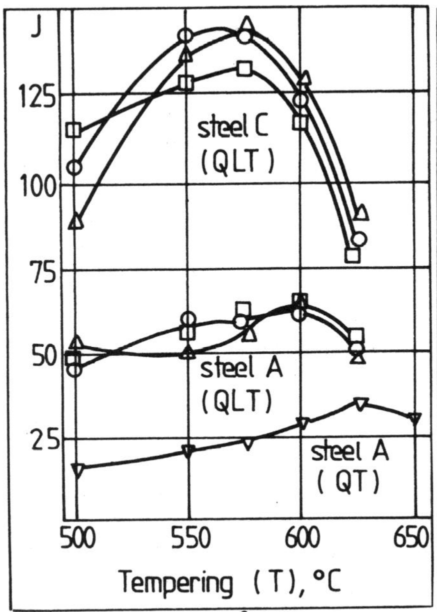

Fig.1. CVN at -120°C for 5.5 Ni vs. heat treatm. temperatures.

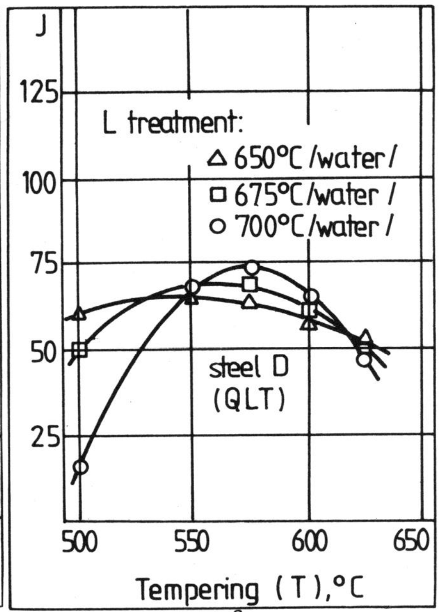

Fig.1. CVN at -120°C for 6 Mn vs. heat treatm. temperatures.

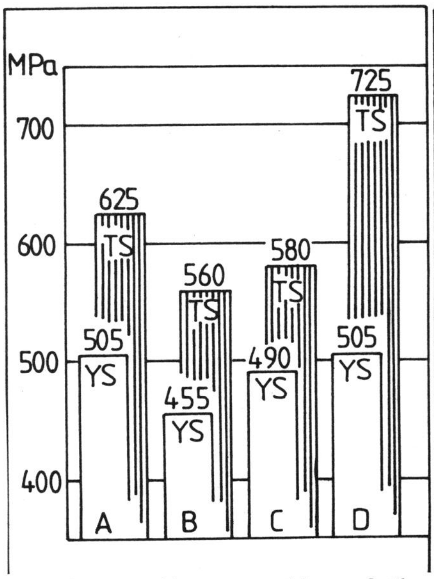

Fig.3. Tensile properties of the 5,5% Ni and 6% Mn steels.

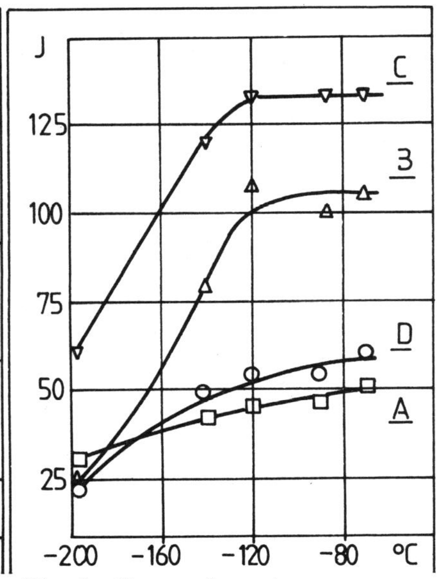

Fig.4. Charpy impact energy vs temperature curves.