EFFECT OF TMT ON THE TOUGHNESS AND FRACTURE CHARACTERISTICS OF TWO Fe-Mn-Ni ALLOYS

B. Sarkar*, R. K. Ray* and A. K. Seal*

INTRODUCTION

Recent work has shown that Fe-Mn-Ni base maraging steels although exhibiting quite high strength properties, sometimes comparable to those of conventional Fe-Ni base maraging alloys [1, 2, 3] generally show a much lower toughness value. In this investigation the effect of TMT on the strength, toughness and fracture characteristics of two Fe-Mn-Ni alloys has been studied.

EXPERIMENTAL PROCEDURE

The chemical compositions of the alloys are shown in Table 1. The alloys (3 Kg. each) were air melted in a high frequency furnace using high purity raw materials. Thermo-mechanical treatment was done by rolling between temperatures 600 and 450° C followed by water quenching. A deformation of 33% was given. Aging characteristics of both worked and unworked samples were studied in the usual manner. While thin foils of quenched and aged samples were examined by TEM, fractured surfaces were studied by SEM.

RESULTS AND DISCUSSIONS

Table 2 shows the results of isothermal hardness studies on both the alloys at 400° C. It is to be noted that TMT accelerated the ageing process and raised the peak hardness values in case of both the alloys only marginally. However, in both the alloys the toughness values were markedly improved by TMT (see Table 3). The SEM photographs taken from the fracture surfaces of the alloys are shown in Figure 1a to 1d. It can be seen that for both the alloys in the unworked and aged to peak hardness condition the fracture is mainly of an intergranular nature. The fracture path follows the prior austenite grain boundaries. Isolated patches of ductile dimples can also be seen. In contrast to these, the fracture surfaces of the worked and aged alloys show micro-void coalescence on most of the grain facets, which is typical of a ductile material.

TEM studies indicate that while unworked samples show a high dislocation density or a dense dislocation-nucleated precipitation within the martensite laths, the worked samples show a distinct dislocation cell structure (see Figures 2a and 2b). This has also been reported in thermo-mechanically treated 18% Ni maraging steels [4]. It has been suggested that such a dislocation substructure can suppress crack initiation [4].

* Respectively, Lecturer, Assistant Professor and Professor of Metallurgy, Bengal Engineering College, P. O. Botanic Garden, Howrah - 711103, India

It has been found that the Izod impact values for both the alloys in the quenched condition are increased about two times by TMT (vide Table 4). TEM studies indicate profusion of twins in the martensites of unworked samples (see Figure 3a) which may account for the low toughness values of the alloys in the quenched state. However, the twins are found to be removed from the martensite plates by prior working (see Figure 3b). That the martensite twins may be dissolved by heavy deformation, has also been demonstrated by other workers [5]. The removal of twins by TMT may account for higher toughness values of the martensites in these alloys. It is suggested that this effect is carried over up to the peak hardened state, thus leading to a change in the fracture modes of the worked and unworked alloys.

REFERENCES

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Table 1 Analysis of Alloy (wt. percent)

Alloy No.	Mn	Ni	C	Balance
A	5.25	10.01	0.05	Fe
B	9.60	5.20	0.05	Fe

Table 2 Isothermal Hardness Results (hardness in VPN)

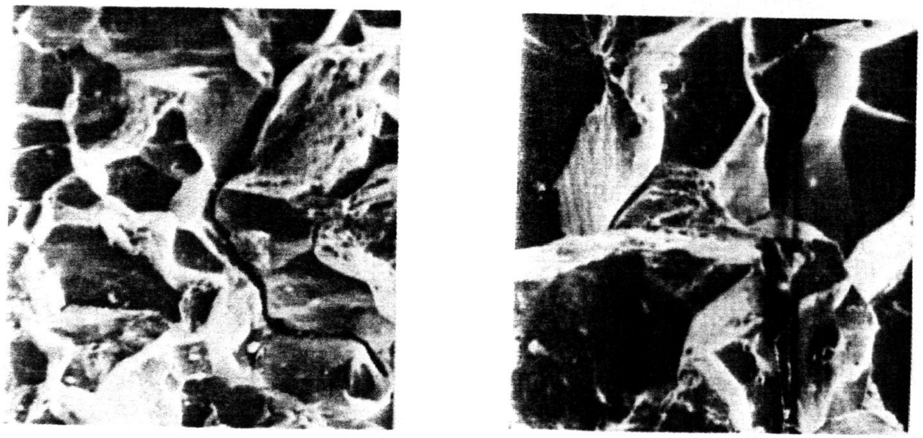
Aging Time	Alloy A		Alloy B	
	Unworked	Worked	Unworked	Worked
As quenched	306	314	302	318
6 mins	339	364	348	368
1 hr	350	403	362	407
2.5 hrs	384	382	375	396
4 hrs	370	345	366	366
10 hrs	324	298	339	315

Table 3 Izod Impact Values (Nm) for the Aged Alloys

Alloy No.	Condition	Time of Aging at 400° C	Impact Energy (Newton Metre)
A (Unworked)	Aged to Peak-Hardness	2.5 hrs	4.20, 4.07, 4.75
A (Worked)	Aged to Peak-Hardness	1 hr	13.56, 13.83, 14.91
B (Unworked)	Aged to Peak-Hardness	2.5 hrs	3.93, 4.34, 4.75
B (Worked)	Aged to Peak-Hardness	1 hr	14.23, 14.91, 18.30

Table 4 Izod Impact Values (Nm) for the Virgin Martensite in the Two Alloys

Alloy No.	Condition	Impact Energy (Newton Metre)
A (Unworked)	Martensitic	23.72, 21.69, 23.04
A (Worked)	Martensitic	47.45, 48.12, 48.81
B (Unworked)	Martensitic	14.23, 15.59, 18.30
B (Worked)	Martensitic	26.43, 29.15, 29.83



(a) 250X (b) 250X

Figure 1 SEM Photographs of Fracture Surfaces of the Alloys
(a) Alloy A, Unworked and Aged, (b) Alloy B, Unworked and Aged

continued

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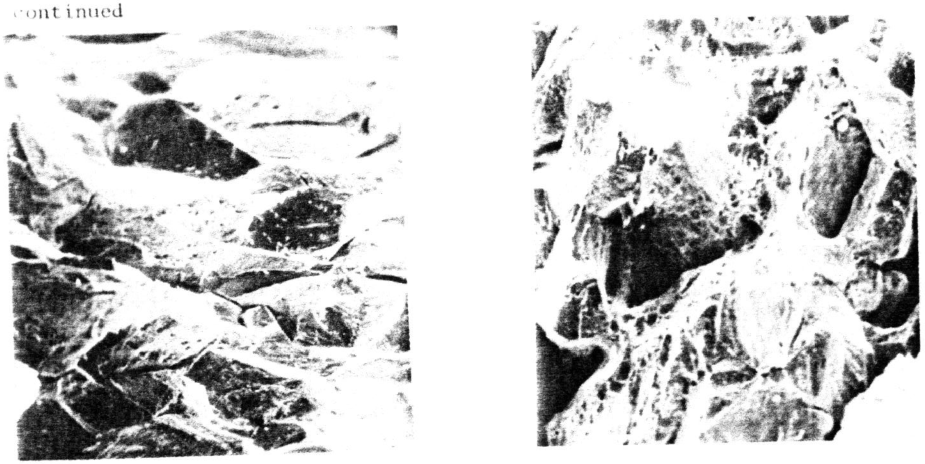
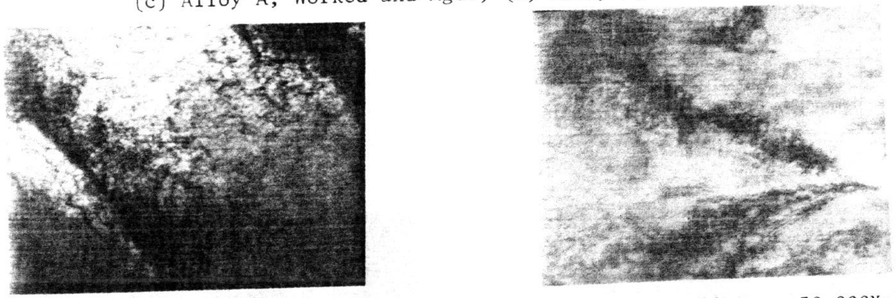


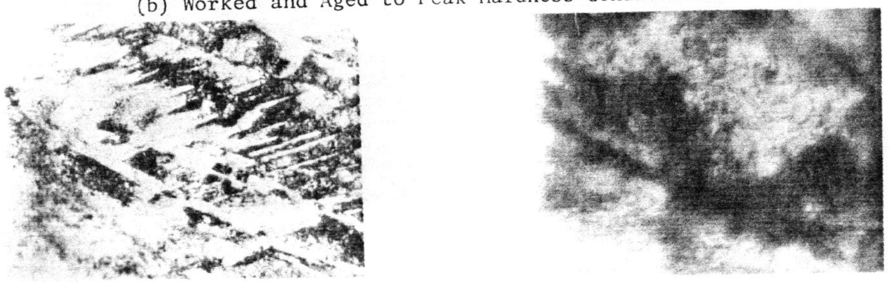
(c) 250X (d) 250X

Figure 1 SEM Photographs of Fracture Surfaces of the Alloys
(c) Alloy A, Worked and Aged, (d) Alloy B, Worked and Aged



(a) 50,000X (b) 50,000X

Figure 2 TEM of Alloy A
(a) Unworked and Aged to Peak Hardness Condition,
(b) Worked and Aged to Peak Hardness Condition



(a) 50,000X (b) 50,000X

Figure 3 TEM of Alloy A
(a) Unworked and Quenched, (b) Worked and Quenched