MICROALLOYED STEEL: ITS ENHANCEMENT IN PROPERTIES BY THERMOMECHANICAL PROCESSING -A CASE STUDY

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ABSTRACT

Microalloyed steels are the product of extensive research of the eighties and are good examples of high strength steels produced by microstructural tailoring of materials through microalloying and thermomechanical processing . This paper is based on the work carried out at the author's laboratory on low carbon microalloyed steel containing minor additions of Nb and Ti and reports the parameters of melting, casting and thermomechanical processing established . The microstructural developments and physical and mechanical properties achieved are discussed.

INTRODUCTION

It is well known that microalloyed (MA) steels appeared in the engineering materials scenario in the early eighties. They possess unique combination of strength , toughness and weldability besides having satisfactory corrosion resistance. MA steels are primarily low carbon (0.03- 0.15%) manganese steels with minor additions (<0.1%) of V, Ti, Nb or Al for formation of carbides or grain size control(1 micron) and Ca, Zr and rare earths like Ce and La for inclusion control. Mn and Si present in solid solution contribute to solid solution hardening. Due to continued research and developments the world over these materials are finding extensive applications in offshore structures, automotive bodies , oil and gas pipelines and drilling rigs, ship plates, pressure vessels and tubing, earth moving and rail road equipment , high rise buildings, bridges, transmission towers , storage tanks, reinforcing bars etc.

It is recognised that grain size, solid solution and precipitation contribute to strengthening . In MA steels all these factors are exploited fully and the major contributing factor namely precipitation is facilitated by thermomechanical processing(TMP)(1-3). TMP is a combination of thermal treatment, phase transformation and plastic deformation . The structure, morphology and grain size of parent phase (e.g. austenite) can be made optimal by designing the processing schedule to yield the best results. The main objective of TMP is, thus, to achieve very high strength, improved ductility and greater toughness in a wide variety of steel products.

It is well known that grain size influences the yield strength following Hall Petch relation and any reduction in grain size will improve yield strength.

Solid solution is another factor contributing to the enhanced properties of MA steels. This may be of interstitial or substitutional type. C or N form the former type and Mn, Si and Ti form the latter.

The precipitation strengthening is the next most effective mechanism enhancing the mechanical property (Table 1). Precipitation also improves the toughness properties. In MA steels micro addition of selected elements like Vanadium, Niobium and Titanium enable formation of carbides/nitrides which precipitate during thermomechanical pròcessing

Table 1 : Effects of microalloy carbide/ nitride precipitates on precipitation Strengthening in Microalloyed steels

Precipitate	B in MPa per wt% alloy		Alloy range Wt%
	Maximum	average	
VC	1000	500	0-0.15
VN	3000	1500	0-0.06
Nb(CN)	3000	1500	0-0.05
TiC	3000	1500	0.03-0.18

B= σ_p → Precipitation strengthening factor

MAIN OBJECTIVE

i) To study the role of minor additions of Nb and Ti on the structure and properties of micro alloyed steel

ii) to study the effect of temperature and time of soaking, rolling parameters and finishing temperature on mechanical properties of microalloyed steel, specifically on YS, UTS, %RA and CVN

EXPERIMENTAL

Three compositions of MA steels (Table 2) were melted in a 40 kg Vacuum induction furnace at a vacuum of 10^{-5} mm Hg using low C iron (0.015% C), Fe-60Nb, Fe-20B, Fe-40Ti (4). The furnace has a separate chamber for alloy addition.

The ingots were hömogenised at 1100°C for 24 hours. The thermomechanical processing was carried out as given in the flow sheet in Fig.1 . This involved:

i) heating the homogenised ingots at 1150°C for 4 hrs

ii) hot forging the homogenised ingots to 35 mm thick plates

iii) heating one set of forged plates to 1100°C and another set to 1200°C for 90 minutes.

iv) hot rolling to 15 mm plates in a number of passes and finish rolling at 700, 800 and 900°C respectively.

Specimens for Tensile and Impact test were prepared as per BS:18: Part 2, 1971 and ASTM-E23 respectively.

Table 2 :Nominal chemical compositions of MA steels (wt%)

Alloy	C	Mn	Si	Ni	Cr	Mo	B	Ti	Nb	Fe
N1	0.05	1.6	0.3	1.2	0.6	0.5	-	-	-	rest
N2	0.05	1.6	0.3	1.2	0.6	0.5	30ppm	0.05	-	rest
N4	0.05	1.6	0.3	1.2	0.6	0.5	30ppm	0.05	0.05	rest

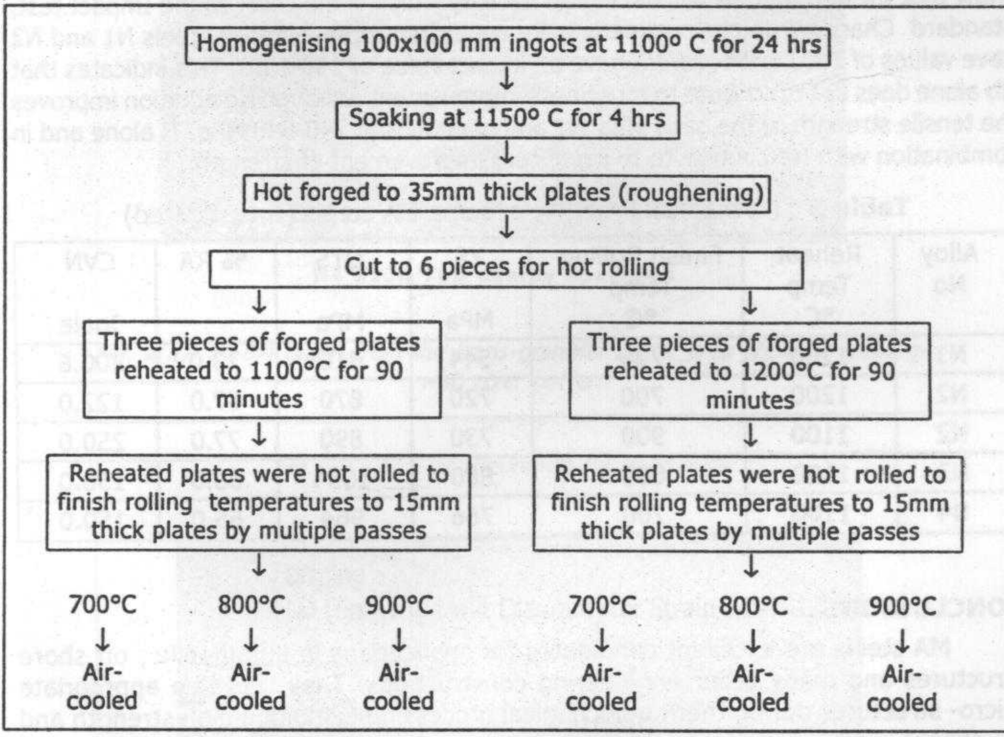

Fig.1 : Thermomechanical processing flow-sheet

RESULTS & DISCUSSION

Mechanical properties like proof strength (YS) , UTS, % elongation and % reduction in area of all the alloys were evaluated on standard specimens. Tensile data & room temperature impact test values of some representative samples are given in table 3. The values reported are average of 3 to 4 independent tests. In many cases the microstructures were also studied and found to be having correlation with the properties observed. It may be seen that N4 which contains both Ti and Nb has the best strength and toughness when soaked at 1100°C and finished rolled at 700/800/900°C. Basically the microstructure consisted of fine ferrite and pearlite with precipitates of complex compounds of TiNb carbides or carbonitrides (5). soaking at higher temperature for prolonged time has enabled formation of homogeneous solid solution structure necessary for fine precipitation of second phase particles during the subsequent thermomecahnical processing schedule . It was also noticed that greater the reduction per pass during rolling the finer was the ferrite grain size. It is well known that in the microalloys containing both Ti and Nb precipitation and grain size refinement take place simultaneously .

Impact values of the samples containing Ti and Nb are also good. It was observed from SEM study (Fig.2a&b) of the surface of the charpy impact tested samples that the fracture has occurred by cleavage mode which is indicative of high impact values. Elongated dimples and the river pattern in the SEM stereograph also show that these materials will have high ductility which is the case. In the Impact test, Standard Charpy V notch specimens were used. Two representative steels N1 and N2 gave values of 200J or above. N3 gave an impact value of 130-150J. This indicates that Nb alone does not contribute to toughness improvement although Nb addition improves the tensile strength of the base alloy N1 and maintains at 740-840 MPa. Ti alone and in combination with Nb contribute to significant improvement of strength.

Table 3 : Mechanical Property of some MA steels (Investigated)

Alloy No	Reheat Temp °C	Finish Rolling Temp °C	YS MPa	UTS MPa	% RA	CVN Joule
N1	1200	700	544	816	73.0	200.6
N2	1200	700	720	870	67.0	122.0
N2	1100	900	730	890	77.0	250.0
N3	1100	800	880	1054	68.0	138.0
N4	1100	700	766	964	65.0	150.0

CONCLUSIONS

MA steels are excellent candidates for applications in automobile , off shore structures and many other engineering constructions. They develop appropriate micro- structures during thermomechanical processing exhibiting high strength and toughness .

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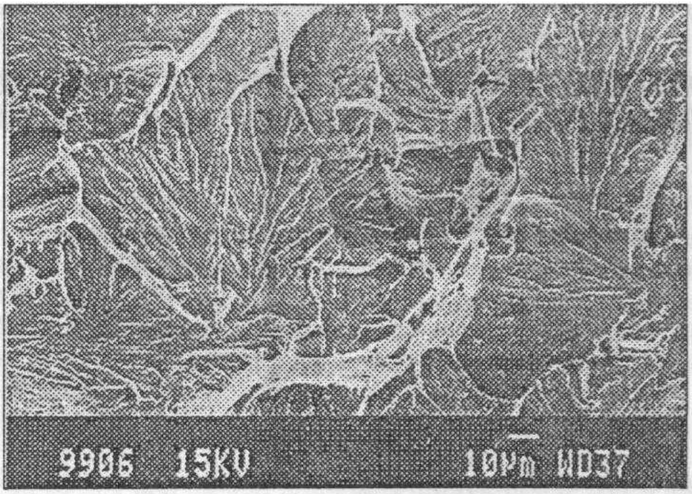
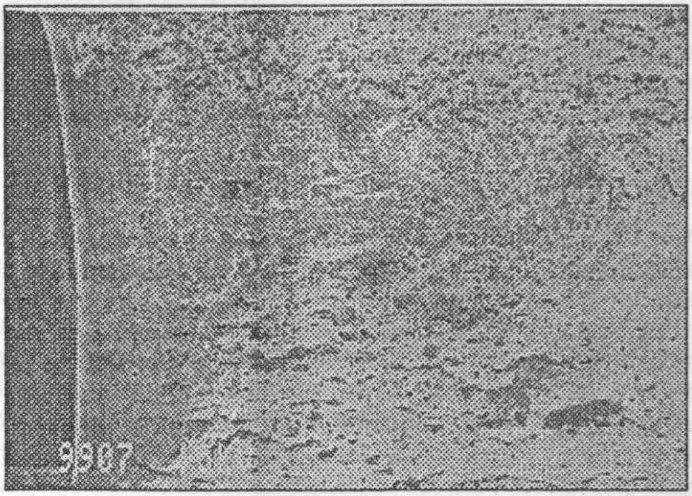


N4 1100/700 Charpy Specimen

Fig. 2(a) : SEM taken from the trans-granular brittle area showing cleavage with river pattern



N4 1100/800 Charpy Specimen

Fig. 2(b) : SEM showing mixed mode of fracture. Initially ductile dimple, intermediate zone brittle cleavage with river pattern and finally ductile zone