ROLE OF THERMOMECHANICAL TREATMENTS ON MECHANICAL PROPERTIES, MICROSTRUCURES AND CORROSION PROPERTIES OF OF MICROALLOYED STEELS.

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Abstract:

The paper deals with the developments in HSLA in general and the effect of thermomechanical processing on mechanical properties and corrosion in particular.The effect of micro additions on the properties are also dealt with.It has been pointed out that there is tremendous potential for HSLA for ship building, offshore structures, autobodies and many other engineering applications.

Introduction

Microalloyed steels or commonly known as high strength low alloy steels (HSLA) are the new entrant high strength to weight ratio materials for construction of bridges, mobile equipments,steel frame buildings,load carrying commercial and military vehicles , off shore strtuctures general engineering structures ,shipbuilding ,autobodies etc.These steels additionally possess good abrasion resistance and were recognised commercially immediately following the World War 11 to respond to the demands of large scale construction through welding fabrication and also to withstand atmospheric corrosion and resistance to brittle fracture. Thinner section of HSLA can be used because of the excellent mechanical properties thereby resulting in considerable weight saving.In the early periods utility and design of steel components were based primarily on yield strength which could be achieved through alloying addition ,increasing carbon levels etc. and little consideration was given to weight,weldability , corrosion resistance and fracture behaviour. Since carbon caused considerable difficulties in welding and strength deteriorated under service conditions attempts were made to reduce carbon levels to very low values of .03 or less. Later it was realised that the properties of a material primarily depended on the microstructure and research activities the World over were directed to achieve enchanced properties through tailoring of the microstructures.This could be achieved through mechanical working like the thermomechanical processing , controlled rolling ,judicious heat treatment,accelerated cooling etc keeping the alloying elements to micro levels.This approach has tremendous potential because significant ductility and toughness can be introduced taking advantage of phase transformation of the iron (1-5).

Strengthening and toughening in HSLA are basically through precipitation hardening and grain refinement which can be further enhanced through controlled rolling and judicious selection of microelements . It is worthwhile to understand the role of various commonly used elements .Carbon is solely meant for strengthening .It reduces weldability and ductility and hence the plain carbon steels can be used for bolted or riveted construction only. These steels do not resist atmospheric corrosion. Phoshorus strengthening effect but in combination with Cu improves the atmospheric corrosion resistance. Cu also strengthens by solid solution formation and precipitation hardening in presence of other micro additions on ageing of HSLA. Mn along with Ni strengthens and enhances low temperature properties. It is established now that elements like Al,Cr,Nb,Mn,Ni,Si,Ti,V,Zr,Rare earths etc singly or in combination impart high degree of strength,toughness and corrosion resistance besides formability and weldability.

Thermomechanical Processing:

This is a process of deformation while the material is undergoing phase trasformation to produce high strength and toughness.This is achieved by controlled rolling and accelerated cooling whereby a predetermined microstructure could be obtained .Rolling enables deformation of austenite and accelerated cooling enables supercooling of deformed austenite thereby ferrite nucleation sites and subsequent fine grained ferrites with colonies of bainite and/or martensite (Fig.1). The fine grained ferrite imparts low temperature toughness and weldability and reduces significantly susceptibility to cracking. Such TMCP steels are the right materials for off shore structures, ship builidng and oil pipes.

There are three stages of controlled rolling are illustrated in Fig.2 . In stage 1 repeated deformation and recrystallization refines the coarse austenite to fine ferrites.Some non -recrystallized regions and large ferrites grains still exit. Deformation in stage 2 changes the non recrystallized austenite to bands within the grains.Ferrite nucleates in these bands and austenite boundaries producing fine grains.. The transformation behaviour to fine ferrites in Ti and Nb & Mo bearing HSLA at differfent cooling rates are shown in Figs.3 and 4. In stage 3 the deformation continues deforming ferrite grains to form substructures .Accelerated cooling produces substructures from the deformed ferrites.

The role of micro elements in HSLA:

Various elements at micro levels have effect on the austenite recrystallization stop temperature.It is known that Nb increases the temperature to a maximum followed by Ti ,Al and.V .There are a number of mechanisms proposed on why the recrystallizartion temperature is raised (6).One such mechanism is due to the recovery retarding effect of Nb in low c ,Nb steels. Nb is usually present in HSLA because of its retarding effect on the recrystallization temperature.Table 1 summarises the various mechanisms operating and the subsequent properties and the resulting microstructure.

Accelerated Cooling :

Accelertated cooling has an edge over conventional hot rolling or normalising in terms of imparting strength ,toughness ,ductility , weldability, high resistance to environmental degradation particularly hydrogen induced cracking (HIC) and sulphide stress corrosion. It has been observed that accelerated cooling produces great er increase in yield strength as compared to controlled rolling and normalized treatments at different levels of C.Weldability is affected due to susceptibility to weld cracks and low toughness in the heat affected zone.Low toughness is due to formation of coarse grain structure and martensite .Transition temperature augments gradually with increasing grain size.Because of low C in HSLA accelerated cooling is free of hydrogen crack.

Formability

Formability is an important criteria to understand the deep drawing behaviour of materials for various application such as in automobiles , containers etc. Without subjecting the materials to actual pressing the degree to which a material can be deformed without localised thinning can be determined from the formability limit diagram by determining the maximum limit that a steel sheet can deform before the onset of localised thinning at different strain rates. Fig.5 shows tha FLD of low C mild steel and 2 HSLA steels with YS of 345 and 500 Mpa respectively for 2.5 mm thickness.

Corrosion Behaviour of HSLA:

Various forms of corrosion such as rusting - arising out of iron oxide from oxidation of iron,pitting - which is non uniform and highly localised resulting in deep pits, couple corrosion - when there is contact of dissimilar metals ,stress corrosion cracking - which is also licalised and arises out of stress factors ,crevice corrosion - which occurs when moisture and contaminants are retained in crevices are well known. It is also known that the nature and severity of corrosion varies from rural - where agricultural chemicals ,oxygen and carbondioxide atmosphere are prevalent to Industrial - where sulphur dioxide and moisture effects are more to Marine - where sodium chloride is present to indoor - where the atmosphere is not as aggressive but still the airconditioning and other atmospheric control devices could cause problems of corrosion. Corrosion prevention methods like protective coating,hot dip galvanising or zinc metallising, cathodic protection etc are applicable to HSLA.

Whilst many application areas of HSLA do not need any protective coating as care is taken to use judicious alloying elements to take care of corrosion , it may be pointed out that the conventional protective coating are helpful in increasing the service life. A clean surface is the primary requirement and this is achieved by sand/shot blasting (7). In is known that incorporation of upto 0.2 % copper in weathering steels improves the corrosion resistance to 4-8 times than that of the conventional plain carbon steel.On exposure to atmosphere a tightly adhering oxide coating is formed in these steels and this oxide film forms a barrier to moisture and oxygen and prevents corrosion .Fig.6 compares the corrosion resistance of plain carbon steels with copper bearing HSLA tested in industrial and marine environments to illustrate the superiority of HSLA. In order to maintain the corrosion resistance of HSLA care should be excercised in welded structures by choosing appropriate filler material to develope dense adherent coating.

Coating by paints to protect corrosion is also effective for HSLA but as in other cases the effect will depend upon the quality of coating,surface preparation and severity of environment (7). In buried gas transmission pipes and offshore structures coatings such as asphalt,coat tar or epoxy has been found to be very effective. Hot dip gavanising/zinc metallising protect HSLA due the formation of iron-zinc compounds at the interface and relatively pure zinc on the surface expose to the atmosphere as in the conventional materials.(8). Corrosion resistance has alos been improved by passing impressed current from a rectifier particularly in buried pipes where the polarity is reversed to neutralise the corrosion effect.Many structures made of HSLA are also protected by the cathodic protection by sacrificial Zn/Mg where the corrosion has been reduced to zero level. Of late elemental additons are also being used in Zn or Mg which give alloy coating with better results.

Conclusions:

HSLA steels have been commercially exploited for various engineering structures,autobodies, and offshore constructions because of their excellent properties of high strength to weight ratio., abrasion resistance, corrosion resistance.Thermomechanical processing has opened out the possibility of enhancing the properties to a very great extent .With the growth in the automobile sector and the need to reduce weight and save energy it appears that the HSLA will be the answer to engineers in the future.

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Table 1 Mechanism operating in each process and resulted microstructure and properties

Process	Mechanism operated	Microstructure and strengthening mechanism	Enhanced properties
Controlled rolling (CR)	1) α nucleation site in grain interior ; + + + 2) α nucleation rate at grain boundary ; + +	1) α grain refinement 2) α + pearlete 3) grain refinement strengthening	1) high strength 2) good toughness
Interrupted accelerated cooling (IAC)	1) supercooling : activation energy for α grain formation ; - - - 2) α nucleation site in grain interior ; + + 3) α nucleation rate ; + + +	1) further α grain refinement 2) α + low temperature transformation product 3) grain refinement strengthening and transformation strengthening	1) ΔTS : bainite ; + + martensite ; + + + 2) ΔYS : bainite ; + martensite ; - - 3) ΔFATT bainite ; + martensite ; - - 4) Properties : · low carbon equivalaent · superior weldability · high resistance to HIC and SSCC

Increase : small +, large + +
very large + + +
Decrease : small -, large - -+
very large - - -
Δ : difference between IAC steel and CR one

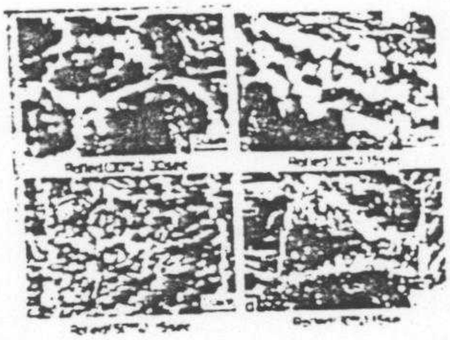

Fig.1. Optical micrographs of nucleation of ferrites during TMT processing, (a) at ferrite boundaries (b) at twin boundaries (c) inside grains (d) on deformation bands

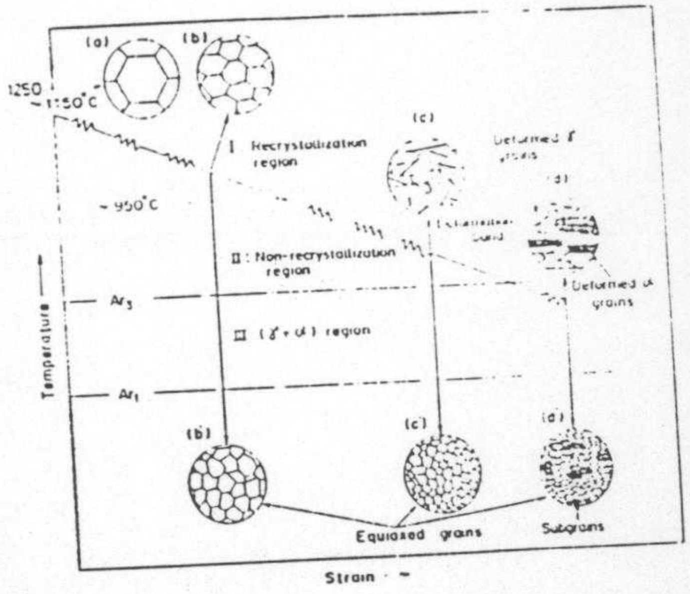

Fig.2.Schematic illustration of 3 stages of controlled rolling process and corresponding changes in microstructure (T Tanaka)

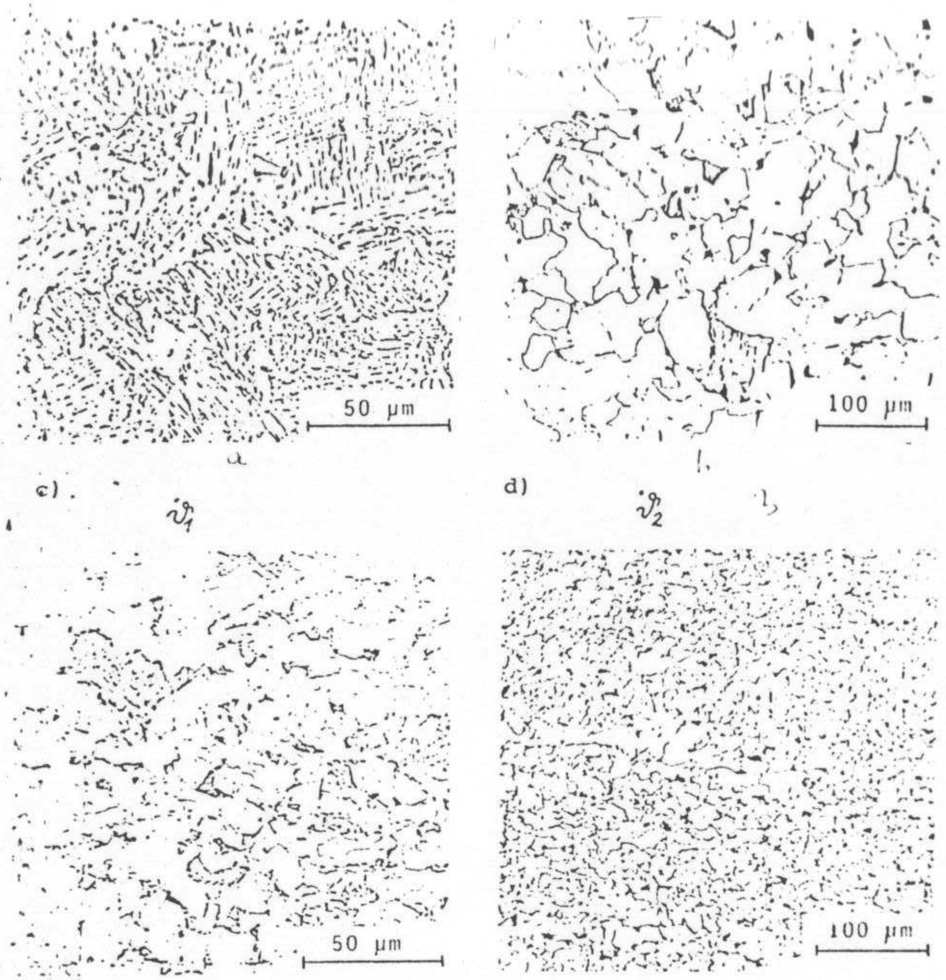

Fig.3. Effect of deformation on austenite on microstructures of Ti bearing HSLA cooled at rates of 60° /s and 12 ° /s

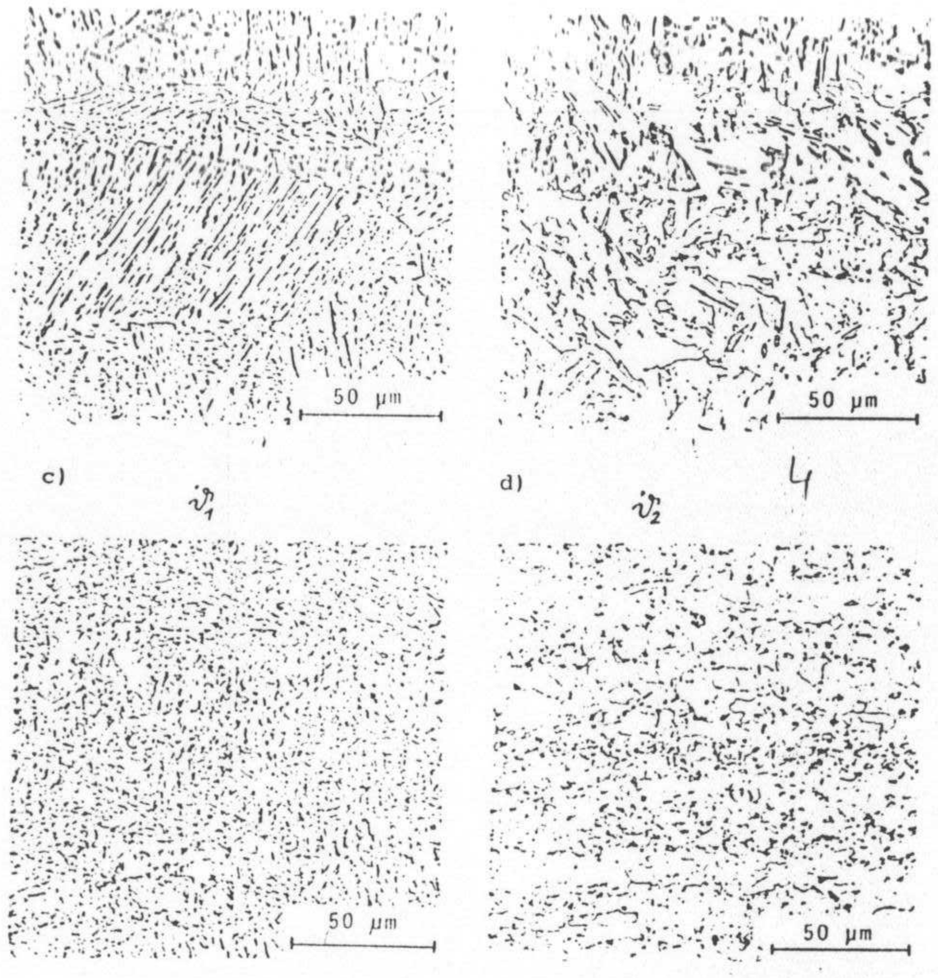

Fig.4. Effect of deformation on austenite on the microstructures of Nb-Mo bearing HSLA cooled at rates 60 ° /s and 12° /s

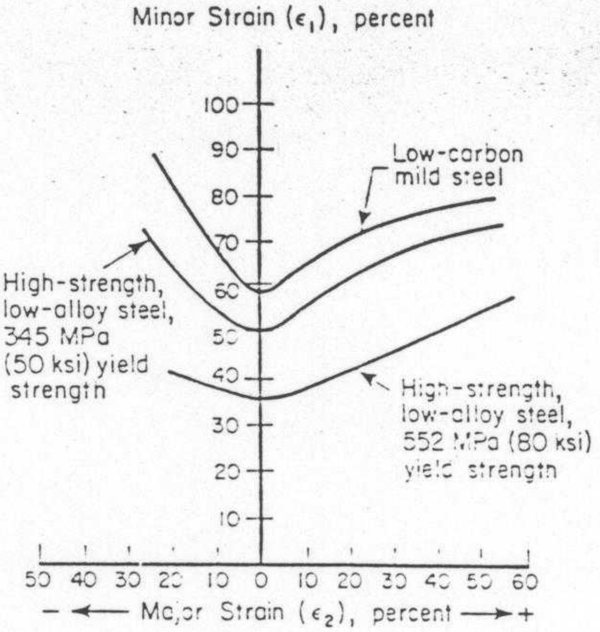

Fig.5. Forming Limit Diagram for 2.54 mm low C mild steel and HSLA steels

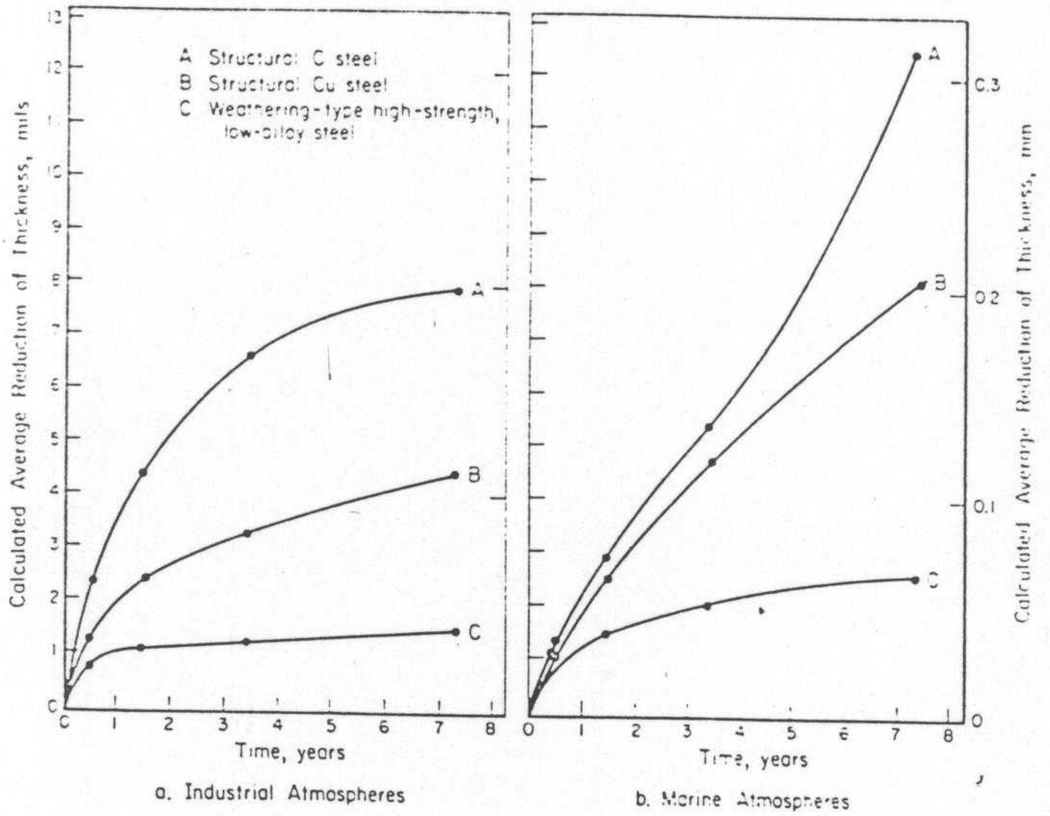

Fig.6. Time - corrosion curves for a weathering type HSLA ., A Cu bearing steel and plain C steel in industrial and marine atmospheres.