WELDING OF 17% CHROMIUM SEMI-FERRITIC HEAT AND CORROSION RESISTANT STEEL

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INTRODUCTION

Chromium has been one of the important alloying elements in steels meant for engineering applications. Its effect as a streigthening element both at the ambient and high temperature has been utilized in designing low alloy steels meant for general structural and pressure vessel/piping applications. With the addition of Molybdenum a number of popular chromium - molybdenum ferritic steels have been in use in power and petrolium Industries. Relatively Less Familiar Alloys of chromium and Iron are the ones with chromium present in excess of 13% that provides the stainless character and specific corrosion resistant character to steel. Though the austenitic varieties of chromium - Nickle Steels are very familiar for use in corrosion resisting and heat resisting applications; They are susceptible to stress corrosion cracking due to chlorine and sulphur. For such applications the recent trend is to use ferritic and semi ferritic stainless steels which are straight chrome types.

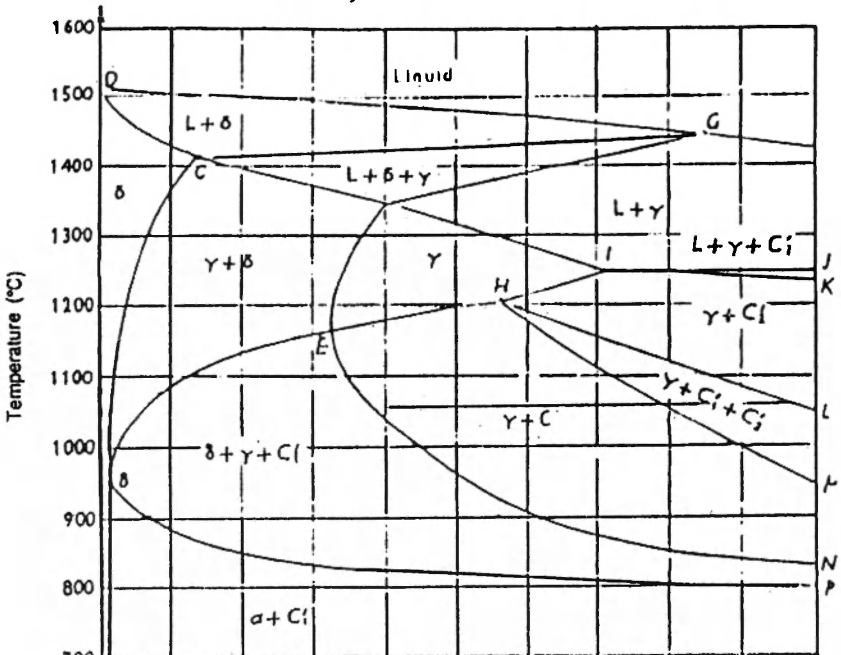
Generally, straight Chromium Steels are less used for fabrication as they are considered comparatively more difficult to handle. These steels demand special understanding to solve asociated problems. This article discusses a few aspects of welding metallurgy and safe practices associated with straight chromium semi-ferritic steels.

General Metallurgy

Straight Chromium Steel can exist either as fully ferritic steel or as semi-ferritic steel and as martensitic steel depending upon the chemical composition and heat treatment condition. These can be generally termed as stainless and heat resisting steels because of their areas of applications.

Stainless and Heat-resisting semi-ferritic steels are Iron chromium based alloys with a composition which on cooling passes through a temperature range where their microstructure is composed of a mixture of Delta-ferrite and Austenite. The Austenite subsequently would transform to Martensite on rapid cooling while the Delta-ferrite would remain untransformed. This mixed structure could be obtained with various combinations of chromium and carbon contents taking into account the usual presence of minor Alloying elements. To obtain a Semi-ferritic steel it is necessary to relate the carbon content to a minimum proportion of chromium content, this proportion being higher as the carbon content increases.

The most common of the semi-ferritic steels in practice are the 17% chromium grades containing 16% to 18% of chromium and 0.05 to 0.12% carbon compared to the conventional 13% chromium martensitic steels. They have better corrosion resistance & are only moderately hardening on quenching. As a result of their structure and lower carbon content they are quite amenable to deep drawing and cold forming. To this category 13% chromium steel with carbon content restricted to 0.07% maximum can also be included.



Vertical section at 17% chromium of the phase diagram of an industry Fe-Cr-C alloy (Ni < 0.13%N < 0.13% Si ~ 0.4% Mn ~ 0.5%)

Fig. 1 shows the vertical section of the equilibrium diagram for the commercial quality 17% chromium alloy steel containing the commonly used minor alloying elements with the carbon contents normally used. The alloy solidifies as Delta-ferrite, then enters the temperature range over which Austenite starts appearing and subsequently enters temperature range over which chromium and iron carbides are formed. When the cooling rate is sufficiently slow the austenite changes into alpha-ferrite so that below 850 - 900°C the alloy is composed of delta and alpha ferrite and carbides. But with rapid cooling, the austenite is transformed to martensite and therefore the alloy would consist of Alpha ferrite, martensite and carbides.

When the steels are heated to a sufficiently high temperature where the microstructure would be turned to a fully ferritic phase (i.e. above 1350°C approxmately) they suffer rapid grain growth. Austenite would no doubt form in increasing amounts on cooling down to approximately 1100°C but it would be formed from delta-ferrite and it will tum into alpha ferrite and disappear. This mechanisim would modify the grain boundaries of the ferrite structure as a whole.

Therefore the structure formed at very high temperatures, especially the coarse grain sizes, cannot be removed by a grain refining heat treatment as is normally possible by the alpha- gamma transformation in low alloy steel.

Difficulties in fabrication

In relation to the fabrication of semi-ferritic stainless steels the following can be cited as the main problems :-

- The weld metal and heat affected zones are prone to cracking
- Embrittlement of heat affected zones make it difficult to obtain statisfactory bend performance.

It has been observed that welds in 17% chromium steel may suffer from cracking as a result of the formation of martensite. A number of techniques have been derived to minimize or avoid this problem. One of the methods is to add certain quantity of ferrite formers to the base material so that it will remain as ferrite at all temperatures ; thus avoiding the formation of austenite which could transform to martensite during cooling. One example is to add titanium (About 0.7%) or niobium (about 1.2%) to the initial composition. But unfortunately these steels have an excessive tendency for grain growth to occur in the HAZ immediately adjacent to the weld bead and the cracking tendency persists as a result of concentration of inpurities at the decreased grain boundary surface areas.

It is now believed that the above mentioned problem could be tackled by Associating small amount of other elements with the addition of titanium or Niobuim, so that the dispersion of phases would be effected to oppose to grain coarsening tendency. In the case of titanium additions, aluminium could be simultaneously added causing the formation of Ti02, Tin, AL203, AL N etc. 17% Cr- Nb-Tl-Al combination has been successfully employed for welding consuambles for SAW & SMAW processes. Though sound welds can be produced through this Route, one must still recognize that it will still be liable to hot cracking and delayed cracking due to the effect of defusible hydrogen.

Another method to avoid the problems due to the formation of martensite is to modify the composition of the 17% chromium steel in such a way that the austenetic formed at the elevated temperatures in these semi-ferretic stainless steels would be sufficiently stable to resist conversion to martensite when cooled to ambient temperatures. Such a stability of austenite can be achieved, for example, by adding about 5% manganese and about 1% silicon alongwith various other minor additions. Such a steel, after welding, will exhibit a HAZ and weld-bead microstructure which is a mixture of austenite and ferrite and thus would not get embrittled.

In addition, under conditions which can introduce hydrogen during welding, like from the residual moisture in the fluxes or presence of organic compound at the weld zone etc, atomic hydrogen can enter into the weld metal and cause cracking at the HAZ. For this reason, it is considered necessary to reduce the diffusible hydrogen by preheating or pre-drying the electrodes. If such a pick of hydrogen by the weld a suspected it is advisible to carry out post weld tempering treatment to drive the diffusible hydrogen out and simultaneously improving the ductility of the metal. The temperature and duration of the tempering treatment should be decided based upon the final properties desired of the component. Considerations are to be given to the fact that 17% chromium steel has a very low rate of hydrogen diffusion and liable to suffer delayed caracking with a long incubation period, as compared to other structural steels.

In the heat affected zone failures could often be noticed in bend tests which may be carried out as a part of quality assurance procedures. These have been traced to the presence of coarse ferrite grain and perhaps also to some amount of martensite in a region lying close to the fusion zone. The most remarkable embrittlement was found where the temperature was in the viscinity of 1350° C with the percentage elongation dropping from 33% to about 4 to 5% in SAW welds and to about 7 to 8% in SMAW welds. The Lost ductility can be recovered substantially (Greater than 18%) by giving a post weld heat treatment. The parameters of which would depend upon the heat treatment of the welding process involved. A post heating at 350°C for SMAW and at 625°C for SAW for one hour are considered reasonable starting point for conducting procedure qualification trials to obtain satisfactory results. Post heating at Lower temperatures are not to be used for SMAW welds as danger to loss of ductility exists.

Use of austenitic stainless steel weld-metal is also a standard practice which avoids the problems associated with the weld metal. But the HAZ would still retain its notch sensitivity. However the properties of the joint as a whole would be improved because the low toughness is restricted to a narrow region and the high capacity for plastic deformation of the weld-metal reduces the effect of this narrow region substantially.

Welding Processes

As already mentioned the welding processes employed for fabrication would have a bearing on the mechanical properties achieved in 17% chromium stainless steel weldmentrs, because the welding process determines the width of the base metal region heated to the fully austenitic region where rapid grain growth takes place. It also influences the cooling rate and hence affects the time period during which grain coarsening can occur and the extent of austenite formed in the HAZ and the weld.

Based upon the above criteria SMAW process should be considered preferably to spray MIG or SAW process because SMAW permits the use of lower heat input for the same amount of weld deposit. On the same logic short circuiting MIG. Pulsed and Synergic MIG and to a lesser extent pulsed GTAW with filler metal addition are also advantageous.

When gas shielded welding processes are employed, it is advisible to use pure argon for GTAW and argon - 1% Oxygen mixture for MIG welding. The presence of Nitrogen in the welding are atmosphere either from the gas mixture or through ingress of Air from ambient atmosphere must be avoided because of its ability to increase the amount of martensite in the weld. Sometimes peening of the beads in multipass welds is done in order to introduce cold work in the metal and induce fine recrystalisation during the deposition of subsequent runs. But this technique has met with only limited success and is not persued as a standard practice.

CONCLUSIONS

Thus we find that even though fabrication of semi-ferritic 17% chromium stainless steels do pose problems with regard to the achievability of mechanical properties and cracking, it is possible to surmount these problems by employing proper procedures and heat treatments as described in this paper. Sound welds of 17% chromium steels can be obtained with high enough toughness at room temperature for most practical purposes. However their notch sensitivity must be recognised and carefully tackled in order to employ them in these critical areas where notch toughness is important criteria. However in non-impact loading areas 17% chromium stainless steel can be confidently used in welded form.

CALENDER OF BRANCH EVENTS FOR THE YEAR 1993-94

BOMBAY BRANCH

1. **TECHNICAL MEETS**
   i) "Quality Assurance & ISO 9000" with Video Film by Mr. Vincent A.D'Souza, Technical Consultant to Messrs. Davy Power Gas - September 1993
   ii) "Microstructure & Mechanical Properties" by Dr. Sivaramkrishnan of Elca Laboratories. October 1993.
   iii) "Failure Analysis-Sone case Studies" by Dr. Balasubramanian of Inter Tech Consultants - November 1993.
2. **REFRESHER COURSES**
   i) Pressure Vessel Design at Baroda during October '93 (2 days)
   ii) Bombay in December 1993 and Pune in March 1994.
3. **WORKSHOPS**
   i) One day Workshop on "Maintenance Welding" in Bombay Jan. 1994
   ii) "Inspection & Testing (Destructive & NDT) Bombay in Nov. 1993
   iii) Workshop on Welding of Austenitic Stainless Steel In Pune in December 1993.
4. **ANNUAL WELDING SEMINAR - 'AWS 94'.**

On 12. 2. 1994 at Bombay. Theme "WELDING FOR TODAY & TOMORROW".

COCHIN BRANCH

8th & 9th October '93	-	Refresher Course for Welding Engineers & Supervisors.
12th Nov '93	-	Technical meeting
7th Jan '94	-	-do-
11th March '94	-	do
26th March '94	-	Industrial Visit.