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TEMPER EMBRITTLEMENT

WHAT A WELDING ENGINEER NEEDS TO KNOW?

What is it?

Temper embrittlement refers to the decrease in toughness of alloy steels when heated in or cooled slowly through, a temperature range of 400°C to 600°C. Temper embrittlement can also occur as a result of isothermal exposure to this temperature range.

What is its effect?

Although the loss of toughness is not evident at operating temperature, equipment that is temper embrittled may be susceptible to brittle fracture during start-up and shutdown.

What are the different types?

There are two types of temper embrittlement that happen in steels.

- Tempered Martensite Embrittlement
  - Occurs during low temperature tempering (230°C-290°C)
  - Also called as “Blue Brittleness”
  - TME is irreversible and its effects are permanent
- Tempered Embrittlement
  - Occurs during medium/high temperature tempering (350°C-560°C)

- Effects of TE can be reversed. This is done by re-tempering above the initial temperature of $560^{o}C$ and then cooling rapidly. Impact toughness can be restored.

What factors affect this?

- **Chemical composition:**
  - Susceptibility to temper embrittlement is largely determined by the presence of the alloying elements manganese and silicon, and the tramp elements phosphorus, tin, antimony, and arsenic.
  - In order to assess susceptibility to temper embrittlement in Cr-Mo steels, two compositional parameters are commonly employed, the Watanabe J factor and the Bruscato X factor.
    - J = (Mn + Si)(P + Sn) x104 (in wt %), has been applied to parent steels and weld metals.
    - X = (10P + 5Sb + 4Sn + As)/100 (in ppm), is applied to weld metals
  - If J is less than or equal to 180, or if X is less than 20, the risk of temper embrittlement is considered to be low for base plates. For the welds J < 100 and X < 15 are advised. A limit in this form can be specified for procurement, where concerns over temper embrittlement exist.
- **Temperature & Holding Time:**
  - The diffusion rate of trace elements strongly depends on both time and temperature.
  - The higher the temperature and the longer the time of diffusion, the more can be the amounts of brittle phase precipitates within the boundaries, hence the more is expected to be the amount of embrittlement of the alloy.
- **Applied stress:**
  - The application of tensile stress causes an increase in the embrittlement of the steel, but its effect is much less than other parameters mentioned earlier.

- Temper embrittlement of 2.25Cr-1Mo steels develops more quickly at 482 deg C than in the 427 deg C to 440 deg C range, but the damage is more severe after long-term exposure at 427 deg C to 440 deg C.

- Some embrittlement can occur during fabrication heat treatments, but most of the damage occurs over many years of service in the embrittling temperature range.

What is the mechanism of embrittlement?

Two mechanisms are suggested.

- The gradual migration of impurity elements such as P, Sn, As, and Sb to grain boundaries and formation of brittle phase in there, causes brittleness. These phases are usually very small.
- Changes in size and morphology of carbides in a long time, causes brittleness of the alloys.

Which steels are affected?

- Plain Carbon Steel
- Cr-Mo Steel
- Cr-Ni Steel

- Primarily 2.25Cr-1Mo low alloy steel, 3Cr-1Mo (to a lesser extent), and the high-strength low alloy Cr-Mo-V rotor steels.

- Some high strength low alloy steels are also susceptible.

- The C-0.5Mo and 1.25Cr-0.5Mo alloy steels are not significantly affected by temper embrittlement. However, other high temperature damage mechanisms promote metallurgical changes that can alter the toughness or high temperature ductility of these materials.

Cr-Mo Steels

Cr-Mo & Cr-Ni steels are more susceptible than other materials. Cr-Mo steels are mainly used in boilers with different service conditions which are tabulated as below.

TYPE OF BOILER	SERVICE CONDITION
Sub Critical	565°c max/165 bar max
Super Critical (SCB)	565-585°C / 248 bar max
Ultra Super Critical (USCB)	593-621°C/ 248 bar min
Advanced Ultra Super Critical (A-USCB)	675-710°C/ around 300 bar

Nowadays super critical boilers are widely used and USCB/AUSCB is under development conditions. These boilers are operated minimum of 100000hrs service

Service Clinics
During the Month of May 2012

- M/S KERLA AUTOMOBILES LTD TRIVENDRUM - KOCHI AREA - 12 Machines
- M/S PEEKAY STEELS & CASTINGS PVT.LTD CALICUT - KOCHI AREA - 11 Machines
- M/S GOVERNMENT ITI.CALICUT- KOCHI AREA - 18 Machines
- M/S SREERAMA SCAFFOLD SYSTEMS PALLAKAD- KOCHI AREA - 06 Machines
- M/S SEPR REFRACTORIES (I) LTD PALLAKAD.- KOCHI AREA - 05 Machines
- M/S B.G.SHIRKE PVT.LTD.MUNDHWA –PUNE AREA - 22 Machines

Ador Welding Academy (AWA)

(known as Creep Property) at a particular temperature & load. When the material is subjected to prolonged time service, due to the presence of higher amount of trace elements in Cr-Mo steels, temper embrittlement occur at this tempering temperature. So creep resistance of this material reduced due to embrittlement. The same applies to areas like reactors, exchangers & hydro processing units which are used in high temperature applications.

How do we evaluate the susceptibility to Temper Embrittlement?

There are two methods

- Isothermal Ageing Technique
- Step Cooling Treatment

Isothermal Ageing is the process in which specimen are subjected to prolonged period in constant temperature. The time of exposure is about 100000hrs of Isothermal Ageing.

In Step Cooling method, the time required is approximately 233hrs only.

The typical critical step cooling cycle is shown in Figure 1. The specimen is subjected to Stress relieving (SR) & Stress relieving + Step Cooling (SR+SC) treatment. After carrying out SR & SR+SC, all the samples are subjected to Charpy V Notch Impact Test. The impact test is carried out in different sub zero temperatures and charpy curve (Figure 2) is generated between Absorbed Energy in Joules VS Test Temperature in °C for the condition - SR and SR+SC.

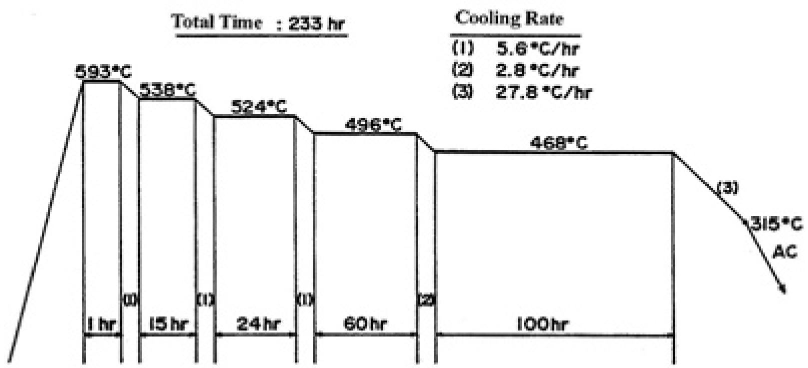

Figure 1

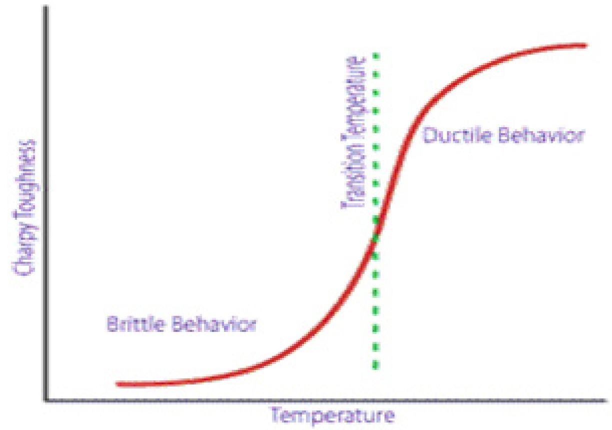

Figure 2

The transition temperature for SR & SR+SC is generated from charpy curve. The difference in this temperature between the step cooled & non-step cooled specimen at a particular energy value is used to derive acceptance criteria for a particular application. The following formula is used by various authors to establish acceptance criteria.

CvTr54 +2.5 < 10°C

Where,

CvTr54 - The charpy V notch 54J impact energy transition temperature of completely heat treated specimen without step cooling

- The shift in charpy V notch 54J impact energy transition temperature of completely heat treated specimen after step cooling

The loss of toughness is not evident at operating temperature; equipment that is temper embrittled may be susceptible to brittle fracture during start-up and shutdown.

Which units / equipments get affected by this problem?

- Chrome Moly steels used in thermal power generating plants as well as in the petroleum industry are most susceptible to this phenomenon.

- Temper embrittlement is most often found in hydro processing units, particularly reactors and hot feed/effluent exchanger components after long term exposure to temperatures above 343 deg C.
- Other units with the potential for temper embrittlement include catalytic reforming units (reactors and exchangers).
- Boilers
- Welds are often more susceptible than the base metal.

How do we eliminate/ minimize temper embrittlement during welding?

- The trace elements like Sn, Ar, Sb and P should be low in the plate as well as weld. Si & Mn need to be kept to lower levels. Please refer to the allowed J & X factor levels for plates and welds.
- If weld repairs are required, the effects of temper embrittlement can be temporarily reversed (de-embrittled) by heating at 620°C for 2 hours per inch of thickness, and rapidly cooling to room temperature. It is important to note that re-embrittlement will occur over time if the material is re-exposed to the embrittling temperature range.

Please contact **Central Marketing** for guidance in welding of steels susceptible to temper embrittlement as well as suitable consumables.

For more information, Please write to us cmo@adorians.com or visit www.adorwelding.com

Welding Consumables

Welding & Cutting Equipment

Welding Automation

Project Engineering