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Research Paper

HEAT TREATMENT AND THE IMPROVEMENT OF STEEL SPECIFICATIONS AND ITS ALLOYS

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Improvement of steel specifications and its alloys defined as any heat treatment after welding is often used to improve the properties of a welding. In concept, improvement of steel specifications and its alloys can encompass many different potential treatments. Improvement of steel specifications and its alloys can be used to reduce residual stresses, as a method of hardness control, or even to enhance material strength. If Improvement of steel specifications and its alloys is performed incorrectly, or neglected altogether, residual stresses can combine with load stresses to exceed a material's design limitations. This can lead to weld failures, higher cracking potential, and increased susceptibility to brittle fracture.

Keywords: Steel specifications, Residual stress, Hardness control, Weld failures

HEAT TREATMENT

During heat treatment. A material or work piece is subjected to temperature changes in order to create appropriate processing and utilization characteristics via structural changes. A distinction is made between different heat-treatment methods:

- Stress-relief annealing
- Soft annealing
- Normalizing
- Coarse grain annealing
- Hardening
- Quenching and tempering

STRESS RELIEF ANNEALING

Stress-relief annealing serves to reduce stresses caused by uneven cooling or by welding, heat treatment are relieved by means of creeping, in fact up to the yield strength of the material, which is reduced due to the temperature. Complete stress relief (i.e., stress-free annealing) is not possible because the yield strength cannot be lowered to zero.

SOFT ANNEALING

Without altering the iron carbon ratio, soft annealing should make a steel suitable for subsequent shaping. In an unalloyed structural steel, perlite is the harder structural proportion,

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which is to be converted to a softer form by means of soft annealing. Therefore, the heat treatment must be carried out in the region of the A_1 line. For this purpose:

- A pearlite can be dissolved by annealing it for 2-3 h at temperatures of 10-20 °C below A1. The pearlite consisting of cementite and ferrite lamellae changes its structure to such an extent that the cementite lamellae are formed into spherical structures. Indeed every substance endeavors to take on a spherical shape since this has the smallest surface;
- The cementite can be formed by means of cyclic annealing (20 °C) around A1. This case, the cementite lamellae are strained and clenched constantly unit they begin to tear. These shorter frag-mints are formed more easily and rapidly. Therefore, this type of soft annealing proceeds more quickly.

Spherical cementite proportions can shift better in the ferrite matrix, thus improving the plastic ductility.

Normalizing

The objective of normalizing is to achieve a fine-grained structure, which, with the same strength, has higher toughness than the coarser grains. Locally, coarser grains lead to greater stresses at the gain boundaries and restrict the ductility. Finer grains can distribute stresses in the structure by deforming many smaller regions. Fine- grained steel therefore has greater ductility.

In steel, coarse grains may occur in the ferrite and in the pearlite.

In order to influence the grain size, the heating process must be carried out higher than the A3 line so that the entire structure can form again during the repeated cooling.

For normalizing, the A3 line must be exceeded by approx... 30 °C. It is possible to achieve a more fine-grained austenite structure solely be means of rapid heating. Indeed, if the heating rate is higher than the austenite-nucleation rate the majority of these nuclei only occur at temperatures which are just below the A3 line (in the case of slow heating, nuclei which develop into an overall structure arise gradually beginning from A1; this process is suppressed by means of rapid heating). Because of the large number of nuclei, the many crystals forming do not have any space to develop into larger grains. Since they hinder each other, this results in fine-grained austenite. If the cooling process is also quicker than the rate at which ferrite grains can grow, the grains in the structure become even smaller. After the cooling process, which is genre-ally, carried out in air in the case of steels, there is then a doubly refined grain.

HARDENING

By means of hardening. The steel should be given high resistance to wear and to compressive stresses. In many cases, the hardening effect occurs unintentionally during welding. Temperatures approx. 30 °C above A3 are assumed for the hardening process. Austenite is thus present. If the cooling rate is increased (e.g., by means of cooling in oil), the step-by-step mechanism of gradual temperature-dependent ferrite precipitation is suppressed. this results exclusively in pearlite with an average carbon content corresponding to that of the original overall structure (not 0.8% as otherwise customary) since the alternate formation of ferrite and cementite lamellae must take place in an accelerated process. The more frequent alternation leads to more and finer lamellae.

Because cementite (the harder proportion of the pearlite) occurs more often, the steel is harder although the average proportion of the carbon content in the pearlite is lower than 0.8% with regard to a normally formed pearlite, a value between those for the hardness of the cementite and ferrite lamellae is determined when the tip of a hardness testing device is pressed in. In the case of pearlite which forms more rapidly and therefore has fine streaks as well, the tip of the hardness testing device basically rests on the cementite lamellae and therefore indicates higher hardness values.

This process which can be achieved just by cooling the steel in oil can lead to direct quenching by means of water cooling. In this case, the temperature decreases more quickly than ferrite and pearlite can form from the austenite. Because the carbon is not given any time to shift into the lattice of the residual austenite, it remains locked in the a lattice which wants to from. The lattice and structural shape produced is marten site which is shown as a whisker in the micrograph. Because the hardness depends on the number of locked-in carbon atoms, marten site is already formed at a lower critical cooling rate as the carbon content increases. The critical cooling rate designates the cooling rate at which marten site forms for the first time. A high carbon content and/ or a high cooling rate result in a large number of carbon atoms locked in the lattice and lead to an increase in hardness. By means of prior normalizing, a finer marten site structure with smaller and shorter whiskers is produced instead of a coarser marten site structure, thus once again resulting in a slight improvement in the mechanical laudability of the steel. It makes sense to harden stills with a carbon content as from 0.4%.

QUENCHING AND TEMPERING

Hardening and subsequent tempering is designated with the term quenching and tempering. By means of tempering below A1 after

Figure 1: Normalizing and Hardening

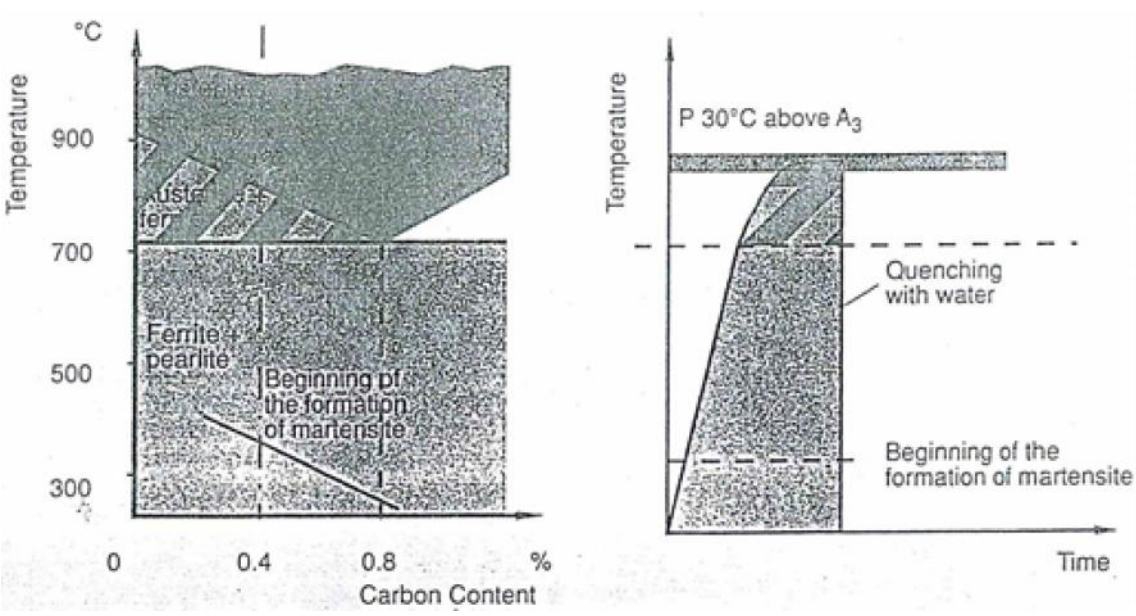
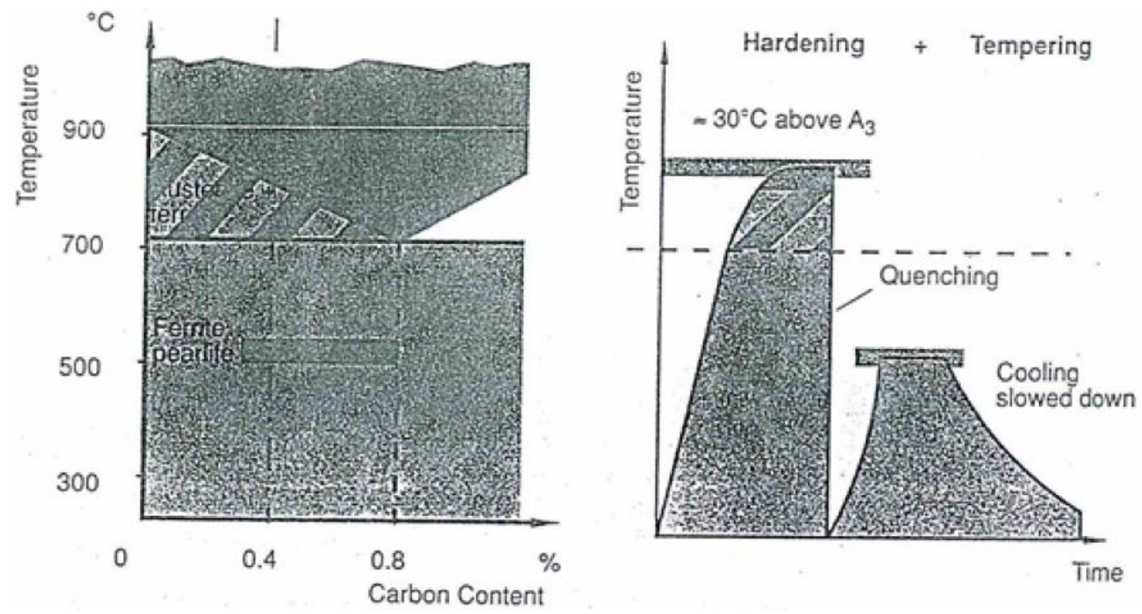


Figure 2: Quenching and Tempering



the hardening process, it is possible to increase the ductility of the structure to the same extent as its hardness decreases. Bothe characteristics are directly coupled with each other and are directly dependent on the temperature.

In comparison with steel which is only hardened. Quenched-and-tempered steel has one fundamental advantage: quenching and tempering produce a steel with high hardness. Tensile strength and yield strength as well as good toughness. One prerequisite for quenching and tempering is hardening as shown on the figure. Normalizing can also be carried out beforehand. After the hardening process. The steel is reheated to temperatures below A1 because the hardness structure would otherwise disintegrate totally or partially once again due to the formation of austenite grains. This process is called tempering. In the case of welding in several passes, the passes welded previously are partially tempered by the welding of the next pass:

The lower the tempering temperatures is, the more the hardness and thus the reduced toughness are retained. The tempering gives rise to the temperature – induced enlargement of the marten site lattice. Some of the carbon atoms which can move more easily as a result of this diffuse out of the marten site lattice, form iron carbides and are added on to the previous marten site. An acicular structure is formed which has a similar shape to that of the marten site whiskers but is softer.

COARSE – GRAIN ANNEALING

In contrast with normalizing, the objective of coarse-grain annealing is to produce coarse grains. During welding, the undesirable effect occurs inevitably as overheating and may lead to extreme embrittlement. If the heat input is unnecessarily high, this overheated zone may be very large.

For coarse – grain annealing in which several grains of the structure grow together in order to form on common large grain without any grain-boundary differences, the structure must firstly be transformed into austenite. High-melting aluminum and silicon oxides (impurities) are situated at the grain boundaries. These are transported away from the grain boundaries or are formed into spherical structures. Where pure lattices are located opposite each other May harmonies their direction one common grain may thus form large number of grains coarse grains may to convert into fine grains by means of normalizing, i.e., by crossing the A3 line in the upward direction once again.

RECRYSTALLIZATION ANNEALING

The heating does not exceed 723 °C; usually. This does not result in any changes in the structure or in the material properties. Two exceptions are important for practice:

1. At temperatures between 500 °C and 700 °C, a cold-formed structure undergoes a change in the grain size. This process is called recrystallization. Cold forming of approx. 5-15% (critical degree of deformation) results in a coarse-grained structure exhibiting low toughness. Attention must be paid to this when cold-formed steels are welded. The welding heat may cause the cold-formed regions to become so coarse-grained that there is a risk of brittle fracture. The conditions for the welding of cold-formed steels are therefore stipulated in standards and technical guidelines.
2. At temperatures of 200-400 °C (blue temper heat), "artificial ageing" may occur. The prerequisites for this are a cold-formed structure and a minimum concentration of nitrogen in the steel. The ageing leads to an extreme drop in toughness.

INTRODUCTION

During the fabrication process, welding is the most commonly used method of joining items together. The welding process involves melting

Figure 3: Coarse Grain Annealing

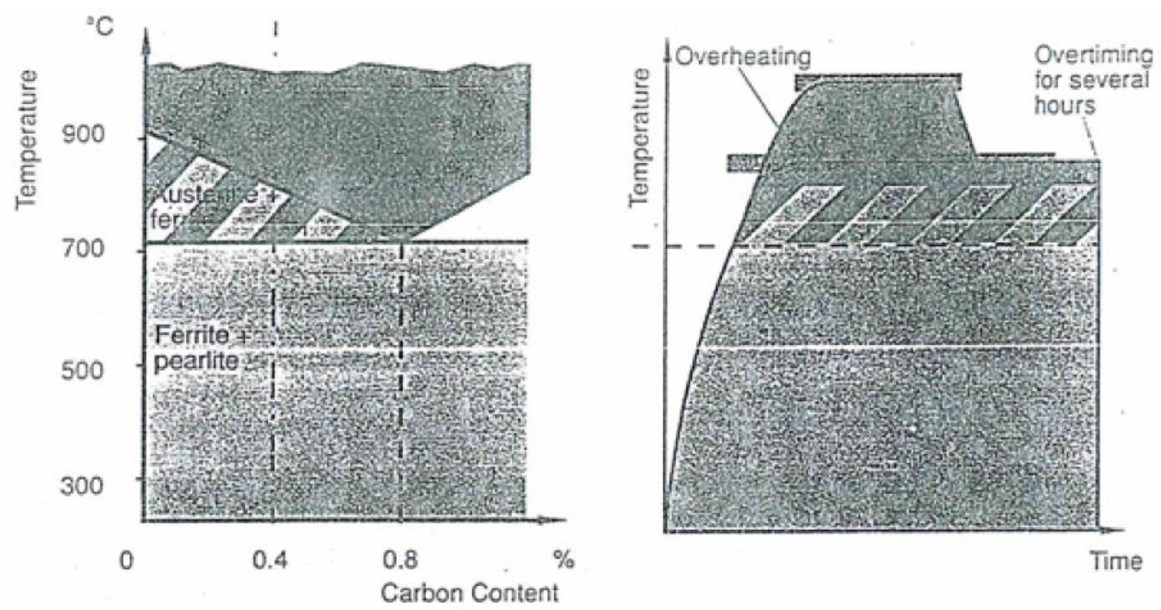
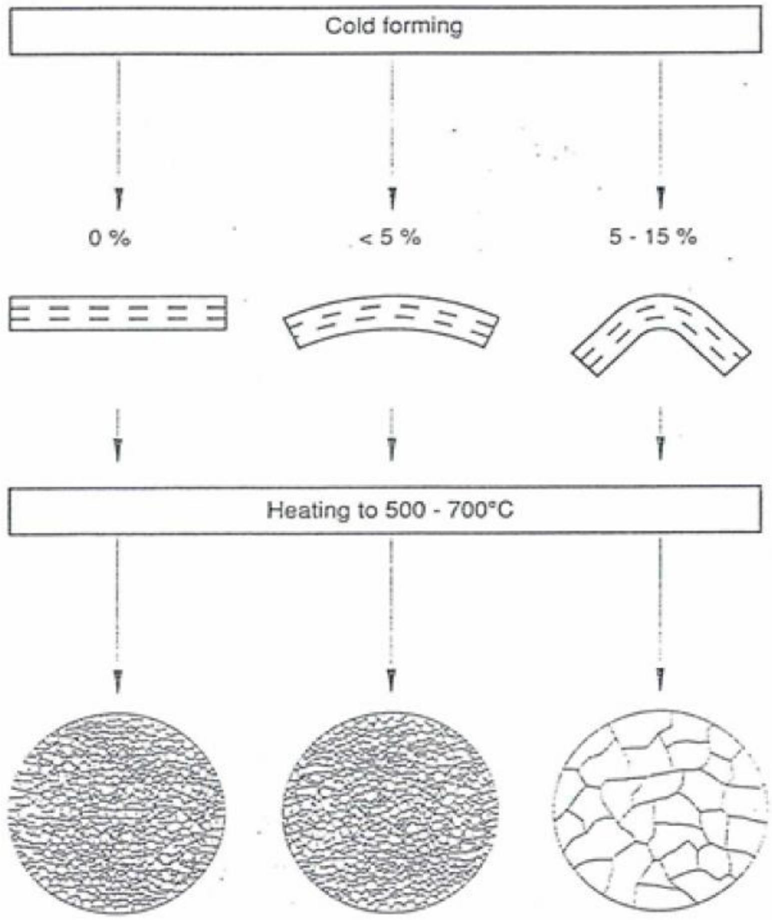


Figure 4: Percentage of Carbon



and cooling, and the result of this thermal cycle is distortion if the welded item is free to move or residual stress if the item is securely held. There comes a point when the amount of residual stress can create potential problems, Improvement of steel specifications and its alloys the most widely used form of stress relieving on completion of fabrication of welded structures.

Scope

Improvement of steel specifications and its alloys refers to the process of reheating a weld to below the lower transformation temperature at a controlled rate, holding for a specific time and cooling at a controlled rate.

No consideration has been given to normalizing of welds in carbon-manganese and low alloy steels, to solution annealing of stainless steels or to any precipitation hardening treatments to other alloy materials.

The development of stresses approaching, even exceeding, or even exceeding the yield stress is possible when welding thick sections.

Improvement of Steel Specifications and its Alloys Conditions

Each specimen for mechanical properties evaluation was subjected to Improvement of steel specifications and its alloys. For weld metal A, the PWHTs were conducted fat five temperatures.

Mechanical Properties Evaluation of Weld Metal

The mechanical properties evaluated were tensile strength, chirpy impact absorbed energy at 20 °C and the creep rupture time at 600 °C (applied stress: 108 MPa and 147 MPa).

TEMPERING EFFECT

Improvement of steel specifications and its alloys will generally result in a modification of the microstructure of both the weld metal and heat affected zone. With the exception of the 9 Cr1 Mo and 12 Cr1 MOV materials, the microstructure of all other materials should contain a mixture of ferrite and iron or alloy carbide. The effect of short-term (1 to 2 hours) heat treatment on the carbide is generally beneficial, whereas longer times result in a reduction in toughness due to spheroid sing effects.

Creep Properties and its Effects

For creep resisting material, Improvement of steel specifications. In addition, its alloys is required in order to fully develop the creep strength. This is especially true for thicker components such as headers. There has been a tendency in recent years to allow waiving of the post weld heat treatment stage for thinner materials used typically for superheated and reheated coils in the power generation industry, but a variety of conditions have to be met.

BENEFITS

Improvement of Steel Specifications and its Alloys

1. Softening the area heat affected zone and Tus improving the material toughness.
2. Improve ductility of the materials.
3. Reducing the effects and its cold work.
4. Improving the resistance to stress corrosion cracking.
5. Improving the diffusion of H2 out of welding metal.
6. Improving during machining dimensional stability.

Heating/Cooling Rates v

These are specified in most of the construction standards, and are reasonably similar. As 4458 for carbon manganese steal vessels limits heating and cooling rates to 200 °C/hour for thicknesses up to 25 mm, and 5000 °C hour divided by the thickness. For vessels over 25 mm there is also a minimum limit of 50 °C hour for very thick vessels. However, for ½ Cr ½ Mo ¼ V and 2¼ Cr1 Mo alloys, the heating rate is limited to half that of carbon manganese steels. For comparison, EN 13445 allows 220 °C/hour up to 25 mm thick, 5500/thickness for 25 to 100 mm and 55 °C/hour above 100mm thick. There are no restrictions on the alloy steels in EN 13445.

Omission of Process of Heat Treatment

There are situations where pressure equipment requires work to be done due to the service environment, and such work often involves welding typical situations include:

- Repairs due to mechanical of parts damage.
- Repairs cracking.
- Repairs creep damage.
- Repairs to service-propagated defects.
- Repairs due to original manufacturing defects.
- Advantage of the economic productions.
- Modifications due to changes in raw material feed.

Welding Suitability of Steel

Influences on the Weldability

The weldability is a characteristic of the material. A material is weld able if it is possible to manufacture welded joints with certain material properties. The weldability of a steal is depended on:

- Chemical composition (content of companion elements – content of alloying elements).
- Metal-manufacture and heat treatment method (manufacture method-deoxidation method – heat treatment).
- Physical properties (melting temperature – thermal conductivity – strength-ductility and toughness).

Structure of Welded Joint

The heating and cooling result in structural changes in welding joint. The structural formation in the weld and in the heat – affected zone is dependent on the temperature level, cooling rate and chemical composition.

Welding with Slow Cooling

Not only the temperature course across a weld joint on steel with 0.22 carbon but also the relationship with the iron-carbon diagram, the structural changes in area in the work piece.

- In weld pool (this area with temperatures above the liquid line melted completely during welding. The chemical composition of the weld pool is not easy to predetermine. It result from molten parent metal deposited filler metal and the burning-off or burning-out of element due to the welding heat, during cooling, the weld pool solidified into cast structure).
- In fusion line (temperature between the liquids and solids line occur in this area and crystals and molten mass are present. The residual molten mass proportion is richer in alloying elements).
- In overheated structure (the heating extends well in 911 c. This leads to a coarse – grained structure in most cases with somewhat higher hardness and lower ductility than parent metal marten site may arise here because of the higher cooling rate).
- In normalized structure (this area is heated just above for short time only in this result in structural transformation which is comparable with normalizing and leads to a fine-grained structure. The area frequently has better mechanical properties than the uninfluenced parent metal since it has finer grains).
- In partial structure transformation (at temperature below the line but above 723 °C. There is partial incomplete transformation of the pearlite into austenite and back into pearlite).

Welding with Accelerated Cooling

If the welding heat is dissipated in an accelerated process. The critical cooling rate may be reached or exceeded. The level of the hardness caused by this is dependent on the chemical compassion of the steel. The structural transformation no longer proceed according to the iron-carbon diagram. Hardening may therefore occur in weld area.

The hardening zone has the following characteristics:

- High hardening
- Very low ductility
- Low toughness
- High internal stresses
- Coarse grains in many cases

If the hardness of structural steel is well above the hardness value of 350 hv, there is risk of cracking in hardened zone.

Welding on Cold-Formed Components

If the plate is subjected to extreme cold forming, this always results in a limited region with deformation of approx... 5-15%. If this region is heated to 500-700 °C.

During a welding process, recrystallization may lead to the formation of coarse grain. There is risk of brittle fracture.

Effect of the Structural Transformation on the Weldability

The processes in the welded joint during the heating and cooling result in two important limits for the weldability of unalloyed and low-alloy steels (Impermissible hardening and hot cracking due to Sulphur).

Hardening

The risk of hot cracks resulting from high cooling rates cannot be ruled out for example welding of the root pass of a butt weld on steel with stick – electrode with diameter of 2.5 mm low heat input or in gas – shielded metal arc welding of butt welds in vertical – down position.

That is mains the cooling rates in excess of the critical cooling rate should not be expected. Dangerous hardening processes may occur the case of these steels as well.

Examples of this are:

- Arc strike very short tack – welding points.
- Welding of very thick components.
- Welding in wintry conditions, component temperature below 5 °C.

Steel with limited weldability can only be welded reliably and without any cracking if the parent metal is preheated. The preheating and heat treatment process reduces the temperature difference between the weld pool and the parent metal. The heat dissipation is thus slowed down, in such a way, the critical cooling rate is not reached and a normal structural transformation can take place in the heat-affected zone. The heat treatment temperature must be stipulated after consultation with the steelmaker and the welding supervisor taking account of all the welding condition.

The risk of hardening is influenced by not only the chemical composition but also the component thickness.

Hot Cracks

Hot cracks may arise in steel, which have a wide melting range (large distance between the liquids line and the solidus line). In unalloyed and low-alloy steed, this caused, above all, by the companion element Sulphur.

Welding of Free-Machining Steels Containing Sulphur

Free machining steel have high manganese and Sulphur contents order to achieve good free machining properties by forming manganese sulphides. In conditions which are customary in practice it is not possible to weld free machining steels without any risk of cracking.

Weldability of Creep-Resisting Steels

A steel is creep-resistant when sufficient tensile strength at higher temperature is still available. This property attainable by allowing with for example chromium and molybdenum.

Compare with weld able mild steel, creep-resisting steel have the disposable to hardness increase. In order to avoid hardness increase by welding:

- The workpiece must be preheated before tacking and welding.
- The heat treatment or preheating must be kept constant during the completely welding process.
- The rate of cooling of the workpiece after welding must be slow.

Heat Treatment and Preheating

Preheating temperature depend on:

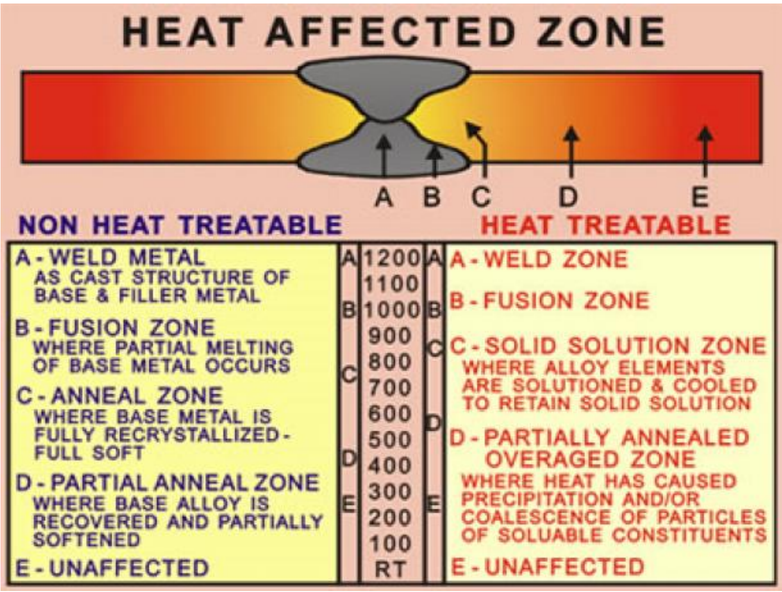
- Parent material.
- Welding procedure.
- Workpiece thickness.
- Type of weld joint type.

EXPEREMENTS FOR HEAT TREAMENTS THE WELDING PARTS

Notes

- Welding parts with hard heated should be slowly cooled to avoid cracks and bending as a result ciaos stretching for all parts.
- High speed of heating causes burns the edge of parts and oxidizing.
- To get perfect structure grains that we needs we should rise the welding parts vertical at the surface of cooling liquid with fast action.
- Cooling liquids should be clean and without slags materials.
- Heating time should be chick depending on heat treatment proses.
- Heat treatment for work piece take (20 * 20) mm takes (15) min at least.
- For hardening proses the metal should be rise the heating (30-50) degree above line (KSP) CARBON STEEL DIAGRAM to get fine grains structure.
- With fracture test for carbon steel at row materials the grains is large.

Figure 5: Experements for Heat Treaments the Welding



Parts with Heat Affected Zone

- Non-heat treatable
- Heat treatable

EXPEREMENT (1)

To Determine the Relationship Between the Temperature of Heat Tretments and the Grains Size

Type of Work Piece: C60

Experement Steps

- Prepare 5 piece with (40) mm diameter 14 mm.
- Mature with hardening (67, 5) HRC with (20 °C).
- First work piece with (200 c) and hardening (63) HRC.
- Second work piece with (260 c) and hardening (57, 5) HRC.
- Third work piece with (300 c) and hardening (56, 5) HRC.
- Fourth work piece with (360 c) and hardening (53, 5) HRC.
- Fifth work piece with welded parts (360 c) and hardening (53, 5) HRC.
- Work pieces should be stay in furnace for (200 min) thin leave to cooldown slowly.
- Record the results.

Results

- First work piece (fine grains structure).
- Second work piece (fine grains structure).
- Third work piece (big and rough grains structure).
- Fourth work piece (Medium-grains structure).
- Fifth work piece (medium grains structure).

Note

The carbon steel welded parts with hardening structure in high temperature heat treatment will be get more ductility with no healing affected zone and fine grains structure.

Results

With anneling there is less hardining, more ductility, fine grains

Good Properetіes.

EXPEREMENT (2)

To Improve the Relationship Between the Hardining and the Specific Time of Cooling

Type of Material: Carbon Steel (C60)

Size of Work Piece: Prepare 5 piece with (40) mm diameter 14 mm.

Experement Steps

- Rising temperature of furnace to (840 °C).
- Heating First work piece for (3 min) and cooling down in water.
- Heating second work piece for (8 min) and cooling down in water.
- Heating third work piece for (11 min) and cooling down in water.
- Heating fourth work piece for (15 min) and cooling down in water.
- Heating fourth work piece for (18 min) and cooling down in water.
- Every work piece with handing number (37/ 53, 6/65/65/65) HRC.
- Make fracture test for all pieces.
- Chick the grains for all piece.
- Record the results.

Note

The rote material with hardning number (30) HRC.

Results

- The hardening rise until getting at (11 min) then stay hardening number constant whatever if rise the temperature.
- The grain structure of the material will more fine until we get at (15 min) and it will be bigger grains as we rise the temperature.
- We will reach the note that is the time for heating (1 mm) is (1-0, 75) min.

Technical Advantages

Of the effects that post weld heat treatment has on a weld, residual stress will obviously remain if post weld heat treatment is waive, and for creep resisting materials, the full creep strength will not be developed. However, there are welding techniques that can simulate the tempering effect of post weld heat treatment, and there are some claims that mechanical properties in the HAZ can be improved compared with conventional post weld heat treatment. The particular property that is influenced more than any other when welding with these alternative techniques is heat affected zone toughness. Most of the so-called temper bead techniques are:

Primarily designed to give adequate toughness in both the weld and the heat-affected zone and to produce a satisfactory hardness profile. Whether the room temperature, and sometimes sub-zero impact. Properties are the most important consideration with alloy steels operating in the creep range is indeed questionable.

After having said that, there is no doubt that for materials susceptible to reheat cracking, the absence of post weld heat treatment and the absence of the coarse – grained heat affected zone are definite advantages. Care needs to be exercised however, and suffice it to say that the justification for waving post weld heat treatment on technical grounds should not be confused with economics.

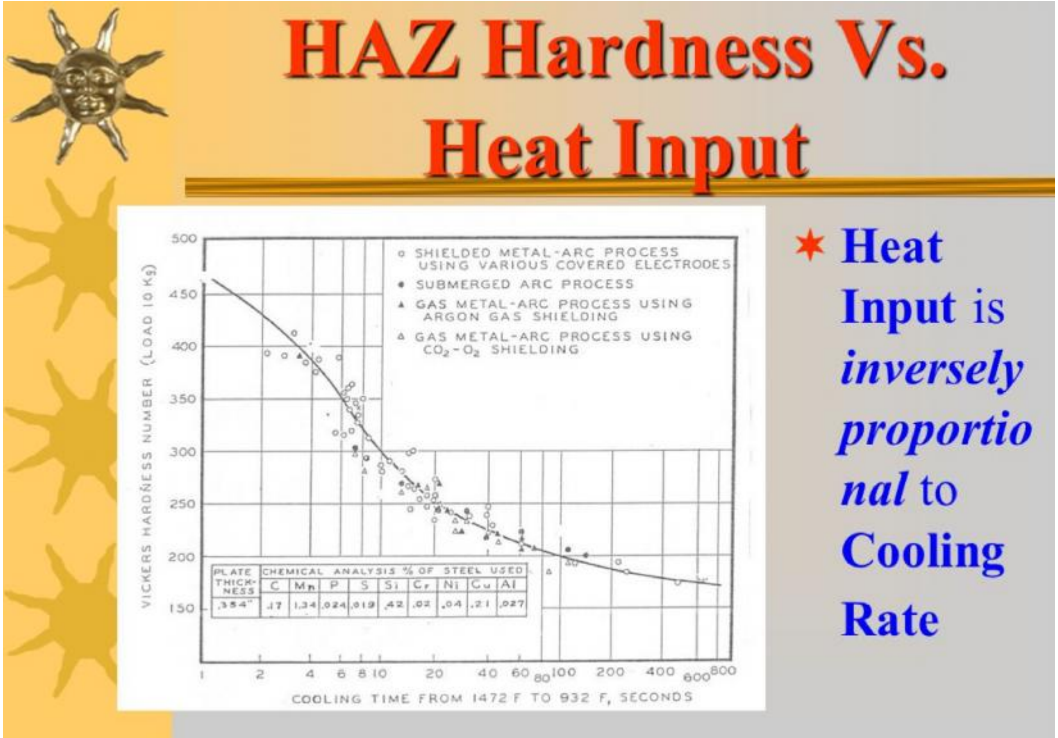
Qualification of Welding Procedures

The application of post weld heat treatment is and essential variable. This means that the application of post weld heat treatment to a procedure or the removal of it from a procedure requires re-qualification. This is because pose weld heat treatment affects the mechanical properties of the weld, and this is the whole purpose of procedure testing.

There are even more restrictions if heat treatment is above the lower transformation temperature, but this guidance note has been limited to the stress relieving aspect of post weld heat treatment.

Caution must also be exercised when working with the ASME code . the system of supplementary essential variables can be confusing, but basically, these are invoked whenever notch toughness requirements are specified. In the case of post weld heat treatment, there is and additional essential variable that specifies that the procedure qualification test shall be subjected to post weld heat treatment essentially equivalent to that to be encountered in production, including at least 80% of the aggregate time at temperature. Taking a practical example of this, a 50 mm thick procedure qualification test plate requiring impact testing and representing a 50 mm shell plate would normally only have been held at temperature for 2 hours (i.e., 1 hour/25 mm). In practice, that same vessel may have different shell thicknesses or even a tube plate, and the

Figure 6: Cooling Rate



50 mm shell may have reached the holding temperature long before the rest of the vessel. Quite often, the shell is at temperature for 5 or 6 hours, so the procedure qualification test needed to be at temperature for 6 hours x 80%, i.e., 4 hours 50 minutes and not the 2 hours it received.

Under these conditions, re-qualification would be necessary.

CONCLUSION

- Using heat treatments softening the heat affected zone and it will be improve toughness for the welding parts.
- It will be reduce the effect of cold work.
- Improve the ductility in welding joints.
- It will be improve the resistance to stress cracking.
- Improve dimensional stability during machining.
- Improving the diffusion of hydrogen out of weld joints.

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