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MODULE A
Introduction to the problems of welding

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Heat-affected zone of welded joints

Heat-affected zone of welded joints

- HAZ (IP) is formed by welding.
- At welding of metals and alloys without polymorphic transformations (CuNi, Al), the microstructure in HAZ unchanged.
- Here occurs only changes substructure, grain growth or recrystallization.
- At steel welding varies microstructure in HAZ.

On conversion of a particular effect:

1. Chemical steel composition
2. Original microstructure
3. Thermal cycles (heating rate, cooling rate).

Partial zone recrystallization defined temperatures Ac1 and Ac3

- For low carbon steels with unalloyed ferritically pearlitic structure does not begin pearlite transformation to austenite at Ac1 equilibrium temperature, but at higher temperatures.
- Thermal Hysteresis is the greater, the greater the heating rate in the first phase of the temperature cycle.
- After pearlite transformation temperature reached gradually transforms to austenite.
- Because this change is dependent on the diffusion rate is also necessary to partially transform corresponding to a temperature between Ac1 - Ac3, a certain time.
- transformation therefore, it does not take place in the whole volume of grains of perlite at a time.
- From the already transformed austenite, the carbon diffuses the surrounding non-transformed ferrite..

Partial zone recrystallisation defined temperatures Ac1 and Ac3

- The effect of the diffusion of carbon through the grain boundary while crumbles original ferritic grains.
- According to above the temperature reached between Ac1 and Ac3 structure can also be observed a certain amount of the original non-transformed structure that is highly tempered.
- In ue to these changes occurs in the band part recrystallization inhomogeneous structure in terms of grain size and transformation products after cooling.

partial zone recrystallization defined temperatures Ac1 and Ac3

- Different character structure has in the zone heated to temperatures Ac1 - Ac3 welded joint heat treated steels.
- In due to quenching and tempering is starting structure typically consists of a high tempered martensite.
- In Compared with feriticko-pearlite Tempered steel structure has a more uniform distribution of carbon.

The precipitation in the heat affected zone

- Significant changes in the precipitation of carbides, nitrides and carbonitrides It occurs in the heat affected zone.
- IN carbon structural steels may nitrides precipitate at temperatures below the Ac1.
- precipitation nitride Fe16 N2 at ambient temperature is known as the aging of the steel.
- Aging the steel may occur even at temperatures of 200 ° C to 300 ° C when the free nitrogen in the structure.
- Maximal N-solubility in the slag is dependent on temperature.
- Therefore TOO with rapid cooling during welding may occur supersaturated solid solution N in the iron alpha.

The precipitation in the heat affected zone

- After several days, then the supersaturated solid solution precipitate nitride fe16 N2 which is the cause of aging.
- Strength characteristics of this zone is increasing, but the plasticity decreases.
- In the first phase of the n atoms segregate on dislocations and reduce their mobility.
- In second stage precipitated nitrides fe16 n2 from dislocations in the third stage precipitated nitrides throughout the volume of the grain steels.
- This phenomenon is currently already dangerous because most structural carbon steels, new metallurgical methods succeeded in reducing the content of n in the steel, or the free nitrogen bound to stable nitrides eg .: aln. Tin etc.

In a system Fe-N iron may va precipitate nitrides:

- Fe_3N, Fei_6N_2 at ambient temperature or to a temperature of 200 ° C to 250 ° C,
- Fe_4N to a temperature of about 450 ° C.

Heat-affected zone of welded joints

- Aging is especially increasing the hardness of the heat affected zone.
- Microalloyed steels are alloyed with ti, al, nb and v in amounts to 0.15%.
- It are elements which form, with the carbon and the stable n carbonitrides (al nitride only aln) that soften the grain steels and dispersion strengthen steel.
- Size these precipitates is 20 nm 100 nm.

IN reheating part of the temperature cycle, the particles are coagulated first (coarsen), and at a still higher temperature to dissolve:

- Titanium carbide 1150 ° C
- NbC 1150 ° C
- Vanadium carbides 1100 ° C
- Aluminum nitride to 1350 ° C

Precipitation processes in welded joints:

1. Increasing their strength properties and fireproof (in particular the precipitation of small particles of type MX crmov steels)
2. Bind free nitrogen, thus reducing the risk of aging of welded joints,
3. Decrease plasticity of welded joints

Heat-affected zone of welded joints

- It is therefore necessary for the design technology of welding precipitation hardened steels pay extremely close attention to the temperature regime during welding, especially heat treatment of welded joints after welding.
- Tempering the temperature should be selected so as to achieve optimum strength and plastic properties of the weld joint.
- If popustíme weld joint precipitation strengthening of steel to a low temperature does not reach equilibrium microstructure.

Heat-affected zone of welded joints

- Plastic properties of welded joints are low and they may further reduce the secondary hardening at elevated operating temperatures weld.
- Secondary the curing causes further precipitation of hardening particles of the solid solution.
- High tempering temperature increased plastic properties, but reduces the strength properties of welded joints.
- Welded joints tempered at high temperatures have not cure usually secondarily.

Grain coarsening in overheating zone TOO

- After complete transformation or after recrystallization in metals without polymorphic transformations grains are not balanced due to the surface tension of the grain boundaries.
- Big grains tend to grow at the expense of small grains. The result of this process the grain coarsening.
- Coarsen grains can effectively prevent precipitates (carbides or carbonitrides alloying elements) or inclusions present at the grain boundaries up to a temperature where they dissolve.
- Therefore grain coarsening observed only in the zone of overheating too in which a sufficiently high temperature to dissolve precipitates.
- Temperaturesat which the dissolution of precipitates and the grain coarsen significantly begins, we called the superheat.

Grain coarsening in overheating zone TOO

- The superheat temperature depends on the type of precipitates at grain boundaries and its thermal stability.
- It is not therefore, the same for all steels.
- Most often are given in terms of welding i.e. rapid changes of temperature versus time and short endurance at high temperatures (only a few seconds) the following approximate superheat:
  - low carbon steel of 1050 ° C,
  - low-alloyed CrMoV steel 1200 ° C,
  - microalloyed steel to 1350 ° C.

Basic types of inclusions in the heat affected zone of the weldment

- In the steels are two basic types of inclusions - oxides and sulphides.
- Oxides formed already at the stage of steel melting in a period of oxidation.
- Oxides but passes into the slag.
- Oxides haz are very stable and not dissolved even at maximum temperatures influence.
- Dispersion oxides may hinder the movement of the grain boundary and thereby hinder grain growth in the zone of overheating. .

Basic types of inclusions in the heat affected zone of the weldment

- Oxides they can also forming nuclei during deposition of ferrite from austenite during transformation.
- If they contain however, a higher proportion of oxides feo or other component with a lower melting point may be in the range of superheat dissolve.
- Then contribute to the susceptibility of hot cracks (likvační cracking).
- Low melting oxides may also cause the formation of pores in the weld metal, particularly for welding technology in which the weld metal is formed from base material largely e.G. The submerged arc welding.

Basic types of inclusions in the heat affected zone of the weldment

- Usually as inclusions in steel sulphides occur, for example, MnS with a melting point 1610 ° C or FeS with a melting point 988 ° C.
- Sulfides may be in the range of superheat TOO dissolve, and the resulting melt to penetrate the boundary of grains and y is a metallurgical cause cracking of steel under heat.
- Sulfides They are the most common cause likvační cracking of steel.
- Alike properties have also karbosulfidy and sulfonitridy.
- Influence sulphides weldability of steel is therefore unfavorable.
- Sulfides as cracking caused by heat, but also lamellar and annealing cracking.

band in heat affected areas and their properties

- Partial zone recrystallization
- Zone normalization HAZ areas
- Zone overheating

partial zone recrystallization

- Strength loss of the heat affected zone of welded joints is particularly obvious when welding compensating and thermomechanically treated steels.
- Smaller strength reduction can also be seen with other steels in partial band recrystallization TOO at temperatures just above Ac1 in the base material affected by the welding thermal cycle at a temperature just below Ac1.
- The reason a high degree of tempering the microstructure and recrystallization.
- IN this band nadir rm, Re and HV10 of the entire IP weldment contrast value KCV, A5 and Z are usually the highest of the whole IP.

Band normalization heat affected zone

- In this zone, which is determined by the ac3 temperature and the superheat does not occur coarsening of austenite grains in reheating delivery temperature cycle during welding, since the temperature is below interference temperature superheat.
- Distinguished the fine grain, and it is also sometimes referred to as fine-grained too area.
- Speeds cooling in the cooling part of the temperature cycle at the welding are only slightly larger than the cooling rate in normalizing the base material prior to welding.
- Microstructure this band is less turbid than the band overheating.
- Therefore mechanical properties of this zone are comparable to or slightly higher than in welded normalized base material.
- Yippee the zone where it achieves the optimum ratio of strength and plastic properties.

band overheating

- In the superheat zone operates these two factors:
  - Large reinforcement material caused by high speeds of cooling austenitizing temperature, leading to the formation of supersaturated Martensiticbainite structures with high strength and low plastic properties.
  - Grains coarsening, which causes a reduction of strength properties and reduces the plastic properties.
- On the mechanical properties of the heat affected zone bandwidth has great influence transformation hardening.
- Zone Overheating is characterized by the highest values rm, Re and HV10 from across the HAZ of the weld metal.