Crane rail welding and rail steels

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Crane rails are typically supplied in 10 or 12 metre lengths but cranes run best on continuously welded rail. Crane rails are made from hard steels, which contain high percentages of carbon and other elements that make welding more difficult. Thus the choice of rail, steel or strength grade and welding process is important in designing a crane rail installation. All crane rail welds should weld the full cross sectional area of the rail. Partial penetration welds almost always fail early in their service life.

Rail Steels
Crane rail steels are formulated to give high wear resistance together with a suitable tensile strength. One of the largest suppliers sells in the strength ranges from 690 N/mm2 to 1100N/mm2. But most crane rails used are either 700 or 900 N/mm2 grade nominally. These correspond to hardness values of 207 and 265 Brinell or 207 and 270 Vickers. For heavier duty applications, the higher grades tend to be used. Steel producers use both ultimate tensile strength and hardness in their quality control checking of rails. However, they typically specify rails by tensile strength only. The rail user requires the rail to be hard and hence hard wearing and is normally less worried by tensile strength, other than as a means of proving the correct grade is in use.

Stresses in Crane Rails
The welds for joining crane rails need to be suitable for the stresses to which the rail will be subjected. There are four frequently encountered mounting systems for crane rails, which influence the stress they must carry:-

- Continuous rail on continuous steel support
- Continuous rail on continuous elastomeric pad on continuous steel support.
- Discontinuously rail supported on individual steel soleplates.
- Discontinuously rail supported on elastomeric pad on individual soleplates.

Unlike the railway where rails are mounted on elastic pad places on concrete and wooden sleepers, crane rails are not mounted directly on concrete.
In all cases the rail will be subject to bending stresses as well as the compressive stresses at the head. But it is only in continuously welded rail that is not mounted on pad that the strength in bending is unimportant. Thus it is good practice to adopt sound welding methods for all rail joints.

Rail Welding Methods
Rails steels have carbon contents, which are very much higher than steels used for most other engineering purposes. Thus the welding techniques and consumables have developed to meet these needs. Three techniques are commonly used:

- Puddle Arc also called Enclosed Arc
- Aluminothermic
- Flash butt

The Puddle Arc or Enclosed Arc Method
Puddle Arc Welding was developed by Philips Welding, probably in the 1950s. The method was developed as a means for joining any large cross section steel items together. The welding of crane rails became a particular application, which is now a specialist area. In the method, the two rail ends to be joined are cut square and placed about 20 mm apart. The base of the rail at the gap has a copper strip placed beneath it and a mild steel strip of 16 mm by 3 mm section is placed on the copper. This steel strip prevents the arc of

the welding process striking on the copper. The strip is fully melted in the welding process and becomes alloyed with the weld metal. Thus the composition of the strip is not important, providing it does not contain significant impurities.

The welding process uses large diameter electrodes (5 or 6 mm) and a high current to fill the majority of the gap. The process is to strike the arc on the rail ends and to melt the electrode and rail into a puddle of weld metal, which is covered with liquid slag, derived from the coating on the electrode. As the steel of the rail and characteristics of the flux are both very different from other welding processes, special electrodes have been developed for this process. While it is possible to use some conventional low hydrogen electrodes for puddle arc welding, it is discouraged. The gap between the rail ends is filled in two stages normally. The foot of the rail is first welded. This is done run by run with the slag being chipped off after each run. Following this the remainder of the weld is completed. To prevent the puddle of weld metal and flux from flowing away from the weld, copper mould pieces are placed either side of the weld. The welding is stopped about 10 mm from the top of the head to allow the rail to cool to the weld preheat temperature. It is continued to above the head of the rail and then it is ground back to form the final running surface for the crane wheel. This pause in the welding allows the upper layer of weld to attain a higher hardness then full annealed material.

The precise procedure for puddle arc welding rails needs to be specified on the basis of the rail steel and the application details. The rail ends must be placed at a small angle to each other, (in the vertical plane). This is to allow for distortion due to shrinkage of the weld metal. The ends of the rails must be pre-heated to a temperature dependant on the carbon content of the steel. Some electrodes are not suitable for some carbon contents. Gantrail can supply draft procedures. The completed weld may need to be cooled under controlled conditions, i.e. insulated with a thermal blanket, depending on rail steel composition.

Puddle arc welds are never perfect. It is normal to entrain some slag and to have a limited degree of lack of fusion or undercut at the bottom. They cannot be inspected easily thus it is wise to agree the quality control standards for production welds before work starts. The agreed standard should be based on trial welds or past experience.

Aluminothermic Welding

In aluminothermic welding a refractory sand mould is placed around the two square cut rails ends. The gap between the rail ends is about 20 mm. The rail is preheated to a temperature dependant on the chemical composition of the rail and the precise welding process. A crucible containing a combustible powder, iron and alloying elements is placed above the mould. The powder is ignited and when it attains the correct temperature, it melts a plug and flows into the mould. On completion of the weld and solidification of the steel the mould is broken away and the runners and risers are removed either manually or by means of a special shearing machine. The cooling and post weld heat treatment of the rail are chosen dependant on the rail material and the application.

Comparison of Aluminothermic and Puddle Arc

Both the aluminothermic and puddle arc processes are suitable methods for welding most grades of crane rails. The choice of method is normally dependant on local factors. Puddle arc is cheaper on its use of consumables. Aluminothermic welding is quicker per joint. As there are normally two men to an aluminothermic welding team, the manpower requirements of the two processes are similar. Thus overall puddle arc is cheaper. In some cases, aluminothermic welding is considered to be potentially too dangerous to be undertaken above ground level. Puddle Arc is the most economical process for a small number of welds.

The weld metal quality of aluminothermic welds is of high integrity compared with puddle arc welds. However, the performances of the two systems are both adequate as the fracture resistance of puddle arc weld metals is higher than that of aluminothermic.

Flash butt welding

Flash butt welding is commonly used for railway rail welding in steel mills before shipment. It is also used on site for railway rails. It requires thousands of amps current and hence heavy equipment. The rail ends are heated while in contact and when they are hot enough they are forged together. The process is used for crane rail welding on site in North America but it has not found much application in other parts of the world.

Rail Head Hardening

There are a number of situations when it can be beneficial to harden the head of the rail. The puddle arc process can tend to leave a soft spot at the rail head in the weld metal and adjacent to it. The design of container crane's boom hinges and rail expansion joints results in the rail being split. This can mean that the crane or trolley wheel load is carried on half the rail head width. In these cases, the rail head can be hardened by using a welding process. The material of the head is removed by grinding down to 10, 15 or 20 mm. ideally, the cut is tapered or stepped and spread over 200 to 400 mm of rail. The rail head is then built up with a work hardening welding electrode. This is soft when welded so that it can be ground to the correct profile. After a few passages of crane wheel, it develops the hardness and wear resistance required.

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