Welding in Excavator Production

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Design of earth moving equipment is evolved either on castings or fabrication. Some designers prefer to have the major members made as a casting for obvious reasons of cost reduction. This paper is concerned with a design that goes in for complete fabrication of excavators.

Excavators are mainly operated in quarries, iron ore mines and dam sites where the terrain is rugged and conditions of operation are most unfavourable to the life of a machine. Hence the designer attempts to provide the maximum amount of rigidity in the various members enabling them to withstand the severe working conditions to which the machine is subjected yet keeping an eye on the overall weight of the machine since weight affects the crawling, speed of operation and lifting capacity of the machine which is of primary importance to a user.

Principal Parts

The basic members that make up an Excavator are

(1) Revolving frame or Upper

(2) Carbody or Lower

(3) Attachments

The last embraces

(a) Shovel for earthmoving

(b) Crane for lifting

(c) Back Hoe for trench digging

(d) Clamshell for dredging

(e) Dragline for canal forming.

Revolving Frame

The revolving frame is an intricate fabrication consisting mainly of plates, channels and rounds. It houses the complete mechanism for hoist and digging operations. The heaviest concentration of welds is in the base and because of this, suitably positioned restraints and sequences of welding have to be introduced to take care of shrinkage which is maximum across the longitudinal axis. Because of its design, the job of welding and fabrication proceeds in stages sandwiched together. To ensure that component members are within machining tolerances checking must be done at each stage. Flame heating has to be widely applied. Welding is done on a 10 ton manipulator.

The entire frame goes through a cycle of machining operations after which a machined ring 8′-00″ in outer

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diameter and 7′-6″ inner diameter x 1¼″ thick is welded on. This is the most critical part of the weldment since concentricity after welding must be maintained within ± .015″. Preheating, sequence of welding and proper clamping contributes to the success of the job.

Carbody

The carbody, axles and crawler frames are built from a combination of plain carbon and low alloy steels with sections ranging from 1″ to 2½″. It is the heaviest basic weldment and because of its size no machine is able to accomodate it for the turning and vertical boring operations. Hence welding has to be done on premachined parts which carry a tolerance of ±.002″. Since the sections are heavy and welding naturally so, great care has to be exercised during welding. Proper sequence of operation, rigid clamping arrangement and built-in shrinkage tolerances contribute immensely towards maintaining the required dimensions. The crawler frame is not an integral part of the carbody. The design, almost a box section, is very rigid and does not permit effective straightening by flame heating. Distortion along the longitudinal axis is taken care of by providing a camber in its four main members. Hence no particular sequence of welding is necessary though welds are excessively heavy.

The swing gear, a 9′ diameter medium carbon, alloy grade chrome-moly casting, provides 360° swing for the entire upper member on which the attachments are mounted. The gear is welded to the carbody on both sides. Positioning with the centre bore is very critical and must be held within .010″ after welding.

Preheating, weld sequence, rigid clamping and particularly uninterrupted working contributes to the success of the job.

Shovel Attachment

Among the shovel attachments, the dipper is worthy of mention. The other attachments are also constructed from heavy section alloy steels but the dipper is a combination of mild steel, alloy steel, alloy steel casting and austenitic manganese steel casting. Foundries experience much difficulty in making a cast of manganese steel. Shrinkage cracks and inability to produce a quality product make it necessary for the welder to work on these defects prior to proceeding with further operations. The recommended procedure for the welding of manganese steel castings, that of keeping the heat in-put as low and as near the area of weld, has to be closely guarded. As long as this prerequisite is not met, cracks will develop. Peening each weld as it cools assists in preventing contraction cracks. Stainless electrode or manganese-nickel-molybdenum electrodes are the recommended filler metal.

The bucket takes the maximum rubbing and is subjected to very rough use. These considerations have been taken in the design. In doing so, the welds have had to be excessively heavy. Notwithstanding the use of high tensile steel and alloy steel castings in the building up of the bucket, hard facing of the areas exposed to the maximum wear has to be resorted to.

Dipper Handle

Yet another weldment that makes up the shovel attachment is the dipper handle designed for maximum efficiency and a capacity for doing the most rugged digging. The handle is made up of two box-section sticks 19′ long built entirely of a special grade of low carbon alloy constructional steel having guaranteed minimum mechanical properties. Its chemical composition covers a wide variety of alloying elements. Its specific characteristics, when properly heat treated, include high tensile and yield strength and high resistance to notch sensitivity at subzero temperatures. This steel is commonly referred to as T-1 Steel. The material is normally (except for semi-finished) supplied in the quenched & tempered condition. Surprisingly enough, flame cutting does not in any way reduce any of its physical properties. A preheat is recommended for welding because of its high alloy content. An electrode to match its tensile strength and with a high elongation value is recommended for welding.

Mounted on saddle blocks the digging and retracting motion is provided through a rack and pinion arrangement.

The operation of the shovel bucket is through the dipper handle.

This mechanical transmission of digging power demands proper alignment of the sticks within a tolerance of $\pm \frac{1}{16}$″

To accomplish this, it becomes necessary to control welding right from the initial stages of manufacture.

Sequence of welding, the employment of two welders at the job and control on the weld deposit lead to the work piece turning out fairly accurate. At times, however, a twist does show up in the stick. The cause of this is carelessness on the part of the welders in not following instructions to the letter. In such a case, straightening can only be done by flame heating and the use of shop made aids. The rack segments — alloy steel forgings — are welded on the sticks after the dipper handle is completely fabricated.

There is no machining on the segments other than what is done prior to assembly. This should suggest the degree of straightness and the surface accuracy required of the sticks.

Crane Booms

The most critical weldment is the crane boom built from alloy steel chord angles, medium carbon pipe bracing and connecting mild steel angle frames.

The boom has a rated capacity of lifting loads upto 80 tons and is broken up into sections.

(1) Boom point 30′ long

(b) Boom Lower 20′ long

(c) Inserts 20′, 10′ and 5′ long.

A combination of all three determines the length of the boom which varies from 50′ to 150′.

Since the boom is subjected to shock loading with some of its members under compression and others under tension extreme care has to be exercised in the initial fitment of all its members. The parts should mate perfectly leaving no room for gaps. Welding is done on a planned sequence and no welds are permitted beyond 5/8″ from the edge of the chord angles. This precaution is taken to avoid the brittleness that is induced in a heat affected zone on alloy steels.

Prior to fabrication, the angles are checked for defects, its chemical composition confirmed and all foreign matter brushed off. All corner welds are ground smooth to eliminate points of stress.

Since the boom is made up of sections, its alignment has to be closely guarded all through the manufacturing stages. A 150′ boom when coupled must have a common centre line from foot to point. Each section is held together through a bolting arrangement. 24 alloy steel bolts go into the fastening of two boom sections. It is therefore obvious that the holes mate with each other dead accurate. The clearance between the bolts and holes are measured in thousandth's of an inch. This should give one an idea of the precautions that have to be taken in welding the structure.

Welding on Induced Hardened Material

It does become necessary at times to weld components that have been subjected to a heat treatment operation either, carburizing, induction hardening or flame hardening, while attempting to salvage a job or weld jobs that are intentionally planned that way.

It must be remembered that when steel goes through a process of induced hardening the intensity of the heat only affects the surface of the steel to a maximum depth of 1/16″. The bulk interior remains unaffected. The cold metal adjacent to the heated layer is a very effective quench. Quenching the surface with a spray of water is so rapid that a hard martensite layer results. Under these conditions, welding is not recommended. However, due to the demands of the job from an engineering standpoint, welding has to be resorted to after heat treatment. In such a case, the area to be welded has to be preheated to a temperature of 1300°F. This will temper the martensite and restore some of the ducility making it possible to produce a weld that will meet the engineering requirement of the job.

Welding Electrodes

In welding excavator components, the welder has to deal with steels having a high carbon and manganese content besides such alloying elements as, Nickel, Chromium, Molybdenum and Vanadium. 80% of his weldments are built from alloy steel or castings. Hence the choice of electrodes is most important.

It is very satisfying to note that our indigenous manufacturers have been able to provide all the types of electrodes that excavator production demands. In the need for providing weld metal capable of developing hardness on heat treatment special electrodes have also been developed.

Since all electrods used are of the low-hydrogen type the need for drying them prior to use has to be enforced with a system. A battery of electrode ovens thermostatically controlled and assigned for a particular electrode cotributes tremendously to the success of a job particularly since a number of weldments do call for a variety of electrodes and the danger of using the wrong electrode is likely to happen if a control is not kept on their issue.

The choice of electrode is of extreme importance and quality has at no time been sacrificed for cost.

Summary

By way of conclusion it should be said that in the welding of excavator components the welding engineer must bear in mind the metallurgical structure of the weld cross section. If he can produce a joint that will be sound in all respects and meet satisfactorily the engineering requirements of the job, that is all to it. To achieve this he has to observe the following.

(1) Adopt correct sequences

(2) Use the proper electrode

(3) Apply the proper preheat temperature. Temperature crayons are now indigenously manufactured.

(4) Maintain a high speed of welding.

(5) Keep the heat input as low as possible. Welders are prone to using a very heavy current keeping the molten pool as large as he can control. This must be closely watched since it is detrimental to the joint.

(6) Cooling rates to be controlled. This can be achieved by a combination of speed and heat input.

In general the cooling rates can be controlled by prepost heating and the recomendations given below may be of guidance.

	Steel group	*Preheat recommended*
(a)	Under 0.25% c or low alloy steel under 0.12% c.	No preheat. But for thick plates and rigid joints upto 300°F.
(b)	Plain carbon between 0.25%—0.35% or low alloy steel 0.12%—0.20% c.	For thick sections preheat to 400°F for this section (half inch or below no preheat).
(c)	Plain carbon 0.35%—0.45% or low alloy 0.20%—0.30% c.	Necessary 300°F to 500°F.
(d)	Plain carbon 0.45% or low alloy above 0.30% c or alloy steel above 3% alloy content.	Essential 400° — 600°F.