Grooved Deformation Resistance Seam Welding (GDRSEW) of a Cast Iron Member to a Steel Tube

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Cast Iron to Steel GDRSEW: Introduction

- It is useful to be able to resistance seam weld a steel tube to a cast iron member using resistance seam weld equipment commonly used in the shock absorber industry
- Such joining enables the use of cast iron mounting rings for the shock absorber without the need for mechanical assembly to fasten the rest of the shock absorber to the cast iron mounting ring
- There is a need to weld effectively in the solid-state without melting the mating members, since any molten nugget formed by some cast iron and some steel will be likely to become brittle upon solidification
- There is also a need to weld the parts without the water coolant flooding the weld joint during welding as in a conventional shock absorber seam weld operation
- The welding of cast iron by conventional welding techniques is considered difficult. Deformation Resistance Welding (DRW) can facilitate the welding of cast iron to steel. Grooves machined in the cast iron member facilitate its deformation during welding exposing a nascent surface in contact with the mating part at high temperature, resulting in a solid-state bond.
- DRW of tubes to a node may also facilitate the design of a tubular vehicle space frame

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Cast Iron to Steel DRW Considerations

- Cast irons are characterized by high carbon content [2%-4%]. Nodular Cast irons, with ferritic matrix are known to exhibit good weldability.
- High amount heat, high heating and cooling rates and high amount of carbon promotes the formation of cementite and martensite, which are hard and brittle in nature and therefore undesirable in the weld zone.
- Welding of cast irons normally needs some form of pre-heat and/or post-heat treatment to limit the hardness and brittleness of the microstructure.
- The difference in the melting temperatures of cast iron and steel has to be considered. Cast iron begins to melt at 1148 ^{0}C whereas steel begins to melt above 1500 ^{0}C.

- With GDRSEW -
  - Solid state bonds can be engineered, which would prevent the active dilution of cast iron and steel by each other.
  - Due to the influence of force and geometry, any molten cast iron can be squeezed out from the weld joint and some problems associated with the melting and solidification can be prevented.

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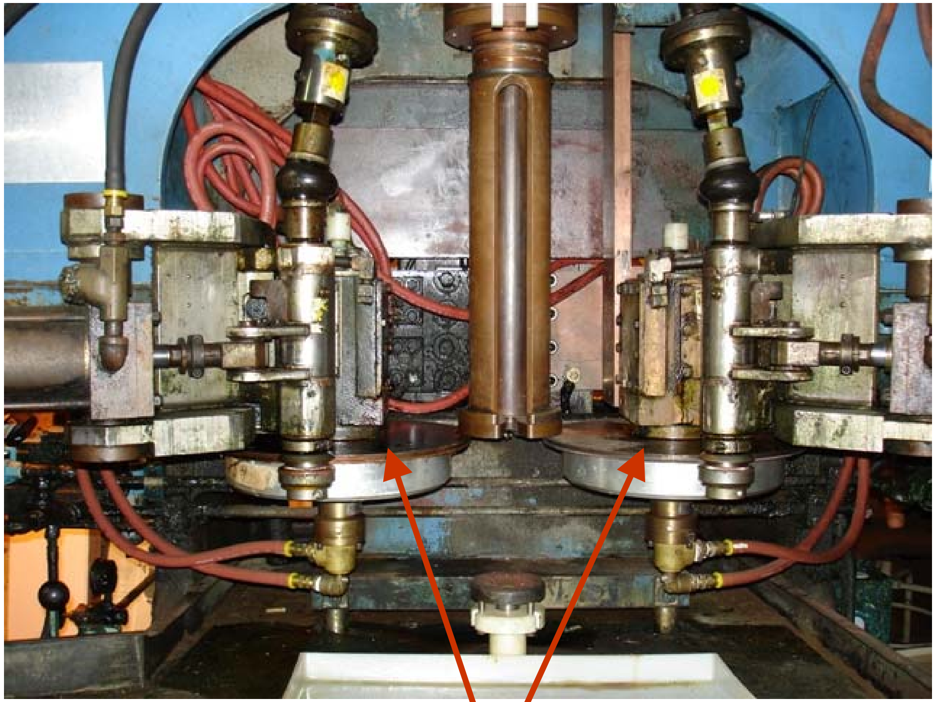
GDRSEW: Process Overview

- Equipment used for GDRSEW is shown on the right
- The weld wheels grip and rotate the parts to be welded at a surface speed determined by the knurl drive that drives the weld wheels
- Weld wheels shown here are internally water cooled without any flooding coolant splashing on the parts welded or the wheels
- Weld current flows from one wheel to the other through the parts welded
- Two locations 180 degrees apart get welded at the same time
- The top and bottom holding fixtures for the parts being welded are non-conducting



Weld wheels

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Parts Welded

- The parts to be welded are shown on the right. The cast iron member shown on the left had grooves machined in it (1 mm wide, 1 mm deep and 1 mm apart) to facilitate deformation during welding. The tube has a sliding fit with the outer diameter of the cast iron member
- The welded part is shown on the lower right corner. The welds were leak tight and left at least 3 mm of the tube on the cast iron member after a peel test all around the circumference
- The process window was satisfactory with the high limit weld current being 15% higher than the low limit weld current

Parts for welding: Grooved mounting ring and tube to be welded

Welded Parts

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Cast Iron to Steel GDRSEW: Trials

- Nodular cast iron ASTM grade 654512, and 1007003 were used for the cast iron blocks and AISI 1008 steel was used for the steel tubes.
- Weld current was passed in pulses to form overlapping weld bonds that cooled down sufficiently before they exited the weld wheel pressure. Such cooling down before exiting the weld wheel is essential, since there is no flooding coolant that cools the weld bond as it exits the wheel. If the weld is very hot while exiting the wheel, it can separate at the weld interface due to the deformation and cooling stresses.
- This pulsing sequence had to be adjusted every 6-7 weld current pulses in order to account for the weld heat building up in the part welded. The proportion of heating and cooling times in the welding pulses had to be adjusted to help cool the weld bond sufficiently before it exited the wheel pressure
- At the weld overlap, this adjustment had to be done even more carefully, since resistance to current flow and the heat generated due to current changed at the weld overlap.

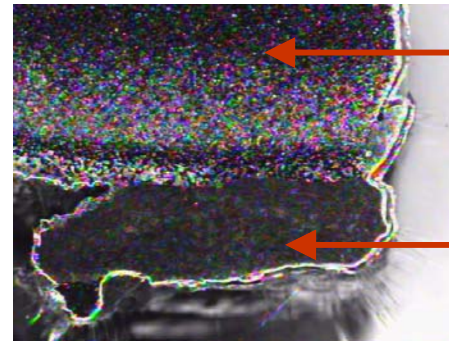
Weld test results and microstructures

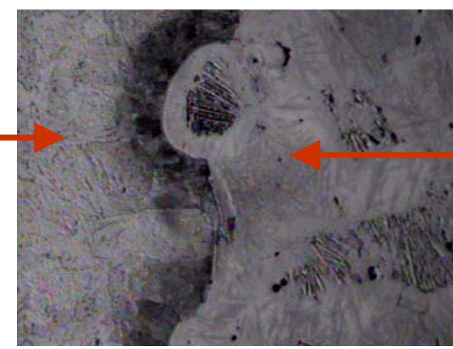
• The photograph on the top right corner of this page shows a peel tested sample. It is seen that a button of the tube is left on the cast iron member indicating that the weld is stronger than the tube welded

•The micrograph on the right shows the weld interface at a magnification of 500X. It is seen that the mating parts have bonded well. Also, neither material is seen to have melted during the weld process resulting in a solid-state bone

•There appears to be some carbon diffusion into the tube, probably due to its austenitizing during welding and the cast iron matrix not austenitizing due to its being stabilized by ferritizing elements

•There were no hard and brittle zones in the microstructures with the hardness across the weld interface studied using a microhardness traverse. Hardness values were all below Rockwell C50.





500X Magnification

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Summary and Findings

- Grades of nodular cast iron evaluated was found to be weldable by the GDRSEW process resulting in leak-tight and strong welds consistently.
- Grooves machined in the cast iron member was found to deform and facilitate a solid-state bond with the tube material during welding
- Heating and cooling pulses had to be adjusted continuously during welding to effectively cool the weld bond before it exited the weld wheel pressure
- Peel tests proved the welds to be consistently stronger than the part.

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