Microplasma Transferred Arc

SSME Nozzle Tube Repair

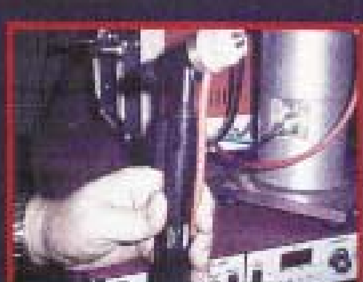
Advantages

- Constricted High Energy Arc
- More Precise Control
- Excellent Properties
- Less Heat Input To Part

MPTA Tube Crown Cross Section
50x

GTAW Tube Crown Cross Section
50X

Optional Method
(Excised Tube Crown Area)



Equipment

External View
(Overlay Repair)

Repair In Progress
(Inside SSME Nozzel)

SSME Hot-Fire Test

Marshal Space Flight Center
Productivit Enhancement Complex

BOEING

MICROPLASMA TRANSFERRED ARC FOR THE REPAIR OF SPACE SHUTTLE MAIN ENGINE NOZZLE TUBES.

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Abstract

Tubes that line the ID of Space Shuttle Main Engine (SSME) nozzles are very small and operate in extreme environments. Due to the pressure and extremely hot gas flow in the region, these tubes can, over time, develop leaks. Repair of these leaks to date, have been accomplished using a wire filler material and a Gas Tungsten Arc (GTA) welding torch. A method of repair utilizing a manual, powder fed, Microplasma Transferred Arc (MPTA) torch has shown improvements in the ease of use, more precise control, and lower heat input.

Background

SSME Nozzle tubes can, over time, leak due to cracks or small holes which form from the deteriorating effects of the environment (3000F, 3000PSI) to which they are exposed. The tubes are nickel plated A286 stainless steel. The wall thickness of the tubes at the forward end is less than .010" and tube diameters in this region are approximately .080". The tubes are brazed to each other and to the surrounding Inconel 718 jacket.

Repair of cracks and holes has traditionally been done with GTA brazing with a high strength braze alloy. The primary disadvantage of the GTA braze technique is that the heat input into the substrate is difficult to pinpoint. This requires a high level of operator skill. Even a skilled operator finds it difficult to direct heat to only the tube being repaired. Undamaged tubes adjacent to the repair area are often adversely affected. Another disadvantage of the GTA braze process is the need to use hand feed solid filler wire. Melting of the filler material itself requires significant heat input, normal variations in the manual feed of the alloy can result in wide variations of heat input into the tubes themselves. This can result in either overheating and damage to the tubes or cold laps and leaks in the repair. A study was conducted to find a better weld process for SSME nozzle tube repairs.

MPTA PROCESS

The MPTA process employs a very dense, highly constricted, arc to focus relatively low energy to the workpiece. The filler metal of choice for this process is powdered material as opposed to wire used in most other arc weld or braze processes. The use of powder is advantageous in applications requiring less overall heat input to the part. Microplasma was developed originally for welding materials requiring very low dilution of the base material and very small parts. Recent improvements in welding system technology have made possible the new micro-plasma systems for welding or surfacing, with stable currents as low as .2 amps.

PROCESS ADVANTAGES

Two benefits of this braze repair technique is the low heat input and the ability to deliver filler material to a precise location with pin-point accuracy. Using very low amperage, a minimal amount of filler can be added and subsequently melted over a small area of substrate. This feature allows less heat input to the area of repair and minimizes the heat input to adjacent areas.

The attributes of the MPTA process have facilitated repairs which were not possible using the conventional GTA standard repair process. Examples include a development test unit which required a tube repair along a 9 inch axial length initiating in the region of the smallest tube diameter and thinnest wall section. This repair has endured 8 hot fire test cycles without any subsequent maintenance required. The second example is a flight unit which required a repair of a rupture between two adjacent tubes, also in a region where the tube diameters and wall thicknesses are very small. The repair required the removal of a small access window (approximately .10 inch diameter) at the rupture site, followed by insertion of a small close-out section that was attached and sealed using MPTA braze overlay. This repair successfully passed inspection and proof tests that validated the repair method.

An unexpected benefit of the new process has been improved ease of use for the operator. With the MPTA process the powder is fed automatically, through the torch, in pre-set amounts. The operator only requires one hand to make the weld, as opposed to the other hand feeding the material as would be required using GTA. Additionally, because of the reduced amperage the operator can wear a lighter filter lens improving his ability to see exactly where the arc will be initiated. The non-transferred pilot arc passing through the torch orifice places a spot of light , further pinpointing where the arc will be transferred. These factors have proven to be important when working in very small areas and on thin substrates.

Most tube repairs on the SSME nozzle must be made in awkward positions. The precise control of heat input and filler additions, combined with the improved ease of operation allows the welders to produce consistent results over a wider range of conditions with the MPTA process as compared to the GTA process.

SUMMARY

The MPTA process has been proven to overcome many of the GTA process deficiencies for the SSME nozzle tube repair application. The primary advantage of this process is the significantly reduced heat input introduced to the substrate material during the repair procedure. This is made possible because of the powder form of the filler which requires less heat input for melting. The powder is injected directly through the plasma arc and deposited onto the substrate. The constricted arc allows the location of the arc impingement to be more precise, thus, directing the arc to only one tube in need of repair instead of to several adjacent tubes as is the case with GTA repair. Less heat is required to melt the powder form of the filler material. The GTA technique requires solid wire to be fed into the weld puddle and requires significantly more heat for melting. The heat is broadly distributed and thus can adversely affect adjacent coolant tubes. The MPTA technique is a more user friendly process that allows operators to successfully perform this operation with repeatable success.