Welding for space travel: the ultimate challenge

In order to guarantee the safety of those facing the challenges of the cosmos via space travel, onboard safety and the manufacturing quality requirements for equipment and vessel structures are exceptionally high. This includes the welding technology standards, which pose their own arduous challenges.

Space travel is undoubtedly the biggest adventure in the history of mankind. Satellites, space flights and space stations head ever deeper into the endless expanse of the universe – all the while braving conditions that are unlike anything found on Earth.

Right from the beginning of their journey, spacecraft and satellites are subject to enormous strain. The initial acceleration can reach up to 4G, meaning that each part must withstand four times its own weight. The vibrations of the engines are also transmitted to the entire structure, which can cause damage. Once outside the Earth's atmosphere, spacecraft enter a vacuum in which no air or pressure is present. Temperatures cannot be measured using conventional methods, but they can fluctuate by up to several hundred °C.

In addition, there is always a risk of collision with other objects. Meteorites and an increasing amount of space debris from destroyed or discarded satellites and exploded rocket stages can all be found in the Earth's orbit. These objects travel at such high speeds that even a collision with the smallest pieces can have serious consequences.

All of these challenges are the reason that organisations such as NASA and ESA, or private space travel companies such as SpaceX, have extremely high manufacturing quality requirements. This applies in particular to welding technology, which has a decisive role to play in space travel.

Special materials for special welding challenges

One thing is clear: only very special materials can be used for the difficult journey into space. Materials such as titanium, stainless steel, ceramics, and above all, aluminium and its alloys, have proved to be particularly suitable. Just as in lightweight automotive construction, aluminium impresses with its low weight, high specific strength, corrosion resistance and low thermal expansion coefficient. However, welding of this material is more difficult than welding conventional materials such as steels, most notably because of aluminium's low melting point and its significantly higher thermal conductivity.

The right welding process for space travel

For a long time, tungsten inert gas (TIG)/gas metal arc welding (GMAW) was the only welding process that could reliably meet the high demands of space travel. It is still successfully used in countless applications today. The TIG welding process creates particularly smooth, level, and non-porous weld seams that can withstand dynamic forces, making it a particularly good choice for root passes – and the process offers many other weld quality advantages.

Other specialised welding processes are now being used for an increasing number of tasks in space travel. Plasma and friction stir welding are particularly widespread and both are well-suited to creating aluminium joints with high weld-seam quality, which is the basic requirement for structurally stable spacecraft.

Welding can even be done in space now, and this is made possible by portable laser welding torches that do not need a protective gas shield or a vacuum. This is particularly important when working inside spacecraft. However, the compact devices are only used for urgent repairs that are absolutely necessary.

Finally, back on Earth, ever simpler and more reliable welding results of excellent quality can continue to be achieved. ☐

This article is the first in Fronius' new series: Ultimate Welding Challenges, which takes a look at welding in extreme and unusual conditions.

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Welding technology has a decisive role to play in space travel due to the extremely high safety and manufacturing quality requirements.

Above: ***TIG/GMAW used to be the only welding process that could reliably meet the component quality high demands of the space industry.*** Below: ***For hygiene reasons, the internal and external weld seams of process piping in the food industry, have to be very clean, smooth, and spatter-free.***

TIG: a superhero welding processes

The tungsten inert gas (TIG) welding process is always used when there are stringent requirements for the appearance and quality of the weld seam. Fronius has brought out two new developments for this purpose for 2018: a TIG process for mechanised applications with high speeds and a series for manual work. But why is TIG welding such an important topic?

The TIG welding arc is established between a non-melting tungsten electrode and the workpiece in an oxygen-free gas atmosphere. The inert shielding gas prevents chemical reactions with the liquid weld pool. This results in smooth, level, and non-porous weld seams.

A typical example of where the process is widely used is in the manufacture of food containers from high-alloy chrome-nickel steels. No staining colours must be visible on these tanks. These are a result of oxidation of the metal surface and can contaminate the contents and degrade the corrosion resistance around the weld.

For hygiene reasons, it is also important that the weld seams are clean, smooth, and spatter-free. This is the only way that the manufacturer can ensure that the containers are corrosion resistant and easy to clean. When joining stainless steel, gas metal arc welding results in spatter and high welding reinforcement, which takes time to sand down. This is not the case with TIG welding.

Containers made of aluminium alloys also have high quality requirements for weld seams. These include being helium-tight, for example. Helium is light and diffuses particularly quickly when there is a leak in a container. TIG welding is one of the few processes that is capable of producing weld joints in containers that are helium-tight.

When used in turbines for the aviation industry or power plants, the weld seams have to be tested using non-destructive testing (NDT), to make sure they are defect free: that is, free of pores or cracks. Gas turbines have to withstand temperatures of up to 700 °C, so they are manufactured using nickel-based alloys or titanium.

Using the TIG welding process, it is possible to weld these materials to be defect free. In pipeline construction for power plants, each weld seam is also NDT tested. The pipelines, and particularly the weld seams, have to withstand high pressure. The TIG process guarantees the high quality levels necessary to keep them secure during this process. ☐