

## Welding and Joining

### Welding and Joining Guidelines

The HASTELLOY<sup>®</sup> and HAYNES<sup>®</sup> alloys are known for their good weldability, which is defined as the ability of a material to be welded and to perform satisfactorily in the imposed service environment. The service performance of the welded component should be given the utmost importance when determining a suitable weld process or procedure. If proper welding techniques and procedures are followed, high-quality welds can be produced with conventional arc welding processes. However, please be aware of the proper techniques for welding these types of alloys and the differences compared to the more common carbon and stainless steels. The following information should provide a basis for properly welding the HASTELLOY<sup>®</sup> and HAYNES<sup>®</sup> alloys. For further information, please consult the references listed throughout each section. It is also important to review any alloy-specific welding considerations prior to determining a suitable welding procedure.

The most common welding processes used to weld the HASTELLOY<sup>®</sup> and HAYNES<sup>®</sup> alloys are the gas tungsten arc welding (GTAW / "TIG"), gas metal arc welding (GMAW / "MIG"), and shielded metal arc welding (SMAW / "Stick") processes. In addition to these common arc welding processes, other welding processes such as plasma arc welding (PAW), resistance spot welding (RSW), laser beam welding (LBW), and electron beam welding (EBW) are used. Submerged arc welding (SAW) is generally discouraged as this process is characterized by high heat input to the base metal, which promotes distortion, hot cracking, and precipitation of secondary phases that can be detrimental to material properties and performance. The introduction of flux elements to the weld also makes it difficult to achieve a proper chemical composition in the weld deposit.

While the welding characteristics of Ni-/Co-base alloys are similar in many ways to those of carbon and stainless steel, there are some important differences that necessitate the use of different welding techniques. Ni-/Co-base molten weld metal is comparatively "sluggish", meaning it is not as fluid compared to carbon or stainless steel. In addition to the sluggish nature of the weld pool, Ni- and Co-base alloys exhibit shallow weld penetration characteristics. Therefore, weld joint design must be carefully considered, and proper welding techniques are needed to ensure that there is adequate fusion. Since the oxides that form on the surface of the metal typically melt at much higher temperatures than the Ni-/Co-base alloys being welded, it is especially important that they be removed prior to welding and between passes in multi-pass welds. These important considerations will be discussed in more detail in later sections.

Generally, it is suggested that welding heat input be controlled in the low-to-moderate range. In arc welding, heat input is directly correlated with welding current and arc voltage, and is inversely correlated to travel speed. To achieve successful welding results, it is suggested that relatively low welding currents and slow travel speeds be employed. Stringer bead welding techniques, with some electrode/torch manipulation, are preferred; wide weave beads are not recommended. Preferably, weld beads should be slightly convex, and flat or concave beads that may be acceptable with carbon and stainless steel should be avoided. Both Ni- and Co-base alloys have a tendency to crater crack, so grinding of starts and stops is recommended.

It is suggested that welding be performed on base materials that are in the annealed condition.

Materials with greater than 7% cold work should be solution annealed before welding. The welding of materials with large amounts of residual cold work can lead to cracking in the weld metal and/or the weld heat-affected zone.

Chemical treatments, such as passivation, are normally not required to achieve corrosion resistance in Ni-/Co-base weldments. The solid-solution strengthened alloys can typically be put into service in the as-welded condition. In certain instances, a postweld stress relief may be desirable prior to exposure to certain service environments. Precipitation-strengthened alloys must be heat treated after welding to achieve their full properties.

As a way of achieving quality production welds, development and qualification of welding procedure specifications is suggested. Such welding procedures are usually required for code fabrication, and should take into account parameters such as base and filler metals, weld joint design/geometry, preheat/interpass temperature control, and postweld heat treatment (PWHT) requirements. Haynes International does not develop or provide specific welding procedures. The general welding guidelines and any alloy-specific welding considerations should be used to develop a specific welding procedure.