

B. Recent Developments in Understanding and Preventing Humping and Undercutting

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Weld bead defects such as humping, undercutting, and tunnel porosity result in a rejected weld, even when the metallurgical properties of the material are optimal. The avoidance of these defects results in limitations on the welding productivity, implying combinations of traveling speed and heat input that cannot be exceeded. Often, an intuitive solution with lack of understanding of the process leads to a productivity below the maximum potential. Occasionally, the generation of these defects prevents welding altogether and alternative manufacturing processes must be employed.

There are two types of humping, one due to premature freezing in arc welding; and another, due to capillary instability. In this paper we review the causes of both defects and explore concrete cases in GTAW, GMAW, microwelding, and SMAW. For the case of premature freezing in a weld pool at high currents, the arc pressure pushes the molten metal to the rear of the weld pool, creating a thin layer of liquid metal under the arc. The thin nature of the liquid layer is the cause of increased penetration at high currents. Depending in the welding conditions, premature freezing can create one, two, or three parallel humped beads. We will discuss the influence of arc pressure, torch angle, heat conductivity of base material, and traveling speed among other welding parameters.

For the case of capillary instability, the weld pool resembles an elongated liquid cylinder. When the length of the liquid cylinder exceeds approximately two diameters, the liquid metal will decrease its energy by forming several little spheroids instead of one cylinder.

Undercutting is closely related to humping in arc welding, and this relationship will be explored. The influence of sulfur in steel in undercutting will be discussed. Tunnel porosity is another defect limiting welding productivity, and its relationship with humping will be discussed.

The different mechanisms of weld pool defects will be discussed and summarized in a general dimensionless form, convenient to evaluate different alternatives for improvement, such as twin torches, laser-arc hybrids, and arc management.