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Additive manufacturing of metals at high rate yielding controlled microstructure

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Additive manufacturing, AM, of metals can be accomplished by sequentially melting and solidifying a feedstock to create a freeform shape. In terms of commercial machines the most common feedstocks are flowable metal powders. However, wire feedstock offers advantages in many situations. Many are derived from connection to a large established industrial base (welding) and include a range of available compositions (including cored wire), high material utilization, and relative economy. While AM by localized fusion offers geometrical flexibility, but at a cost and with property compromises associated with the lack of familiar metallurgical processing tools such as mechanical working. Energy efficiency can be limited by sequential heating and reheating the same volume element. Defects arise; in part, this is more likely due to the high specific surface area of feedstock(s).

The laser hot-wire process offers interesting technical advantages. This is an arc-less fusion welding process that is used primarily in cladding applications. Industrial application of cladding includes improvement of wear resistance through creation of a composite overlay of specific metal alloys in which there are dispersed phases. It also can improve corrosion resistance by effectively shelling a component in a different alloy. The low effective peak temperature of the melt (relative to, for example, electric arc processes) give high deposition rate, low dilution, control over thermal stresses, and general metallurgical control including the ability to introduce and preserve desired meta-stable phases. In our efforts the focus has been on using nickel alloys over steel for applications relevant to oil and gas, and titanium alloys for aerospace.

A number of fundamental questions arise in this challenging application of technology. These relate to process control, characterization, and metallurgical control. Presented results will include thermal modeling, stress development, microstructure, part production, and novel process control.