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Experimental and Numerical Study of E-Beam Evaporation of Titanium

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ABSTRACT

The e-beam evaporation of titanium alloys is an important step in the formation of metal matrix composites for aircraft components. In a typical process, an e-beam is used to heat and evaporate alloy from the top of a rod which is pushed from below through a water-cooled cylindrical crucible. A pool of liquid metal at the top of the rod extends to the cold crucible wall where it forms an interface with complex thermal-mechanical characteristics. The liquid metal in the pool circulates strongly as a result of buoyancy and capillary forces. The thrust of the departing vapor depresses the liquid-vapor interface near the beam impingement zone. The performance of this system is strongly influenced by the interaction of flow and heat transfer with the liquid-vapor and solid-liquid interfaces.

Experiments were performed in which an e-beam operating in the 30 - 40 kW range was used to evaporate pure titanium from the top of a 3″ diameter rod. Variations were made in the e-beam power, sweep pattern and sweep frequency. Evaporation rates were obtained from both measurements of rod length as a function of time and from the absorption of a laser beam by the vapor stream. The deformation of the liquid-vapor interface is revealed in video images from a low-angle camera and the shape of the solid-liquid interface was obtained from a cross-section of the metal rod.

A finite element model was developed for this evaporation system which includes the effects of fluid flow and energy transport in the pool and conduction in the solid. The deformation of the liquid-vapor and solid-liquid interfaces are tracked using a mesh which deforms along spines parallel to the rod axis. A comparison is made between the finite element simulations and the measurements.

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