An investigation on water-jet assisted underwater laser cutting process

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ABSTRACT

Water assisted and underwater laser cutting has a wide range of applications, *viz.*, cutting of radioactive components in nuclear industry, processing of brittle materials and medical components with minimum micro-cracks and thermal damages, etc. Conventional underwater laser cutting usually utilises high pressure gas along with laser to create a dry condition in the cutting zone and also to eject molten material. This produces aerosols, gas bubbles and turbulence in water. In order to minimise this, a water-jet assisted underwater laser cutting technique has been developed using a high power Yb-Fiber laser, in which a high velocity coaxial water-jet has been employed in place of gas-jet to remove molten material through kerf. The whole system has been designed and developed in-house, and successful cutting of different metals has been demonstrated. Use of water as an assist fluid reduces the formation of aerosols and bubbles, resulting in a remarkably gentle process. An in-depth investigation on the effect of various process parameters and mode of laser operation on process efficiency and cut quality has been carried out. However, this process has relatively low efficiency due to laser power absorption and scattering loss in water and water vapour formed at the processing zone respectively, and also due to higher convective heat transfer in water than in air. An analytical model has been developed considering material removal mechanism, different modes of heat transfer and laser power loss, and the geometrical aspects of cut front to study the parametric dependence and individual contribution of various losses in the process. Scattering of laser is found to be the most significant loss mechanism, contributing up to 40–50% of total power, followed by laser absorption in water and convective heat transfer. Scattering loss is found to depend on vapour growth and its removal by water-jet. Investigation revealed that the pulsed mode laser operation with small duty cycle and high average power yield better process efficiency due to lower scattering loss compared to CW mode. A statistical analysis also has been done to optimise the cut quality, which showed pulsed mode to produce better cut quality than CW mode.

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