Mechanical Engineering Dissertation Defense

Acoustic Energy Assisted Shaping and Joining Process of Metals

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Abstract

The increasing cost of energy and concerns about the environmental impact of energy-intensive manufacturing processes have necessitated the demand to develop new manufacturing technologies that eliminate the process steps and reduce material usage or part counts, reducing energy consumption in the manufacturing value chain. The conventional metal shaping and joining processes are energy intensive. Shaping metals into complex geometry requires multiple steps of thermal melt-cast process. Apart from the traditional casting process, recently developed additive manufacturing methods such as selective laser sintering (SLM) and electron beam melting (EBM) consume significant amounts of energy and require precise temperature control, making them an energy-intensive process. On top of that, the melting and rapid cooling of the molten pool during any of these processes will yield undesired properties that require further processing steps or a controlled processing environment, which adds costs to the manufacturing process. Similarly, the metal joining process also imposes similar challenges. Other than the conventional tungsten inert gas (TIG) or metal inert gas (MIG) welding process, the conventional solid-state joining processes are limited material thickness, joint types, heat-affected zones, expensive tooling cost, etc. In this work, an energy-efficient route for the metal shaping and joining process has been explored. The proposed innovation is based on acoustic softening, energy-enhanced solid-state diffusion, and continuous dynamic microstructure recovery/recrystallization for metal shaping and joining processes. Two distinct sets of experiments have been carried out to investigate different process parameters such as acoustic energy, thermal energy, process time, and compaction force. The shaping and joining of metals have been done without melting or extensive heating, which demonstrates the process capability of shaping and joining metals by solid-state mass transfer. Extensive materials characterization, such as scanning electron micrograph (SEM), electron backscatter diffraction (EBSD), and mechanical testing, have been utilized to investigate the material properties.

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