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## Multi-station multi-axis hybrid layered manufacturing system

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No process or technology is omnipotent. Material addition (3D Printing) and subtraction (CNC machining) have their own advantages and limitations. Energy sources such as laser, electron beam and arc (MIG & TIG) conflict among themselves in quality, speed and cost. There is different machine kinematics to choose from. Different slicing strategies of building the parts exist although most AM technologies use only the simplest form of uniform slicing. Therefore, optimal manufacturing can be achieved only when we combine these conflicting processes/technologies synergically. Our Hybrid Layered Manufacturing (HLM) is an effort towards this for building metallic objects. It is an integration of a CNC machine and a suitable cladding system. It started with MIG cladding. TIG cladding with rotating feedstock is also used for the same purpose. While most popular laser cladding systems use powder feedstock, we use wire using FhG-ISW's COAXWire laser head powered by a 4 kW laser from Laserline. Multi-axis deposition of planar layers to alleviate the need for a support mechanism is our unique contribution. Apart from building complex objects in planar layers, we have developed a feature-based conformal deposition and demonstrated for an impeller. We will build a few thin layers (about 0.5 mm) of the boundary loops precisely using multi-axis laser wire cladding whose thick interior will be filled quickly using 3-axis MIG/TIG cladding. Thus, we shall adopt discrete adaptive slicing and achieve slant edges of the slices which are more accurate than the vertical edges. Tool steel deposition requires preheating to as much as 500°C. We also relieve the residual stresses through *in-situ* cold working using a pneumatic hammer. In order to have a reliable system, each layer should be inspected through image processing before proceeding further. Therefore, we require at least seven operations to build a layer, viz., preheating three types of cladding, face milling, stress relieving and inspection. Most of these operations abuse the expensive 5-axis CNC machine through the heat and hits; furthermore, there is too little space inside the CNC machine to accommodate all these seven systems. Therefore, we are developing a Multi-Station Multi-Axis Hybrid Layered Manufacturing (MSMA-HLM) System to produce the near-net shape with excellent integrity which will be finished using the accurate 5-axis CNC machine. MSMA-HLM is a transfer line with seven stations along with a multi-axis platform which will visit them in the appropriate order. Use of parallel kinematics in scissor form to achieve Y and Z motions is its unique feature. The details of our MSMA-HLM system will be presented in this paper.

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