INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Programme of Study	:	Ph.D.
Thesis Title	:	Development of Laser-based Directed Energy Deposition System with Non-Pneumatic Powder Feedstock Handling and Synthesis of Toolpath Strategies
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Thesis Submitted to the Department/ Center	:	Mechanical Engineering
Date of completion of Thesis Viva-Voce Exam	:	22/01/2024
Key words for description of Thesis Work	:	Additive Manufacturing, Directed Energy Deposition, Feedstock Handling, Laser, Hybrid Manufacturing, Discrete Element Method, Toolpath Planning, Gradient Density

SHORT ABSTRACT

Pneumatic methods of powder feedstock handling are prevalent in laser-based Directed Energy Deposition (DED). These methods use inert gases (mostly Argon) to meter, convey, and inject powder feedstock into the melt pool created by the laser on the substrate. Although several variants of pneumatic feedstock handling exist in the literature, the difference is mainly in the mechanism of powder metering and the geometric design of the powder delivery nozzle. This work identifies several shortcomings of such pneumatic-based feedstock handling systems and offers an easy solution that could be more economical. A gravity-based system, proposed as part of this study, has been demonstrated to be a viable replacement for pneumatic methods. The gravity-based non-pneumatic system utilizes a helical-grooved shaft rotating inside a powder-filled hopper to meter the mass flow rate. This metered influx of powder is subsequently delivered to the powder delivery nozzle, which creates a conical and convergent envelope of powder stream around the fusion source before finally injecting it into the melt pool.

A DED machine tool was developed by interfacing a 1kW fiber-coupled continuous wave laser with a vertical CNC machine to additively fabricate parts. This machine tool is hybrid in nature, with both additive and subtractive capabilities, such that each process (DED and Machining) can be used in tandem or independently without one hampering the other. The interfacing of the laser with the CNC was achieved by mounting the optical head on the housing of the CNC spindle and repurposing the coolant ON/OFF control to initiate/ terminate the laser beam as dictated by the user (provided toolpath).

Several toolpath strategies were also studied as part of this work. The selection of a toolpath for the deposition of material has an influence on part properties and process efficiency. Space-filling Curves (SFCs) offer a unique opportunity in AM to fabricate parts with a high strength-to-weight ratio and include a density gradient in the

final product. A Traveling Salesman Problem (TSP)-based solver is utilized to synthesize a closed loop toolpath with common start and stop point. The toolpath is generated by first digitizing a domain within a contour via an arrangement of grid points; subsequently, these points (represented by a list of coordinates) are fed to a heuristic-based TSP (Lin-Kernighan) solver to obtain the toolpath. The layout of the grid points within the contour governs the nature of the toolpath. A density gradient in the toolpath, synthesized from a TSP approach, can be obtained by appropriately clustering cities or grid points. A region with a high cluster of grid points will result in a densely packed toolpath, consequently depositing more material, whereas regions with a low density of grid points will lead to sparsely deposited material. In this work, the variation of density in a digitized grid is obtained through a force balance amongst the grid points, which are assumed to be connected through a network of springs.

On a final note, this work is an attempt at the conceptualization of a methodology that essentially enables the development of a machine tool of hybrid (i.e., additive and subtractive) capability. The subsystems that enable DED, such as feedstock handling (non-pneumatic system), energy source (laser interfacing), and CNC motion (TSP-based toolpath planning), are brought together in synergistic sync while ensuring both ease of development and ease of use.