

# LASER MESH DEPOSITION: A NEW LASER DED METHOD FOR REPAIR

THOMAS GIRERD ET AL\*, UNIVERSITY OF NOTTINGHAM

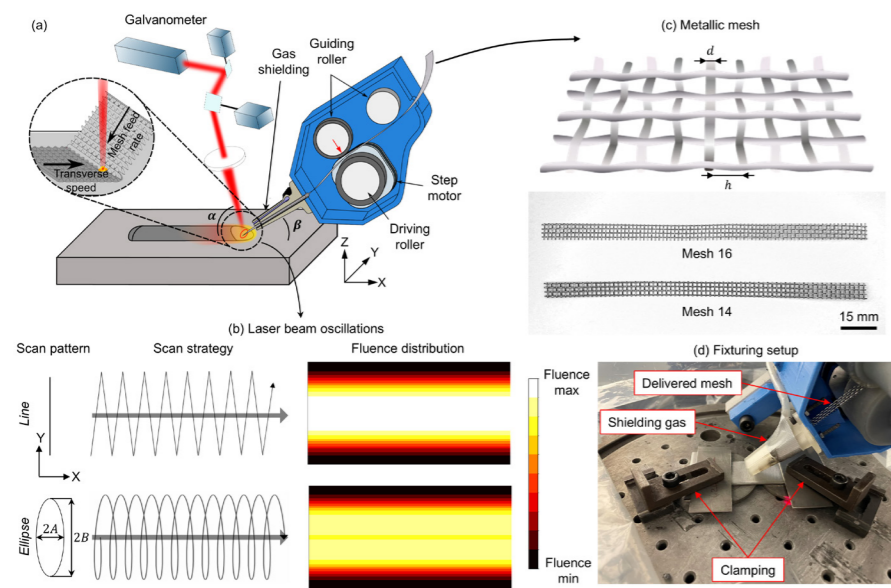


Figure 1: Experimental setup in this work illustrating the mechanism that was used to realise the mesh deposition

## INTRODUCTION

Repair and remanufacturing restore damaged parts to 'like-new' condition, reducing waste, saving costs, and conserving resources. Direct Energy Deposition (DED) is particularly suited for on-site repair, as its feeder and heat source can be mounted on robotic arms, allowing high flexibility without dismantling equipment.

Lasers are the preferred heat source for their efficiency and precision, but challenges remain—especially controlling cooling rates and avoiding defects like columnar microstructures or cracks. Laser beam oscillations are emerging as a solution, enabling finer control of energy distribution and improving microstructure quality.

Feedstock choice also limits repair capabilities. Powder-based DED suffers from low efficiency in confined spaces, while wire-based systems are restricted in geometry adaptability. To overcome these trade-offs, this article proposes a novel DED feedstock: metallic woven mesh.

Combining the adaptability of fabric with the strength of metal, meshes can be customised in density, weave type, and material composition.

This allows scalable material input, high geometric conformity, and even multi-material repair. Pairing meshes with laser beam oscillations - Laser Mesh Deposition (LMD) - offers control over fluence (energy density), melt pool stability, and deposition rate. This study explores the stability and feasibility of LMD across different mesh densities and scanning strategies, demonstrating consistent, high-quality deposition and opening new possibilities for complex, flexible repair operations in additive manufacturing. See [1] for the published paper.

## MATERIALS AND METHODS

The LMD experiments are described in [1] and shown in Figure 1.

The experiments used a 2 kW CW fibre laser (IPG Photonics YLR 2000S) coupled to an IPG mid-power scanner with a working distance of 350 mm and a laser spot diameter of 3 mm. The mesh delivering system and the scanning head were mounted on a commercial CNC milling machine. The whole system was shielded with argon gas at 0.2 bar.

The feedstock was SS304 woven mesh (40 mm × 5 mm) on SS304 substrate (50 × 25 × 2 mm). A

fixed oscillation amplitude of 5 mm matched the mesh width. Process parameters ensured constant fluence distribution profiles. A simple line oscillation (5 mm amplitude) was used to assess stability, with mesh feed rate and laser power varied to study energy and material input effects. To demonstrate the flexibility of LMD, another mesh with a higher mass density was also deposited (Figure 1(c)). An elliptical oscillation pattern was tested, with a maximum energy concentrated at oscillation extremities rather than the centre (Figure 1(b)).

Line and ellipse patterns were selected for their simplicity alongside two commercially available meshes. Cross sections were prepared by embedding and polishing perpendicular to the track, then examined via scanning electron microscopy (SEM).

## RESULTS & DISCUSSION

The mesh feed rate allows modification of the mass input while the laser power will change the average fluence level during the process. As the mesh feed rate and the laser power were varied, two types of mesh depositions were observed: "continuous" deposition and "discontinuous" deposition (Figure 2(a)). The "discontinuous" depositions appear to be semi connected masses instead of one smooth track for "continuous" deposition. Hence, Figure 2(b) shows representative cross-sections in such depositions. At low fluence levels, inferior clads were obtained with either no dilution or discontinuous deposition. When the average fluence levels are high enough, "continuous" depositions were obtained. For "continuous" depositions, a correlation between the dilution and the contact angle can be observed when plotted as a function of the ratio of the energy per mass input (Figure 2(d) and (e)). As this ratio increases, more mesh will be melted into the substrate, leading

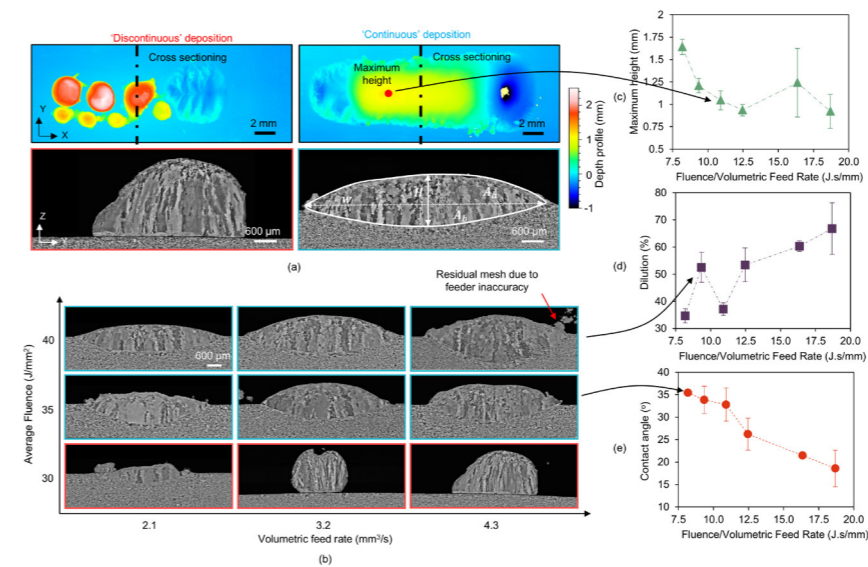


Figure 2: Results for a line scan pattern, an oscillation speed of 400 mm/s, a preheat time of 3s, an amplitude of 5 mm and a transverse speed of 1 mm/s

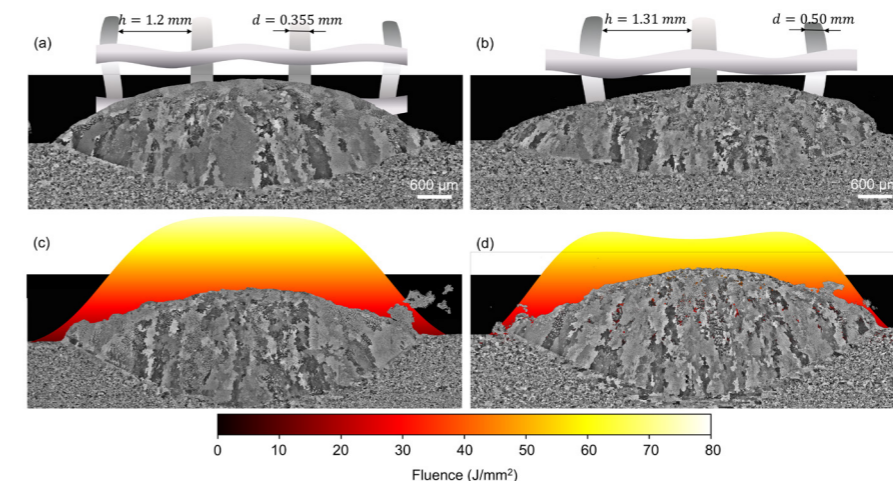


Figure 3: Cross sections obtained with laser mesh deposition by modifying the scan strategies and the type of mesh during the process.

to higher dilution and lower contact angle.

LMD was also tested with varying meshes and scan strategies. Figure 3(a) corresponds to the cross section for the mesh 16 while (b) is for the mesh 14. The total measured surface of deposited mesh from the cross section was slightly higher with mesh 16 than mesh 14 (4.62 mm<sup>2</sup> against 5.62 mm<sup>2</sup> for mesh 16) due to the higher mass input of mesh 14. Figure 3(c) and (d) show the cross sections that were obtained with 'line' and 'ellipse' scanning strategies. Both show good substrate bonding, but the line scan's central fluence maintains a more consistent melt pool than the ellipse scan, giving a more stable deposition.

Overall, LMD demonstrated good repeatability and stability. When the

level of energy is high enough, a good dilution and a good bonding are observed with the substrate, characteristics of a conduction-based process. Hence, small deflection of the mesh was observed sometimes causing the residual melted meshes on the side caused by the design limits. LMD behaves like laser wire deposition. Similar to parametric studies for laser wire deposition, at same fluence level, an increase of feed rate will increase the height reached by the track. If LMD is to be deployed for repair, a good dilution with the substrate is necessary for a good metallurgical bonding [2]. From Figure 2(c), (d) and (e), dilution and height show a linear relation with fluence per volumetric feed rate, and an inverse one with contact angle. Predictability in DED is crucial for repair; thus, this

linear trend supports future LMD repair applications once process parameters are optimised.

## FUTURE OUTLOOK

LMD offers new solutions for repair where the feedstocks can be easily changed to meet different repair requirements. The low added cost of weaving wires into mesh makes possible the creation of customised feedstock where the material input density will be controlled by the different weaving methods occurring along the same mesh to control the level of grain refinement and the flexibility of the mesh. This cost efficiency method makes LMD economically advantageous, especially for repair tasks and large-area coatings. In the future, different materials could also be woven together for creating specific metallic meshes for laser deposition application. In addition, laser beam oscillations are used to guarantee a better melt pool stability but could also facilitate the manipulation of the microstructure [3]. Consequently, LMD could be suitable for a wide range of repair operations.

## REFERENCES

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- [3] Dai, G., et al. International Journal of Machine Tools and Manufacture, 2023. 189: p. 104031.

\* Thomas Girerd<sup>1</sup>, Richard Adamson<sup>1</sup>, Andres Gameros<sup>2</sup>, Marco Simonelli<sup>1</sup>, Andy Norton<sup>2</sup>, Adam Thomas Clare<sup>1,3</sup>

<sup>1</sup> University of Nottingham, <sup>2</sup> Rolls-Royce plc, <sup>3</sup> University of British Columbia, Canada

Thomas.Girerd1@nottingham.ac.uk  
nottingham.ac.uk

Thomas Girerd is a Research Fellow at the University of Nottingham where he studied direct energy deposition processes for repair during his PhD.

