Title:

On the study of effect of coupled parameters of fused deposition modelling and CO_2 laser operation for improved surface finish

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Introduction:

Fused deposition modelling (FDM) is an additive manufacturing (AM)/3D printing process that provides a layer by layer deposition technique to fabricate 3D shapes [1,2]. FDM technology is being used for printing prototypes and full functional parts. Fig. 1 shows a schematic presentation of the FDM process.

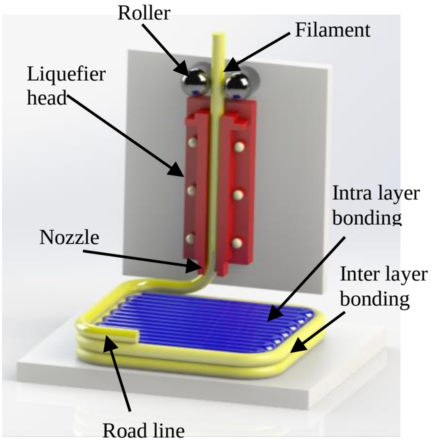


Fig. 1: Schematic diagram of fused deposition modelling (FDM) process.

The one of the limitations of FDM process is that it induces a seam between two layers. This seam results in visible rough pattern and these rough patterns affect the surface roughness of FDM built surfaces. Therefore, to ensure desired aesthetic and proper functionality, surface quality of FDM built surfaces must be improved.

Literature review reveals that the poor part quality is a major drawback of FDM build parts. These issues have been addressed by a number of researchers. They reported that the improving surface of the prototype is best assessed by post-processing or finishing processes [3-6]. Subtractive manufacturing processes such as traditional lathes, milling, computer numerically controlled (CNC) machining and abrasive flow machining (AFM) are generally used for post-processing or finishing processes. In the present time, post-processing or finishing approach is becoming more popular post-processing technique. As these processes use the strengths of individual process to over-come the weaknesses of other process. Post-processing or finishing approach is a useful, albeit somewhat lengthy, technique. It permits control on the product quality without extensive optimization of the each individual processes. As it controls strength and weakness of each process very effectively. Integrated additive and sub-tractive process has achieved widespread popularity. Because this process is very effective and also provides significant niche area for research. In the published research works, there are several relevant integrations of machining process which were analyzed along with FDM process. Literature review also reveals that attempt has not been made to reduce surface roughness of AM build parts through laser operation. This work presents the initial efforts for improving the surface finish of fused deposition modelling (FDM) built parts using laser assisted finishing (LAF). In FDM process critically oriented surfaces lead to poor surface finish. Hence, deviates it from the desired part surface quality requirements. However, poor part surface quality is an inherent constraint to the FDM built surfaces, due staircase effect after slicing, which cannot be eliminated. Therefore, in order to improve the surface finish of FDM surfaces, CO_2 laser based post finishing operation is proposed. The effects of coupled parameters of FDM and CO_2 laser operation were analyzed through statistical analysis approaches. The improved surface finish after the CO_2 laser operation is confirmed through the experimental results and surface profile images.

Main Idea:

In the present work, a high-power CO_2 laser system is used to improve the quality of FDM build prototypes. It shows better feasibility of surface finish enhancement during post finishing operation. The surface roughness of FDM built parts of ABS-M30 material were improved by considering coupled parameters of CO_2 laser as well as FDM systems. In present laser finishing operation, the finishing of samples are done primarily through the action of raster engraving. In raster engraving operation, pulsating laser engrave a sequence of uniform dots in a line pattern [7].

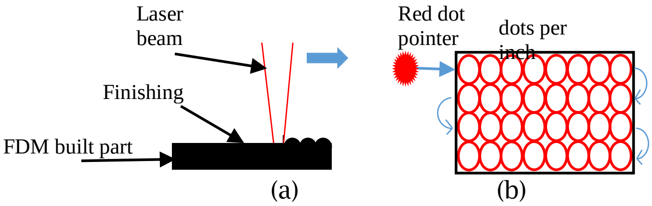


Fig. 2: (a) CO_2 laser operation and (b) Schematic representation of engraving strategy for pocket geometry.

The power densities of these dot patterns are so high that the material melts and evaporates and hence the red dot pattern selectively engrave the samples (as shown in Figs. 2(a) and 2(b)). It is well known that laser is very much affected by the type of material and its capacity to absorb energy. So the focus distance of the engraving laser should be at its sharpest point (50 mm in the present experimental study) during operations.

Conclusions:

Figure 3 shows response for mean effect plot. Main effect plot can be used to decide the optimum levels. From Fig. 3 it is clearly shown that parameter resolution (R) is having highest effect on the process as compared to the other parameters. Instead of parameters main effects influence, the actual contributions of individual parameters for different response are calculated by analysis of variance (ANOVA) [8]. Further, it can be seen in Fig. 3, the change in surface roughness increases with increase in resolution. It is because of the fact that dots engraving increased significantly at higher resolution (Fig. 4). Therefore, higher value of resolution provides finer finishing; hence higher resolution is suitable for better surface quality. This observation can be validated through the experimental results and surface profile images as shown in Fig. 4. This situation occurs may be because, at lower power there is more possibility that surface peaks near to the border of laser spot fills neighboring valleys more uniformly, which results in smooth surface. Therefore, decrease in engraving power results in more change in surface roughness.

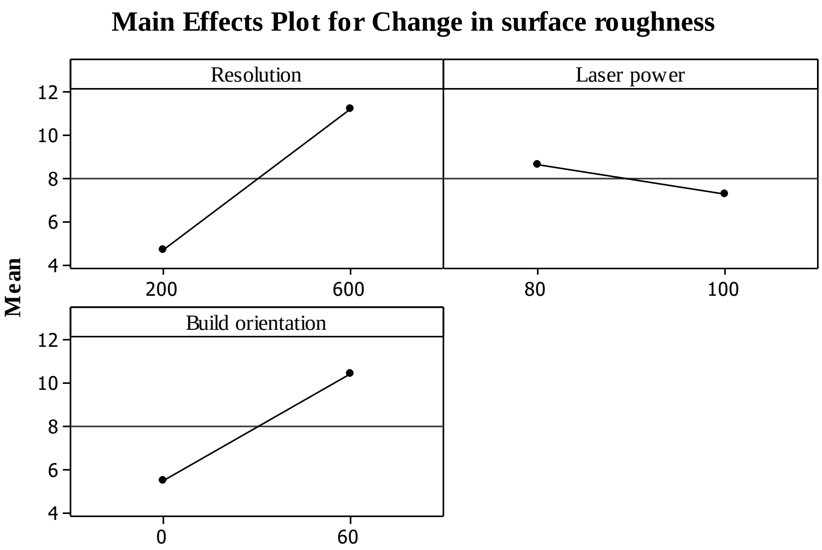
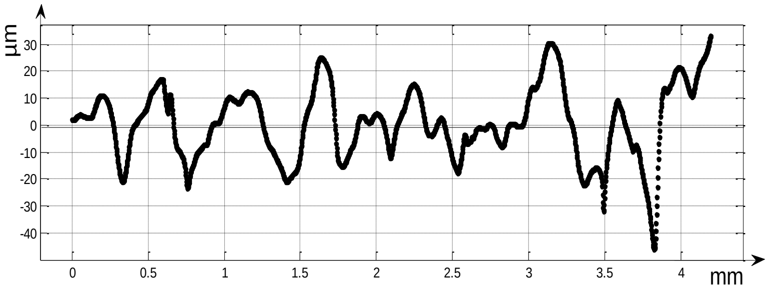
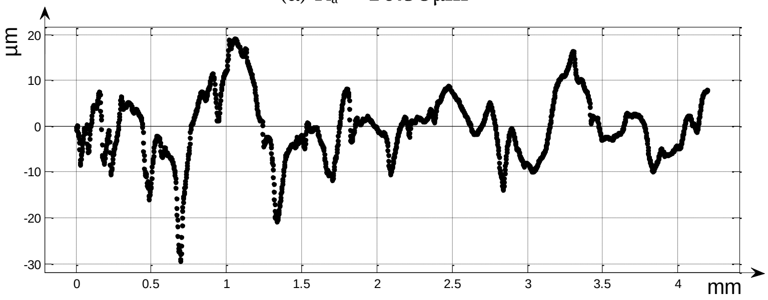


Fig. 3: Main effects of process variables on change in surface roughness.



(a) R_a = 10.58µm



(b) R_a = 5.58µm

Fig. 4: A typical experimental profiles of the laser assisted finish surface (P = 100 Watts, α = 600): (a) Lower resolution (200DPI) and (b) Higher resolution (600DPI).

As the build orientation (α) increases, the change in magnitude of surface roughness increases. This is due to an increase in offset between layers with increase in build orientation.

Based on the above experimental investigation, resolution is found to be the most significant parameter in laser finishing operations followed by build orientation. However, the effect of laser power (P) seems to be small. Although the laser finishing operation has been investigated for FDM process, still there is a wide scope for further investigation this work and this work may be extended for different type and AM processes.

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