

UNIVERSITI TEKNOLOGI MARA

**OPTIMIZATION OF PMMA
ENGRAVING PARAMETER USING
CO₂ LASER BASED ON SURFACE
ROUGHNESS OUTPUT**

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ABSTRACT

The investigation of the laser engraving process has been the focus of a significant amount of research in the field of laser machines. On the surface of the material, gaps and imperfections will appear as a natural result of the engraving process. It is widely held that the surface texture of a material has a significant impact on the material's mechanical qualities, as well as its functional performance and aesthetic appeal. However, there is limited data available on how specific engraving parameters, such as laser power, scanning speed, scan gap, and nozzle distance, affect the surface roughness in both horizontal and vertical measurements. Most researchers only focus on finding the optimal parameter only, although in real application, surface roughness also plays an important role, according to field applications. Furthermore, without optimal parameter settings, the process may result in subpar surface quality and reduced efficiency. This research addresses these issues by systematically analyzing the influence of key CO₂ laser engraving parameters on the surface roughness of PMMA using a Taguchi design of experiments approach. This study aims to identify the most significant parameters and determine the optimal settings to minimize surface roughness in both directions. To explore the effect that laser engraving has on the materials, a total 25 separate experiments were carried out in line with the Taguchi design principle. The measurement of surface roughness was then conducted into two directions: horizontal and vertical. According to the findings, the parameter that most significantly influenced the surface roughness values for Ra, Rq, and Rz in the horizontal direction was scanning speed. Meanwhile, in the vertical direction, the most significant parameters were nozzle distance and laser power. On the other hand, the least influential parameter for the process at both measurement is scan gap. The significance of the parameter was evaluated based on the p-value obtained from ANOVA. P-value less than 0.05 indicates the parameter has significant effect on the laser engraving process. Hence, the p-value for scanning speed of Ra, Rq and Rz at horizontal measurement ranged between 0.018 and 0.027. At vertical measurement, the p-value obtained for nozzle distances of Ra, Rq and Rz ranged from 0.003 to 0.004. As for laser power at vertical measurement, the p-value of Ra, Rq and Rz ranged between 0.031 and 0.030. The optimal parameter setting for the engraving machine (40 W) at horizontal measurement was 25% of laser power, 300 mm/s of scanning speed, 200 DPI of scan gap, and 2 mm of the nozzle distance setting between the bottom of the nozzle and the engraving surface. On the contrary, the optimal setting for vertical measurement was 10% of laser power, 300 mm/s of scanning speed, 333 DPI of scan gap, and nozzle distance of 2 mm. The Ra value obtained for the optimal setting was 1.022 μm for Ra_(H) and 0.829 μm for Ra_(V). On the other hand, the Rq value was 1.262 μm for Rq_(H) and 1.279 μm for Rq_(V). For Rz, the surface value was 5.796 μm for Rz_(H) and 5.132 μm for Rz_(V). The findings of this research offer valuable contributions to the field of laser machining, particularly in optimizing the surface quality of PMMA through CO₂ laser engraving. By identifying the most influential parameters and their optimal settings, the study provides practical guidelines that can help improve the surface finish, reduce defects, and enhance the overall aesthetic and functional quality of engraved PMMA products, especially in industries involved in precision and aesthetic applications such as signage, consumer products and microfluidics, where surface texture plays a critical role in the performance and quality of the products.

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CHAPTER 1

INTRTODUCTION

1.1 Introduction

Laser is used in non-traditional machining for cutting, marking and engraving processes as illustrated in Figure 1.1 (Todorov, 2020). An acronym for LASER, is “Light Amplification by Stimulated Emission of Radiation” (Haron & Romlay, 2019). It plays a significant role in terms of material machining and the development of new processing techniques in the industry (Xie et al., 2020). The cutting operation requires a high energy density of a laser beam to penetrate deeper into the work material to separate the material as shown in Figure 1.1. The focused energy of a laser beam is able to cut any material regardless of the thermophysical parameters of the material being cut (Narica et al., 2019).

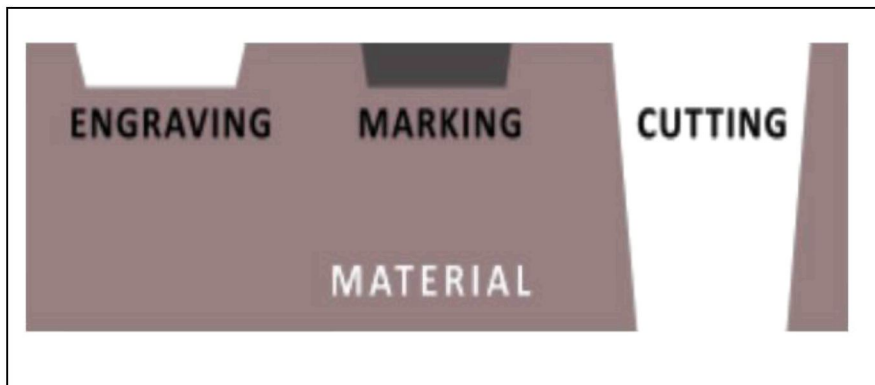


Figure 1.1: Illustration of Engraving, Marking, and Cutting Processes on Material (Narica et al., 2019)

In contrast, the marking operation does not involve material removal from the workpiece but only changes the appearance of the work surface, as seen in Figure 1.1. The effect of laser marking depends on the work material. For metal, small amounts of heat that provoke oxidation change the way the light (laser beam) reflects off the areas of contact. Hence, no surface damage occurs during the marking process on metal, only slight changes to the material surface. On the other hand, for non-conductive material, the colour of the material surface might change due to the large amount of heat density transferred to the material, which affects the laser beam spot (Narica et al., 2019).