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STUDIES REGARDING PROCESS PARAMETERS OPTIMISATION FOR TWO WATT LASER

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Abstract: *The laser process represents advanced production technology that involves welding, melting, vaporizing, cutting and shaping materials with a laser beam. This technology is used due to the speed and accuracy in various fields starting from industrial one up to hobby area. It can be used to create decorative elements due to the precision in assembling the parts and the versatility in terms of the materials that can be cut. One of the main problems when using laser cutting procedure is related to the wrong setting of cutting parameters. The mismatching of the parameters leads to a loss of surface quality related to a burr problem, which is hard to re-establish. The paper presents the influence of cutting parameters on laser cutting process for a material used for hobby purposes. This experiment demonstrates the importance of color-based adjustments in CAM processes for improving and optimizing the entire process. The first steps in establishing the optimum pairing feed speed with laser power is to make some experiments on the lighter and darker colors (white and black). Starting from this, the paper presents the optimization of laser cutting parameters for other colors. Laser cutting foam has totally transformed foam making. It i super precise, quick, and reduces waste.*

Key words: *laser cut, surface quality, laser power, feed, burr, material color.*

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1. INTRODUCTION

Laser cutting is a type of digital manufacturing technique known as "subtractive". It uses a large amount of laser-generated energy, focused on a very small area, to cut or engrave a material. There is a wide range of materials that can be laser cut: wood, plastic, cardboard, textile, metal materials, etc. [7]. Laser cutting machines work by directing a high-powered laser beam through optics and onto the material to be cut. The laser beam is focused through a lens and projected onto the material, producing melting or vaporization in a localized area due to rapid growth of the temperature. The material is then removed by a coaxial gas jet, which blows away the melted material. The gas jet also helps to cool the material and prevent it from warping or distorting. The laser cutting machine is controlled by a computer numerical control (CNC) system, which ensures precision in the cutting process. The laser can cut materials up to 20 mm thickness, depending on the type of laser.

Commonly used in industry, laser cutting machines operate from digital controls based on topographical information contained in a vector file. The material plate is cut or engraved in various locations, thus allowing the surface of an item to be delimited. To use the laser as a cutting tool, a 2D vector file is needed, created on a dedicated software.

The laser cutting technique is constantly evolving: the diversification of materials, the increase in the thickness of the cut and a better-finished appearance of the surfaces has made laser processing one of the most attractive industrial techniques in recent years. It is a processing process widely used to cut parts in the automotive, aerospace, electronics, medical industries, but also to build solar panels, or to design parts for fashion shows. It is widely used by architects [1]

One of the main problems with laser cutting equipment is related to the wrong setting of cutting parameters. The mismatching of these parameters leads to a loss of cut surface quality, which is hardly re-established. This loss of quality is usually related to a burr problem [3].

When designing the laser machining process, a vector file is prepared. A vector file is a mathematical formula that allows the design to be resized without losing quality. An image (jpg or png file) is made up of pixels and will lose quality when resized.

If the design of the workpiece involves engraving, it is not recommended to choose the thinnest material available, because the laser can cut it. In addition, if the material is very thin, the laser could melt if the design is too detailed.

Laser cutting has many benefits over other foam cutting methods. These benefits are a result of laser cutting's high efficiency and accuracy in various applications. Some of the benefits of laser cut foams: intricate and precise design, cleaner cuts, speed, easy design customization, consistency and repeatability, environmentally friendly.

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Laser-cut foams have found utility across various industries due to their precise and immaculate cuts. Here are some of its applications: packaging, interior design, prototyping, architecture, automotive sector, aerospace, medical applications, footwear, acoustic management.

2. LASER CUTTING

2.1. Minimum distance between cutting paths

An important aspect to consider when designing laser machining is the minimum space between two cutting lines. If two lines are too close, the laser beam will melt the material or even cause a fire. The minimum distance is related to the thickness of the material. The thinner the material, the greater the detail that can be successfully achieved. This applies more to decorative projects as the finished product may not be as strong for mechanical purposes [4].

The material should determine the specific laser cutting process.

While metal laser cutters get a lot of attention, lasers can also be used to cut or engrave ceramics, wood, thermoplastics, and polymers. The right technology and parameters for the laser cutting process must be carefully chosen according to the material of the part. Some materials are more difficult to cut with lasers. Thermosetting polymers and organic materials like wood, for example, burn rather than melt when exposed to a laser—a quality that allows for engraving or marking, but not precise cutting [2].

Although increased laser power means it is possible to cut faster - with new developments making it possible to achieve cutting speeds of up to one meter per second - more raw power does not directly translate into more efficient production.

To achieve these high cutting speeds, the laser needs time to ramp up, which makes high power lasers incredibly efficient for cutting large parts or parts without complicated features. These lasers offer less advantage for parts with complicated geometries because the laser usually must switch to another cut before it can reach full speed. Acceleration and deceleration must be considered when considering laser cutting efficiency.

To make the laser cutting process more efficient, nesting is used – the procedure of arranging all the parts to be cut in the smallest possible area to maximize the use of the material. This process can be done manually or automatically with the help of specialized software.

In terms of the trajectories that the cutting head will follow, there is a certain level of risk every time it must traverse the previously cut material. The machining inputs and outputs must be in the optimal location in terms of machine travel and cutting speeds, as well as logistics. Components should not be stepped on once they have been cut. However, if the laser is in an area it cannot exit [without traversing the previously cut parts], the head can rise and traverse safely to the next location

Suppose a cutting head moves from the exit of one part immediately to the nearest entrance of the next part. This sounds logical and efficient, but what if the transition from the opening of one part to the entry of the next part requires the head to pass over the part it just cut, or over other profiles or cutouts of the previously cut part, especially if they have no connection points? This could increase the risk of an accident with the cutting head.

In these cases, it is desirable to use cutting head path optimization to change the entry location in such a way as to ensure rapid feed over as few previously cut part geometries as possible (and ideally none).

2.2 The role of heat

Heat causes material to move, sometimes in unwanted ways, and how the heat is dissipated can make all the difference in the reliability of the cutting process. Focused cutting in a small area can result in some unexpected part movement, including overturning.

So if many smaller parts are cut, there are heat dissipation options that can be used that could help the process and reduce defects. One option is to pre-perforate the entire nest before cutting the perimeters of a part to limit heat build-up. Having a pre-punching step separates the heat-intensive punching process from the cutting process. This allows the heat to dissipate and ultimately the cut pieces to remain stable in the nest [5].

2.3. Testing cutting parameters

In the given analysis, a foam with glitter is used to make some decorative elements. To generate the trajectories is used EdgeCam software. The machine used for tests is a desktop CNC Stepcraft 420 (Fig. 1) that allows the user to process a wide variety of materials such as wood, plastics, non-ferrous metals, elastomers, mixed materials. The maximum feed for the machine is 3000 mm/min, repeatability of ± 0.04 mm and the working space (*XYZ*) 300 mm × 420 mm × 140mm.

The laser tool is a class 4 laser. The Laser allows for a contactless engraving of various materials without requiring a prior clamping and is able to cut smaller workpieces. Depending on the method of processing, the intensity of the laser beam can be adjusted on the computer from 0% to 100%. Additionally, the laser not only contains an integrated zero-point sensor but an active diode sealing air as well which vacuums the exhaust air and guides it through the fine particle filter. This ensures not only the protection of the laser diode but simultaneous cooling as well.

Technical Specifications of the Laser are as follows: 2 W laser diode, 9-fold safety concept, Integrated Zero Point Sensor, Vacuum system with fine particle filter, Sight Protecting Brush.

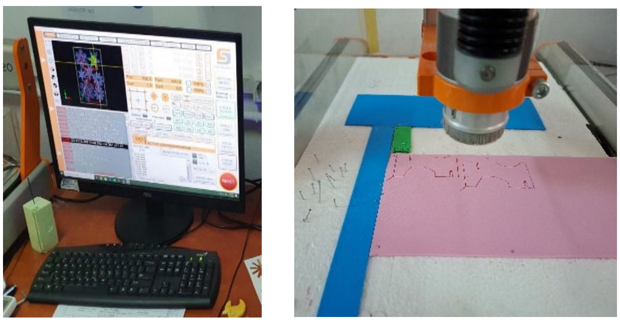


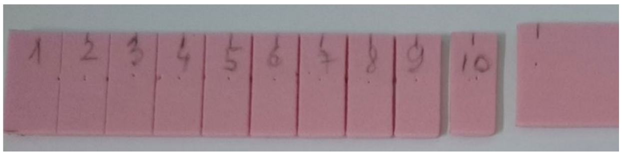
Fig. 1. Stepcraft 420 CNC machine.

The first steps in finding the optimal cutting parameters for the material used is to test different colours. We started with the white and black that are noncolours and we can see the absorption of the laser light. The first values used was the maximum laser power of 2 W and the maximum machine feed speed of 3000 mm/min. As expected, for the white color, low feed speed was needed to penetrate the material, and for the black color, satisfactory results were obtained using the maximum feed speed of the machine. For the black material, because of the absorption of light, we managed to lower the power of the laser until 0.47 W and feed speed of 300 mm/min. In G code programming, Q replaces S for the power scale so in the programs used $Q = 255$ for the laser power of 2 W.

Next, the colors red and pink were also tested to find the right parameters. At the same time, a glitter material was used to see how glue and glitter influence the feed and laser power values. The dimension of each section was 20 mm × 10 mm (Fig. 2).

Based on the values obtained for the white and black material, for the pink material the test was started with the machine's maximum laser power and maximum feed. The values for the laser power and feed speed used for the first tests are presented in Table 1.

As can be seen in Fig. 1, in test no. 9 with F = 600 mm/min and Q = 0.47 W the laser beam cut through the pink material.



a

b

Fig. 2. Materials used: *a* –pink material; *b* – red material.

Table 1

Cutting parameters for pink material

Test number	Feedrate F [mm/min]	Laser power Q [W]
1	3000	2
2	2500	2
3	2000	2
4	1500	2
5	1000	2
6	900	2
7	800	2
8	700	2
9	600	2
10	500	2

Table 2

Cutting parameters for pink material

Test number	Feedrate F [mm/min]	Laser power Q [W]
1	3000	2
2	3000	1.56
3	3000	1.88
4	300	0.70
5	600	0.70

For the red material, because is closer to the black, the values used are presented in Table 2.

As expected, because of the darker shade, with the maximum values the material was cut through. After analyzing the surface quality, the optimum values for the cutting parameters are F = 600 mm/min and laser power Q = 0.70 W. For the material with glitter, the values are as follows: pink material – F = 400 mm/min, Q = 2 W; red material – F = 600 mm/min, Q = 0.78 W.

To verify the cutting parameters, obtained from the initial cut, the second series of experiments were conducted on a shape that contains straight lines and circles, of different dimensions as seen in Fig. 3.

The shape is designed to see how the material behaves in a small area, such as the area of 1 mm wide, where the laser acts longer, and where the area could be burned (Fig. 4).

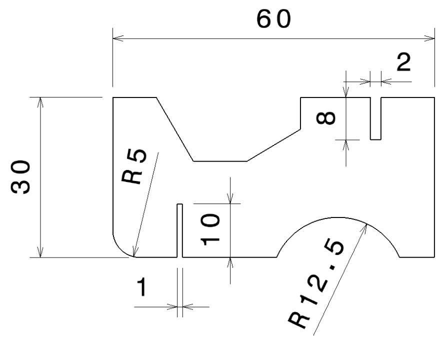


Fig. 3. Shape tested.

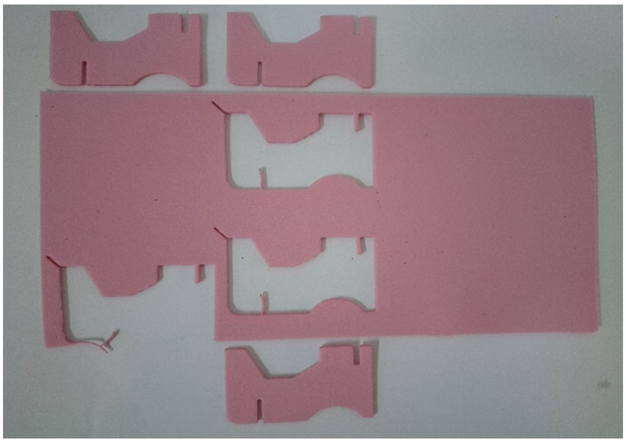


Fig. 4. Shape test on the simple pink material.

For the simple pink material, the parameters values obtained in the first experiments, validates. A series of three cutting tests were done to see if the surface quality was the same and the results were satisfactory as seen in Fig. 5. Figure 5,*a* shows the outer surface of the straight continuous surface, while Fig. 5,*b* shows the 1 mm wide surface, mentioning that the walls are not burned.

The microscope used to analyze the surface quality is a digital microscope LeeXo 50-1600X having the characteristics presented in Table 3.

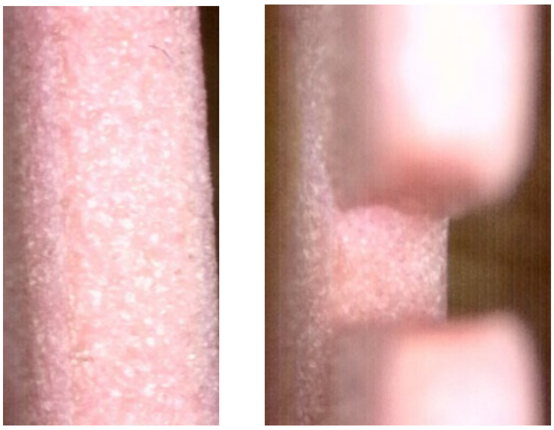
For the red material, the parameters from the initial test were tried and the laser beam did not cut completely in depth (as seen in Fig. 6).

Thus, it was decided to increase the laser power value to 1.01 W and 1.17 W for cutting the material (Fig. 7).

Table 3

Microscope specifications

Image sensor	CMOS
Image resolution	Up to 640×480, 1920×1440
Focus range	15–40 mm
Frame rate	Up to 30 FPS
Adjustable illumination	8 built-in LED Diodes
USB Powered	5 V Direct Current



a b

Fig. 5. Surface quality analisys: *a* – exterior surface; *b* – 1 mm width surface.

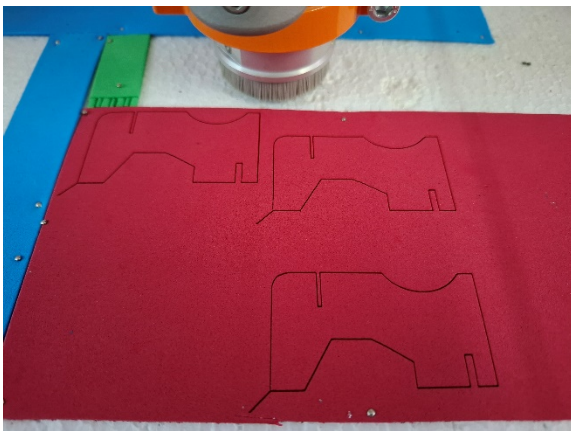


Fig. 6. Red material experiment.

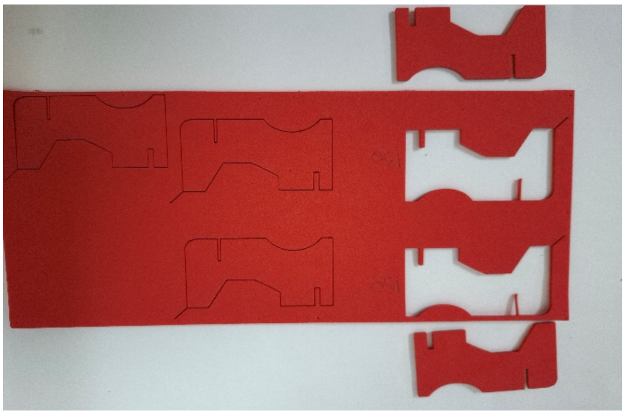


Fig. 7. Red material shape (F = 600 mm/min, laser power 1.01 W and 1.17 W).

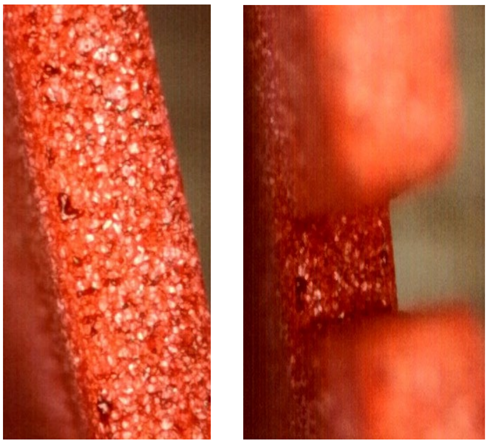


Fig. 8. Red material at 1.01 W laser power.

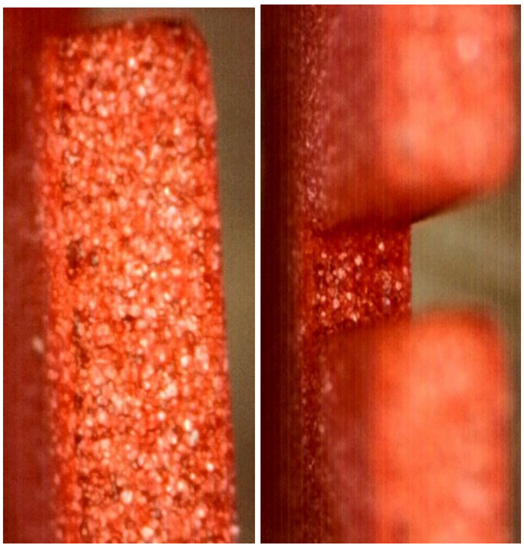


Fig. 9. Red material at 1.17 W laser power.

For this colour, the surface was also analysed, the results being presented in Figs. 8 and 9.

The next step was to find the parameter values for the same colors, but for glitter materials. The tests started with the values established as suitable for the simple pink material. Because the material was not cut completely in depth, the feed rate was modified according to the values presented in Table 4.

Table 4

Cutting parameters for pink glitter material

Test number	Feedrate *F* [mm/min]	Laser power *Q* [W]
1	600	2
2	500	2
3	400	2

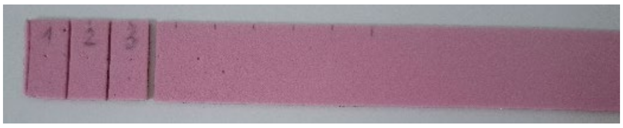


Fig. 10. Pink glitter material.

If in the case of the pink material only 3 tests were enough, for the red glitter material, it was more difficult to find the right parameters (Fig. 10). The values used are presented in the Table 5.

Although it can be seen that for some of the values the laser beam cut the material, the surface quality was not satisfactory, so the tests continued with changing the parameter values until it was observed that test number 9 provided the best surface quality (Fig. 11).

Next, to validate the results obtained, the shape shown in Fig. 3 was analyzed. For the pink glitter material, the values were similar to those from test number 3, the results being shown in Figs. 12 and 13.

Table 5

Cutting parameters for red glitter material

Test number	Feedrate *F* [mm/min]	Laser power *Q* [W]
1	3000	2
2	2500	2
3	2500	1.56
4	2000	2
5	2500	2
6	3000	1.56
7	600	0.70
8	600	0.94
9	600	0.78
10	600	0.86

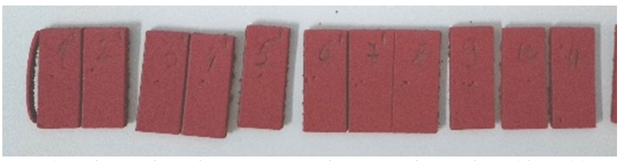


Fig. 11. The red glitter material.

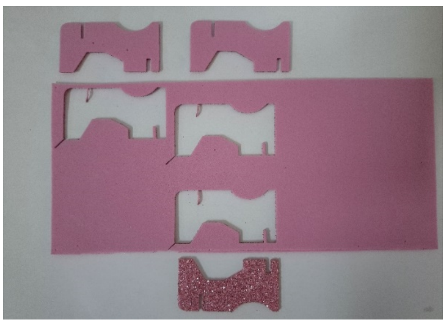


Fig. 12. Pink glitter material shape.

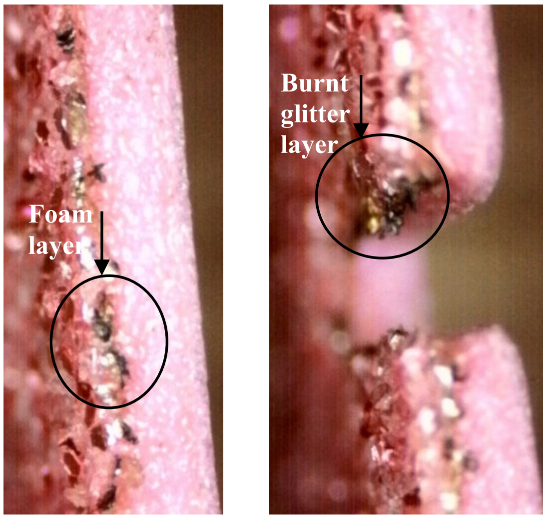


Fig. 13. Surface quality for the pink glitter material.

In the case of the red glitter material, the values used for the initial test did not offer the expected results. For the value of $F = 600$ mm/min and laser power of 0.78 W, the material was not cut through. Therefore, the laser power was increased to 0.86 W. Because at this value the material also was not cut, the laser power was set up to 0.94 W and 1 W. Those values proved too be appropriate for the cutting of this material (Figs. 14–16).

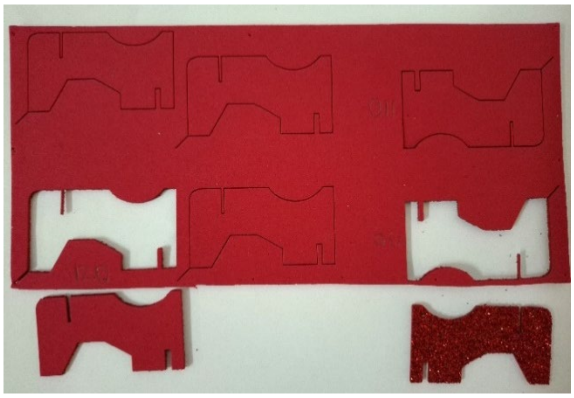


Fig. 14. Shape test on red glitter material.

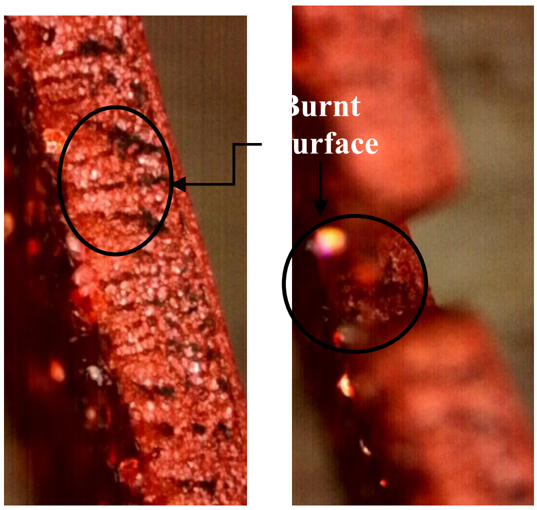


Fig. 15. Surface quality for red glitter material at 1 W.

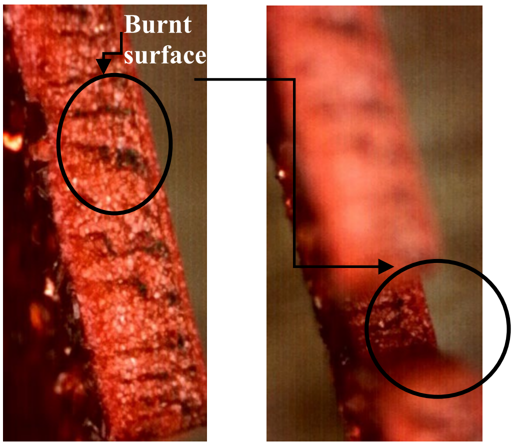


Fig. 16. Surface quality for red glitter material at 0.94 W laser power.

Fig. 17. Complex contours cutting tests.

Since in the case of the pink material, the results were more satisfactory in terms of surface quality, it was decided to use the values for cutting some decorations for the winter holidays (Fig. 17).

3. CONCLUSIONS

The presented research dealt with a series of experiments conducted to test the performance of laser cutting for different colors of materials – pink, red and glitter foam. The trial identified as the optimal configuration for the pink material utilized a feed rate of 600 mm/min on the simple foam, paired with a power setting of 0.70 W. This configuration achieved a precise and balanced cut, minimizing edge distortion and burn marks, despite the lighter color of the paper, which reflects more laser beam energy and reduces the risk of heat buildup. This allowed for a higher feed rate without negatively affecting the quality of the cut.

For the red foam, which absorbs more laser energy due to its darker color, adjustments in feed rate and power were crucial to avoid burning, particularly on intricate shapes. For instance, the values obtained for the simple foam of feed rate of 600 mm/min and a power of 1.01 W, produced cleaned edges but in the case of the glitter material the laser beam did not cut through. This lower feed rate ensured greater precision by increasing laser exposure time but slowed the process significantly.

The comparison between different colors of the foam highlights the influence of color on cutting performance. Darker materials, such as red foam, closer to black on the spectrum, absorb more heat, increasing the risk of burn marks on fine details. In contrast, lighter-colored materials, such as pink foam, allow for faster feeding speeds due to reduced heat absorption, making them less prone to thermal damage on delicate areas. This experiment demonstrates the importance of color-based adjustments in CAM processes, as feed rate and power must be adapted to the color and reflectivity of the material to achieve optimal results in relation to the desired cutting quality.

In addition, the importance of contour dimensions in the quality of cut surfaces is highlighted. Due to heat dissipation in small areas, the edges of the contours are burnt and the quality is not satisfactory.

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