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On the Optimization of Setting up Parameters for the Haas z4 500 Machining Laser

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Abstract

The Haas Z4 500 Machining Laser combines the flexibility and reliability of a 500-watt Coherent Diamond Series CO_2 laser. The system is fully integrated and all laser parameters may be controlled via the full-function Haas control. The Haas Z4 500 Machining Laser provides longer travels and increased laser power to cut a variety of flat-stock materials including aluminum, steel, and plastics. As a state-of-the-art precision machine, in addition to a good understanding of the theory of laser machining, it also requires its operators to know how to set up optimal parameters to ensure high quality products.

This paper presents our research results that further detail the machining parameters of the Haas Z4 500 Machining Laser. Current machining parameters for the vertical laser do not allow consistent smooth cuts into galvanized sheet metal. The machine parameters for the Z4 500 Machining Laser include power (watts), pulse-frequency (Hz), feed rate, and assist gas pressure. Our research combines these parameters into a designed experiment that aims at improving the machining process by optimizing afore mentioned parameters. In our experiment, the parameters for 26 gage galvanized sheet metal will be determined. The results of this research will help establish a baseline for the machining parameters for the Z4 500 Machining Laser.

Our quantitative analysis and statistical inference of gathered data will provide researchers and operators guidelines of setting up a more precise and higher quality production system. The machining parameters resulted from this research will aid in future research of parameter optimization of the Haas Z4 500 Machining Laser.

Introduction

Computer Numeric Controlled (CNC) machines come in a large variety of shapes and sizes, and can be used to machine a range of different materials. For example CNC machines can cut and or engrave into plastics, ceramics, woods, waxes, and many types of ferrous and nonferrous metals as well.

The Haas Z4 500 is a 500 watt Coherent Diamond Series CO_2 laser. It is capable of cutting a wide verity of materials such as previously stated but is limited on the thicknesses of the materials it cuts. The Haas Z4 500 can cut mild steel up to .25” thick, stainless steel up .200” thick, aluminum up to .625” thick, and plastics up to 1” thick. There are materials that the laser can not cut such as brass, copper or copper alloys. In addition to cutting material the Haas Z4 500 can also engrave, drill, and weld materials. [1]

There were four main objectives of the research on the Haas Z4 500. The first objective was to establish baseline settings for power, pulse-frequency, feed rate, and assist gas pressure. The second objective was to setup and collect data using a 2^4 factorial design, keeping material type, material thickness, and laser offset height constant. The third objective was to use statistical analysis (ANOVA) to determine which settings were statistically significant. The fourth objective was to present the results and state recommendations for further research.

Using a 2^4 factorial design the independent variables power, frequency, feed rate and assist gas pressure were assign high and low values. These high and low values or baseline settings for each variable were based on prior research conducted by Hendricks Motor Sports on the Haas Z4 500. The material type, material thickness, and laser offset height were held constant. The response variable measured was the average height of the dross produced by each different machine setup. Dross is the melted material which is displaced and adheres to the bottom of the cut. [1]

Table 1. Independent Variable Baseline Settings

Variables (A,B,C,D)			
A Power (Watts)	**B** Frequency (Hz)	**C** Feed Rate (in/min)	**D** Assist Gas Nitrogen (psi)
HI 500 LO 300	HI 1000 LO 900	HI 40 LO 30	HI 120 LO 90

A CNC program was written for the Haas Z4 500 to cut along the circumference of a 2” diameter disk. Two disks were cut for each machine setup. The Optical Gauging Products Inc. Smart Scope (OGP) and Measure Mind 3D Multi Sensor software was used to measure the average height of the dross produced from each machine setup. A routine was created using the Measure Mind software to measure the Z location of 300 points around the circumference of each 2” disks. A plane was created at Z equals to zero on the surface of the disk. Once all points were taken around the circumference of the disks, two planes were calculated from the Z locations of the points; a minimum contact plane and a maximum contact plane. From these two planes a “Best Fit” plane was calculated. The “Best Fit” plane is the least –square calculation of the best-fit plane from all the data points. The “Best Fit” calculation was recorded as the average height of the dross on the disks. [2]

Data Analysis

Once the data was collected and statistical analysis was performed using an ANOVA procedure in Excel, it was determined according to the p-values that all four of the main effects; power, frequency, feed rate, and assist gas pressure were statistically significant. It was also determined that three two level interactions were significant. These interactions were between power and frequency, frequency and assist gas pressure, and feed rate and assist gas pressure. One third level interaction was also found to be statistically significant, the interaction between power, frequency, and assist gas pressure. Interpretation of statistical terms shown in Table 2 can be found in reference [3].

Table 2. Effect Calculations

	Significant Factors							
Settings								
	A	B	C	D	AB	BD	CD	ABD
[1]	-0.00229	-0.00229	-0.00229	-0.00229	0.00229	0.00229	0.00229	-0.00229
a	0.00326	-0.00326	-0.00326	-0.00326	-0.00326	0.00326	0.00326	0.00326
b	-0.00167	0.00167	-0.00167	-0.00167	-0.00167	-0.00167	0.00167	0.00167
c	-0.00067	-0.00067	0.00067	-0.00067	0.00067	0.00067	-0.00067	-0.00067
d	-0.00438	-0.00438	-0.00438	0.00438	0.00438	-0.00438	-0.00438	0.00438
ab	0.00739	0.00739	-0.00739	-0.00739	0.00739	-0.00739	0.00739	-0.00739
ac	0.00185	-0.00185	0.00185	-0.00185	-0.00185	0.00185	-0.00185	0.00185
ad	0.01053	-0.01053	-0.01053	0.01053	-0.01053	-0.01053	-0.01053	-0.01053
bc	-0.00220	0.00220	0.00220	-0.00220	-0.00220	-0.00220	-0.00220	0.00220
bd	-0.00504	0.00504	-0.00504	0.00504	-0.00504	0.00504	-0.00504	-0.00504
cd	-0.00369	-0.00369	0.00369	0.00369	0.00369	-0.00369	0.00369	0.00369
abc	0.00804	0.00804	0.00804	-0.00804	0.00804	-0.00804	-0.00804	-0.00804
abd	0.00832	0.00832	-0.00832	0.00832	0.00832	0.00832	-0.00832	0.00832
acd	0.00487	-0.00487	0.00487	0.00487	-0.00487	-0.00487	0.00487	-0.00487
bcd	-0.00148	0.00148	0.00148	0.00148	-0.00148	0.00148	0.00148	-0.00148
abcd	0.00581	0.00581	0.00581	0.00581	0.00581	0.00581	0.00581	0.00581
Effect	**0.00358**	**0.00105**	**-0.00179**	**0.00209**	**0.001211**	**-0.00175**	**-0.00132**	**-0.00114**
Contrast	0.05733	0.01685	-0.02857	0.03349	0.01937	-0.02807	-0.02113	-0.01827
SS	0.0001	8.9E-06	2.6E-05	3.5E-05	1.17E-05	2.5E-05	1.4E-05	1E-05

As the independent variable power went from a low setting of 300 W to a high setting of 500 W the effect calculations shown in Table 2 show an increase in the height of dross produced to be an average of $3.85x10^{-3}$''. For the independent variable frequency, as it went from a low setting of 900 Hz to a high setting of 1000 Hz the effect calculations show an increase in the height of dross produced to be an average of $1.05x10^{-3}$''. For the independent variable feed rate, as in went from a low setting of 30 in/min to a high setting of 40 in/min the effect calculations showed a decrease in the height of dross produced to be an average of $1.79x10^{-3}$''. For the independent variable assist gas pressure, as it went form a low setting of 90 psi to a high setting of 120 psi the effect calculations showed an increase in the height of dross produced to be an average of $2.09x10^{-3}$''.

The effect calculation for the second level interaction between power and frequency showed an increase in the height of dross produced to be an average of $1.21x10^{-3}$''. The effect calculation for the second level interaction between frequency and assist gas pressure showed a decrease in the height of dross produced to be an average of $1.75x10^{-3}$''. The effect calculation for the final second level interaction between feed rate and assist gas pressure showed a decrease in the height of dross produced to be an average of $1.32x10^{-3}$''. The effect calculation for the third level interaction between power, frequency, and assist gas pressure showed a decrease in the height of dross produced to be an average of $1.14x10^{-3}$''.

Thru statistical analysis of the four independent variables; power, frequency, feed rate, and assist gas pressure, the power level of the laser was identified as the most significant variable of the four with an f-statistic of 62.853. By moving from a low setting of 300W to a high setting of 500W, there was a $3.58x10^{-3}$'' average increase in dross height. This was the largest increase of any main effect or interaction. The assist gas pressure was identified as the second most significant factor with an f-statistic of 21.448. The feed rate was identified as the third most significant factor with a f-statistic of 15.609 followed by the second level interaction of frequency and assist gas pressure with an f-statistic of 15.068, the second level interaction of feed rate and assist gas pressure with an f-statistic of 8.538, the second level interaction of power and frequency with a f-statistic of 7.175, the third level interaction of power, frequency, and assist gas pressure with an f-statistic of 6.383, and frequency with a f-statistic of 5.430. Minitab software was used to generate Figure 1. [4]

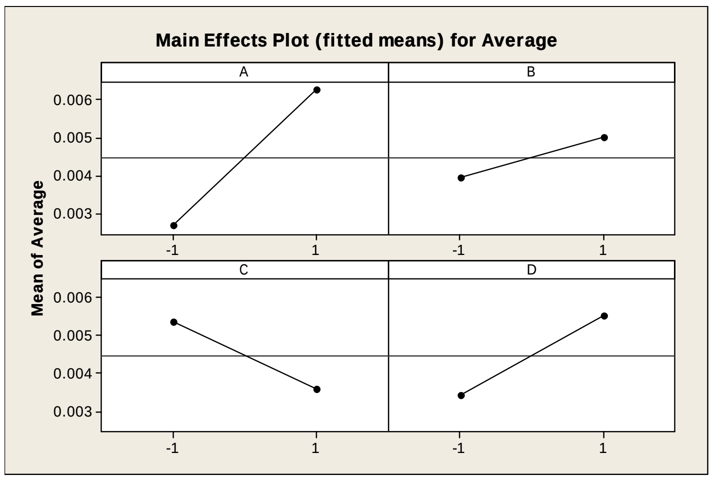

Fig. 1. Main Effects Plot

By analyzing the interaction plots of the run averages in Figure 2, it is clear that even though some of the interactions were statistically significant, there was no interaction with in the range of high and low baseline settings. If the plots were extended though, they would show interaction. For the second level interaction of power and frequency plots showed no interaction within the specified ranges. For the second level interaction between frequency and federate if the plot was extended further there would be interaction. For the second level interaction of feed rate and assist gas pressure interaction would also occur if the plots were extended further. The second level interaction between frequency and assist gas pressure shows a definite interaction within the specified ranges. The third level interaction between power, frequency, and assist gas pressure showed a decrease in the average dross height to be $1.14x10^{-3}$''. Minitab software was used to generate Figure 2. [4]

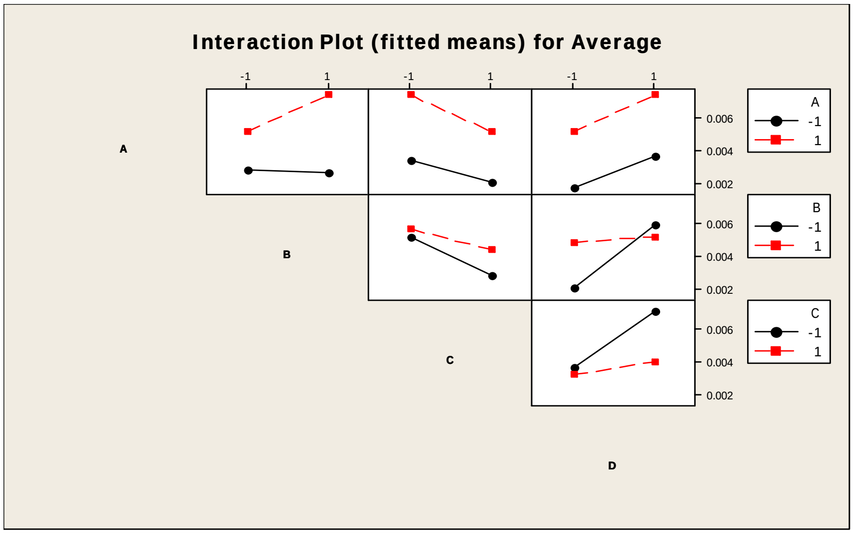

Fig. 2. Second Level Interaction Plots

Conclusion

Statistically analyzing the collected data provided a better understanding of the chosen machining parameters for the Haas Z4 500. The setting which provided the best cut into 26 gage galvanized sheet metal was a low power setting of 300W, a low frequency setting of 900Hz, a high feed rate of 40 in/min, and a low assist gas pressure of 90 psi. This setting provided an average decrease in dross height of $1.79x10^{-3}$''. This 2^k (Two levels, k variables) factorial setup could be used for a variety of different material types and thicknesses within the limitations of the Haas Z4 500 Machining Laser.

It must be noted that the laser offset distance for this designed experiment was held constant at .040'' from the work piece. The offset could be considered as an important independent variable in further designed experiments. Changing the offset distance also changes the focal length of the laser which may affect the quality of the laser cuts. Further experimentation is recommended to analyze the affects of varying the offset distance of the laser. Also the machining parameters generated by this experiment are only relevant to the Haas Z4 500 Machining Laser.

Bibliography

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Biography

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