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PERFORMANCE ASSESSMENT OF LASER DIAMOND CUTTING MACHINE

1. Abstract:

Achieving optimal cut & symmetry of polished diamonds is both an art and a science. As a science, it demands the world's most accurate, reliable cut & symmetry measurement and analysis to ensure results that in some cases even meet micron levels of precision. As an art, it requires deep knowledge and skill of the professional diamond cutter[1]

2. Introduction:

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To many, a rough diamond looks like any transparent crystal or even a piece of broken glass[2]. When cut as a faceted gemstone, however, after cutting, sawing shaping and polishing it becomes a sparkling, shimmering object that is unique in appearance . By adapting computer-imaging techniques, precision measurement systems, lasers, and other modern technological equipment, many manufacturers have improved their ability to cut gem diamonds in ways unimaginable only a few short years before.[3]

A significant result of this revolution is a diamond industry that is now better able to operate profitably. In addition, modern manufacturers can handle rough diamonds that would have been difficult, if not impossible, to cut by traditional manufacturing techniques

Keywords:Diamond Cutting Machine , Linear Motors, PID, System Identification, Motion Controller, Loop Tuning, OEM, EtherCAT, Matlab.

3. Block Diagram:

Diamond Sawing and Shape Cutting Machines (DCM) are used to saw the diamonds with low power Laser. Several shapes of aesthetic importance can be cut with the machine. Low power laser is used as cutting tool. Computerized vision system is used for assistance during sawing and shape cutting. The machine is based on Cartesian X-Y-Z-E axis movements powered by linear servo motors.[4] The control system uses advanced motion controller. Features like Auto changeover and fixture to cut 20 or 40 diamonds enhances the machine capability.

Continuous development in the software has enabled us to increase the throughput, to reduce weight loss & also to minimize diamond breakage. Several sawing and shaping parameters of the diamond such as its length, width, depth etc. are necessary to be understood & set before using it on the Laser machine. Set up station helps user to set these parameters.

PC based system is developed for Setup station for sawing and shape cutting. Various parameters of diamonds such as their own dimensions as well as their location information are found out, which is made use of subsequently on the laser machines during sawing or shape cutting[5].

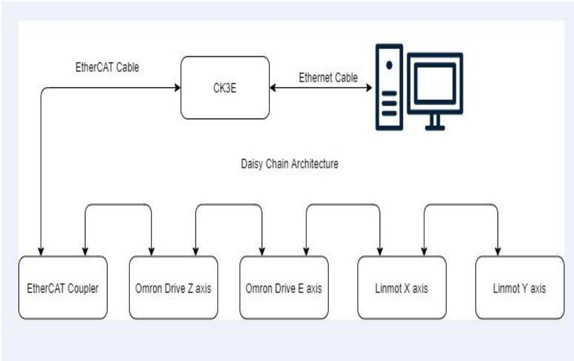

Figure 1:Block Diagram of Diamond Cutting Machine.

Sawing setup and shaping setup can both be done on the same setup station. The machine is based on Cartesian X-Y-Z movements powered by servo motors through ball screws.

There are two CCD cameras used in the system. They are interfaced to the computer. Sawing setup process uses only top camera. Shaping setup process uses both, top and side camera.[7]

Advanced motion controller is used along with computer control. Operator interaction takes place through the user interface developed for setup station. Some of the diamond parameters are manually entered during setup. Values of remaining parameters are found out by computerized image processing.

A daisy chain topology can be linear, where the first and last two nodes are not connected, or a ring, where the first and last nodes are connected.[8] A ring topology allows for bidirectional passing, whereas in a linear setup, a message must go from one machine to another in one direction.

Generally less versatile, a linear daisy chain network setup is similar to an electrical series circuit, where one outage affects other connected items.[9] A compromised network node can cut off any machines beyond that point.

By contrast, a ring structure can send data in both directions, preventing one node failure from cutting off certain parts of the network.

Other network topologies involve a central hub that can pass messages to and from other nodes. An example is a star topology, which can handle multiple node outages without cutting off working machines.

4. Process Data of Diamond Cutting Machine.

Figure(2) and (3) shows the process data has been taken from the DCM .The data has been taken for one cycle rotation of sawing and shaping for X and Y axis.

Graphs in red demonstrates the actual position of X and Y axis for the triggered interval. Graph in blue shows the demand position of the cycle. Graphs in green indicate difference in position and graphs in magenta show the demand current.

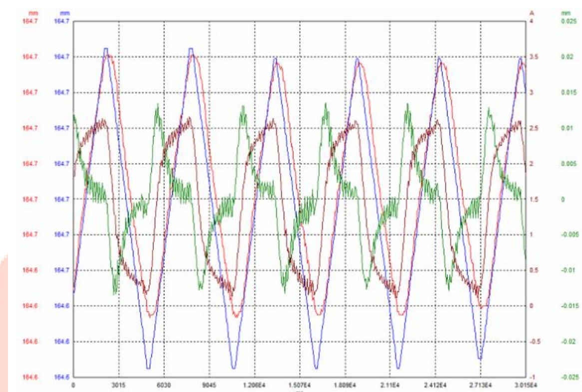

Figure 2:Process Data of X axis of DCM

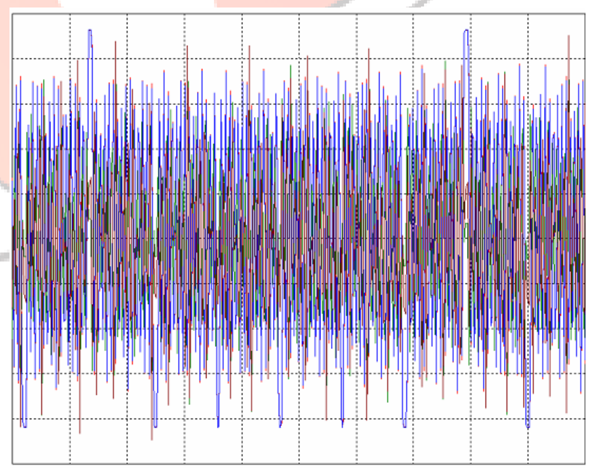

Figure 3:Process Data for Y axis of DCM

5. Transfer Function Models of DCM

In order to obtain the model of DCM, black box modeling technique is been used. First, the input and output model of the process is recorded in time domain with gather data of 30 secs[12]. Once data is gathered 70 percent of this data is used for identification purpose and 30 percent of this data is used for validation purpose. The model structure is then selected using system identification tool box to estimate four models of DCM[13]. Once the models are estimated they are validated by following the same procedure till we reach a validating model of DCM. Different models have been obtained for both X and Y axis.[6]

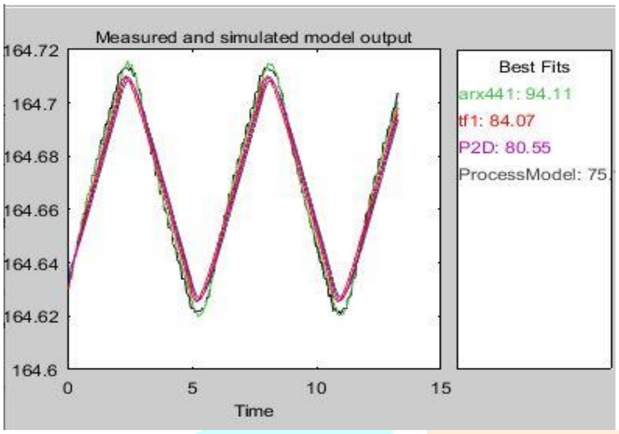

Figure 4:Percentage Fit of X Axis transfer function model of DCM

Figure (4) shows the percentage fit obtain with respect to the validated data for DCM models. Four models namely ARX. Transfer function and process models have been obtained .Percentage fit is highest for ARX model with 94.11 percentage fit for validated data.TF1 has 84.07 % fit and P2D has 80.55% fit.

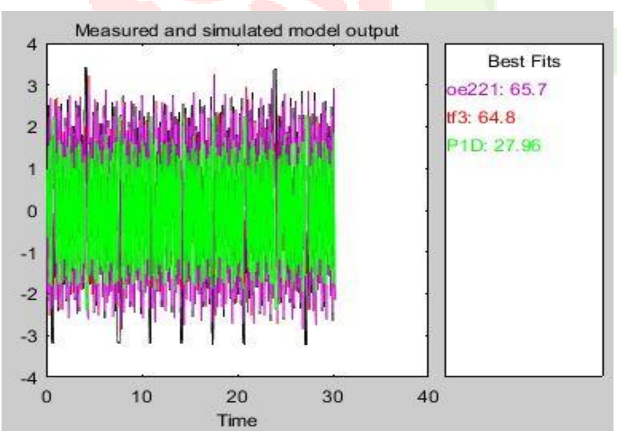

Figure 5:Percentage Fit for Yaxis Transfer Function Models of DCM

Figure(5) indicates for percentage fit obtained with respect to validated data of Y axis .Parametric output error model provides maximum fit with 65.7,followed by transfer function model 64.8 and process model of 27.96 fit.

6. Performance Evaluation

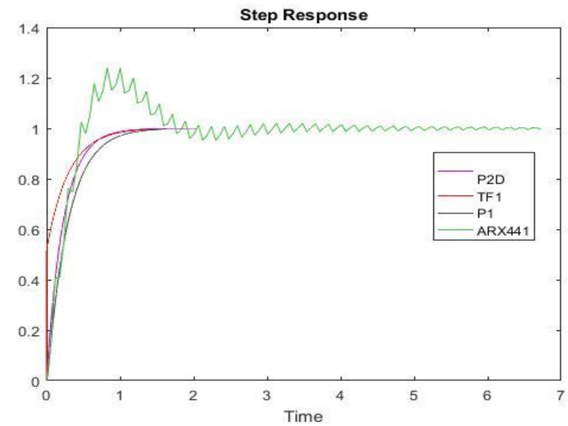

Figure 6:Step Response

Figure(6) shows the step response of a transfer function of DCM. It can be predicted from the step response shown in figure(6) that ARX model has under damped response, whereas TF1, P1 and P2D models have critically damped response.

Table(1) indicates the performance parameter of predicted DCM models. It can be predicted that

Table 1:Performace Paramters

DCM Models	Damping Factor	Rise Time	Settling Time	Overshoot and undershoot
ARX	0.7777	0.6	7	+1.2
P1	0.9999	0.9	1.8	0.003
P2D	0.997	0.7	2.5	0.004
TF	0.999	0.8	1.9	0.006

Figure(7) shows the autocorrelation and cross correlation plots of the series. Autocorrelation (also called serial correlation) is the correlation of a function with itself but with a delay.

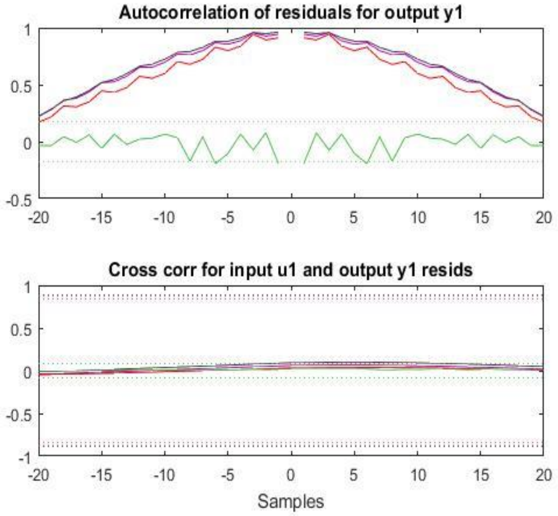

Figure 7:Correlation Plot

So correlation[11] is calculated by the Pearson's co-efficient which is the co-variance between two series divided by their standard deviations. Auto Correlation is the Pearson's coefficient of a function at different times. Auto correlation uses the same series twice - once in it's original form and once in it's time lagged form. Confidence interval used is 99 % which displays the probability that a parameter will fall between a pair of values around the mean[8].

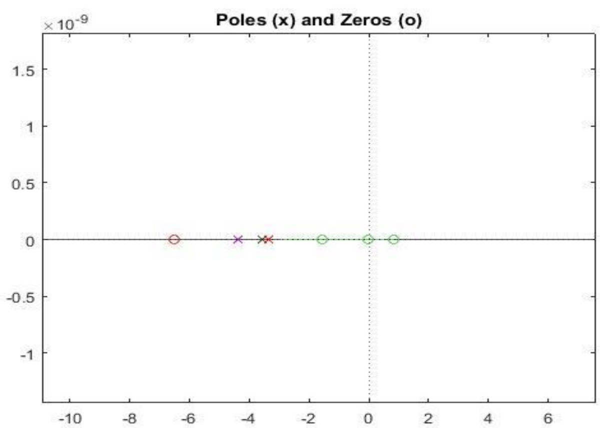

Figure 8:Plot Zero Plots

Figure(8) determines the pole zero plot with 95 confidence level. For multivariable systems it is the poles and zeros of the individual input/ or output channels that are displayed. To obtain the so called transmission zeros, you will have to export the model and then apply the command zero. All the poles of the system lie in left half of the plane indicating that DCM models are stable[9] .

Figure(9) is a measure of magnitude and phase of the output as a function of frequency, in comparison to the input. In simplest terms, if a sine wave is injected into a system at a given frequency, a linear system will respond at that same frequency with a certain magnitude and a certain phase angle relative to the input[10].

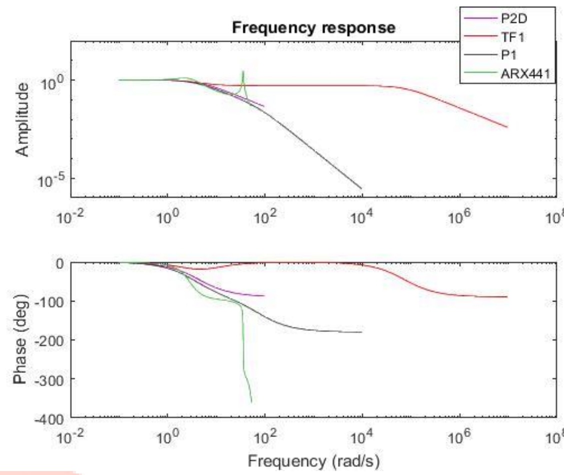

Figure 9:Frequency Response

7. Conclusion

Diamond cutting laser machine is widely used for sawing and shaping of raw diamonds. The machine was initially explained with the help of block diagram.DCM models for both X as well as Y axis were generated using Matlab System Identification toolbox that estimated parametric as well as process models for the system. The paper was concluded with performance evaluation of obtained DCM models.

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