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Experimental Investigation and Optimization of Laser Machining Process Parameters for Solar Cell Cutting Based on Taguchi Method

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In recent times, laser material processing has become a mainstream manufacturing technique in micromachining applications. This trend has been due to the various unique properties of the laser beam. Laser machining has desirable properties like flexibility and the ability to focus the beam to a small point makes it to be embraced leading to high energy density which allows cutting, welding, and drilling almost any material including silicon. In solar cell cutting of solar cell, the input parameters dictate the various output parameters after cutting. This process when it comes to customized solar panels faces challenges because not any input parameter combination produces the optimal output parameters for best quality solar cells. Therefore there is the need for optimization of the input parameters so as to produce quality solar panels.

In this research, the effect of laser beam and process variables (inputs) on cut quality attributes of solar cell was investigated. The input parameters selected for this study were: laser power, scan speed, and spot diameter. The quality attributes (outputs) which were investigated were: kerf depth, kerf width, and material removal rate for the process.

The input parameters were used in the design of experiment by Taguchi 9-orthogonal array implemented in Minitab17 software. The design provided nine experiments for unique combinations of the input parameters. Experiments were then conducted and the results were tabulated and analyzed.

The input factors were found to have a significant effect on the quality attributes of the solar cell. The kerf depth was found to increase with increasing laser power and decreased with increasing spot diameter and scan speed. The kerf width was found to increase with increasing laser power and spot diameter while it decreased with increasing scan speed. On the other hand, material removal rate was found to increase with increasing laser power and spot diameter while scan speed had the opposite effect. From this analysis, models relating the responses to the input factors were developed with the aid of the software.

Optimization process provided the solution for the desirable set values for the responses i.e. kerf depth was set at a target value of 0.1840mm, the kerf width was set to be minimal as possible, and the material removal rate was set to be at maximum as possible to reduce machining time. The optimal conditions were found to be; laser power at 126.67W, spot diameter at 0.4158mm and the scan speed at 3121mm/min.

An experimental validation of the optimized conditions was conducted obtaining kerf depth at 0.1839mm with a standard deviation of 0.00001, kerf width at 0.5828mm with a standard deviation of 0.0005 and material removal rate at 1456mm^3/min with a standard deviation of 1.76. These experimental results showed conformity to the optimal conditions obtained using the software.

In conclusion, the study showed that the input parameters selected have a significant effect on the selected output parameters for the laser cutting process of solar cells. The study also showed that there exists a suitable combination of the input parameters in values which provide optimal output parameters.