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| 1. Title of the Project | Laser Drilling of Ceramics |
| 2. Name of the Principal Investigator | Dr. Anand B |
| 3. Name and Address of the Institution | R.V College of Engineering<br>R.V Vidyanikethan Post, Mysore Road, Bengaluru-560059, Karnataka |
| 4. UGC Approval Letter No. And Date | F.No: 42-906/2013 (SR),<br>Dated: 27-12-2013 |
| 5. Date of Implementation | 1-04-2013 |
| 6. Tenure of the Project | 01-04-2013 – 31-03-2017 |
| 7. Publications | 3 (Elsevier) |

7. **Executive Summary**

Laser drilling of ceramics and ceramic coatings to obtain perfect holes characterized by minimum taper, Heat Affected Zone (HAZ), recast and spatter, meet the increasing demands of microelectronics and aerospace industries concerning stringent geometrical tolerances. Understanding the complicated physical phenomenon of laser drilling such as melting, vaporisation and induced thermal residual stresses along with the knowledge of effects of laser parameters on drilling responses becomes essential to obtain a perfect quality hole. Although several researchers examined the effect of laser parameters on drilling characteristics of bulk alumina and alumina coatings, no comprehensive research has been reported on multi-objective optimisation of laser drilling responses using Grey relational analysis, Response Surface Methodology (RSM) and Genetic algorithm. Residual thermal stresses in the HAZ can cause damage to the material and hence its evaluation enables assessment of quality of laser drilled alumina. Thermal residual stresses using micro Raman spectroscopy is scarcely reported. Hence, the research was focused on studying the effects of laser power, frequency, scanning speed, hole diameter and piercing time on the quality of the hole drilled in bulk alumina and alumina coatings adopting Taguchi's orthogonal array experimentation.

A hybrid approach of Grey Relational Analysis, Response surface methodology and Genetic Algorithm to perform multi objective optimisation of drilling responses was implemented. The laser drilling process was simulated using COMSOL and residual thermal stresses induced at HAZ were evaluated using micro-Raman spectroscopy. The laser drilled holes were characterized using Scanning electron microscopy.

RSM indicated that high frequency (7.5 KHz), high laser power (240W), moderate scanning speed (3.85 mm/s) and lower hole diameter (1mm) are preferred to achieve nominal entrance circularity of 0.963 and exit circularity of 0.965, minimum HAZ of 0.55 mm and minimum taper of 0.351°and these results were in close agreement with those of Grey Relational Analysis. Analytical predictions of Taper and HAZ are in agreement with the experimental results. Thermal residual stresses in the HAZ were measured using micro Raman Spectroscopy. The nature and magnitude of the residual stresses were indicative of the damage to the material as evidenced by the scanning electron micrographs.

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Laser parameters were optimized for micro drilling of alumina coatings. Multi objective optimisation using Genetic Algorithm lead to improvements in HAZ, spatter deposition area, entrance circularity, exit circularity and taper by 5.68%, 12.81%, 2.42%, 8.54% and 20.5% respectively. Overall improvement of 5.22 % was obtained at 416.5 W laser power, 1.4 kHz pulse frequency and 0.4 second piercing time. Performance and feasibility of $CO_2$ laser for drilling alumina and alumina coatings have been demonstrated. Simultaneous optimisation of laser drilling responses enables setting the laser parameters to achieve best quality holes in Microelectronics and Aerospace industries.

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Approved by All India Council for Technical Education, New Delhi.

RVCE / 679 /17-18

20-6-2017

## CERTIFICATE

This is to certify that Dr. B. Anand, Professor, Department of Mechanical Engineering, R.V. College of Engineering, has successfully executed UGC sanctioned project titled 'Laser Drilling of Ceramics'. The project has been completed on 31.3.2017.

The Executive Summary of the project has been hosted on the Institution website and a copy of the same has been kept in institution Library.

Principal

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