Chapter 7

CONCLUSIONS AND FUTURE SCOPE

7.1. CONCLUSIONS

A complete investigation of the phenomenon occurring at the IEG of the μED-milling process has been carried out. The analysis covers the computational fluid dynamics simulation, experimental study and micro graphical examination. The CFD simulation is carried out to study the dielectric fluid flow in the IEG. The trajectory of the debris particles and the accretion rate is computed to understand the redeposition region in the μchannel. Same study is utilized to investigate the flow features using the slotted tools. The important conclusions are drawn as follows:

1. Rotation of the tool is an inherent part of the μED-milling process. Effective flushing of debris from the IEG improves machining efficiency. It is observed from the study that out of various parameters, tool rotation is effective in increasing the velocity of the dielectric in the IEG which enhances debris flushing.
2. In spite of the small IEG, the velocity of the dielectric varies from the tool surface towards the workpiece surface. It is maximum near the tool and minimum near the workpiece. At lower input energy, the IEG size formed is less, but it will not affect the debris flushing due to higher dielectric velocity in the gap.
3. Lower inlet velocity has less effect on the dielectric velocity at the IEG because the effect of tool rotation is predominant. Rotation induced flow-field creates vortex at the back of the tool which creates few stagnation points in the μchannel where the concentration of the debris is higher.
4. Trajectory of the spherical debris particles in the IEG shows various behavior of the debris such as accretion on the workpiece surface, clustering and chain-like structure which affects the redeposition and sparking behavior.

5. Trajectory of the debris particles before accretion depends on the initial position of the particle in the IEG which experiences different drag by the dielectric due to variation of dielectric velocity in the IEG. Accretion of the particles on the workpiece surface makes the μchannel tapered. The particles with smaller size cools at a faster rate and if these are near the tool it travels longer distance before cooling.
6. Slotted tool with greater slot height is efficient in removing the particles from the gap as it accumulates in the slot reducing the concentration in the gap. Accumulation occurs due to pressure difference and vortex flow in the slots. The slotted tool with four slots is found effective as compared to the cylindrical tool in terms of machining performance.
7. The SEM analysis shows that surface machined by slotted tool is relatively smooth than that of cylindrical tool and uniformly distributed particles are present. All this shows that the slotted tools are effective for machining as compared to conventional cylindrical tools irrespective of the higher manufacturing cost.
8. Different methodology used in the present research is useful in understanding the processes happening in the IEG. The investigation of the flow-field in the IEG is useful to track the trajectory of the debris particles in the gap and subsequently find the redeposition region which causes tapered channel.

7.2. SPECIFIC CONTRIBUTIONS

1. The major problem with the μED-milling process is flushing of debris particles from the IEG of less than 50 μm. Inadequate removal creates several problems hindering the surface finish and machining performance. To address this issue an investigation is carried out to understand the dielectric flow and trajectory of the debris movement in the gap. The CFD simulation gives useful information of the flow-field in the gap which would be difficult to be calculated by other method.

2. The applicability of the slotted tool as compared to cylindrical tool is proposed for µED-milling. The CFD simulation is for optimizing the tool geometry and this information is used for experimentation using different slotted tools. The machining performance of the cylindrical and slotted tool is measured in terms of MRR and TWR. The microscopic images of the machined surface showed smooth surface using slotted tool.
3. The images of the spark and dielectric motion are captured using high-speed camera. The images are taken at high frame rate with a time span of 0.4 ms. This is also useful to study the behaviour at the IEG where sparking occurs in short interval of time.

7.3. SCOPE FOR THE FUTURE

1. The simulation is carried out on the slotted tools of various shapes. This study can be further extended to tool shapes such as half cross-section, helical slots, inclined slots to study the flow-field and optimize the tool geometry.
2. The images of the debris can be captured to study the ejection phenomenon by using special microscopic lenses and high-speed camera. To visualize the IEG during sparking, transparent workpiece can be used.
3. The experimental study can be extended by using tools of micro dimensions. Helical and inclined slots can be cut on the micro tool and machining performance such as MRR, TWR, radius overcut, and surface finish can be compared with the cylindrical tool.