ABSTRACT

Micro manufacturing involves manufacturing of products with feature size in the order of micrometers. Specific applications of micro-manufacturing include micro-scale fuel cells, micro-scale pumps, micro-moulds, subminiature actuators, mobile parts, miniaturized bearings, medical devices and implants etc. Miniaturized components normally require processing of materials having distinct/specialized characteristics with high accuracy. These materials are difficult to machine conventionally and can be easily machined using micro EDM / WEDM (wherein no cutting force is involved). Micro wire EDM has been a versatile micro-machining technology used for manufacturing of complex parts and can machine difficult to machine materials (e.g. titanium, tungsten carbide etc.)

Current work involves modeling of the erosion phenomenon for micro WEDM. A two dimensional thermal model capable of predicting temperature distribution within heat affected zone (along workpiece) using micro EDM / WEDM is proposed. The model can be effectively used to predict erosion rate (for any conductive material) corresponding to the value of energy supplied. The model is capable of predicting the shape and size of micro crater produced due to single spark which helps in analysis of the erosion rate in micro EDM/ WEDM process.

One major drawback which restricts wide commercial application of micro WEDM is very low MRR which makes it economically non-viable. Low MRR is attributed towards ineffective evacuation of eroded particles from the working area, which is result of re-deposition. An attempt to improve flushing away of debris using air and gas in addition to liquid dielectric is reported in current work. Due to enhanced debris removal in air and gas assisted condition, increase in material removal rate (MRR) has been observed. The percentage increase in MRR in air assisted mode is 5-12% and that in Nitrogen assisted condition is found to be 20-21%.

Despite its wide use in industry today, EDM has some disadvantages. One of the most serious one is the environmental pollution due to liberation of toxic gases during machining, due to the dielectric fluid used. The conventionally used liquid dielectric is oil based i.e. kerosene which decomposes during the process and liberates harmful vapours (CO and CH₄). Liquid dielectric causes environmental pollution and it is
hazardous to operator’s health. Hence it was strongly felt to consider development of indigenous near dry Micro WEDM setup wherein the total knowhow of the machine is established; leading towards overcoming problems faced with the existing machine; while performing modifications on the existing experimental setup.

A table top dry micro WEDM setup is developed using retrofitting design concepts. Principally retrofitting describes the measures taken in the manufacturing industry to allow new or updated parts to be fitted to old / outdated subassemblies. Such reuse of parts leads to a reduction of cost and carbon footprint. A RC type pulse generator is designed to supply pulsating DC power to the machine. The circuit developed is successfully applied in Micro WEDM. Also the aspect of using minimum number of parts and fewer moving parts is kept in mind while designing this machine. In micro EDM /WEDM, one of the most important indicators of accuracy is kerf width. Wire tension is observed to reduce wire vibrations which in turn influences the kerf width. Wire tension is strongly related to wire bending and wire vibrations. The conventional approach of using number of rollers to keep wire in tension is not suitable for wires having smaller diameters (in microns). The mechanisms using rollers are bulky in nature which require large space and have more number of components. Hence, an innovative tension control mechanism is developed, manufactured and tested successfully.

Developed dry WEDM was tested using air and nitrogen as dielectric. The performance of the developed machine is observed using following conditions:

- Liquid dielectric
- Mixture of liquid and gas dielectric
- Gaseous dielectric

**Keywords:** Micro WEDM, Kerf width, Material removal rate (MRR), Dielectric, Dry micro WEDM.

**Contributions of current work:**

- An erosion model for micro WEDM considering micro scale heat transfer phenomenon has been proposed. The model can be used to predict the temperature distribution along the work piece as well as estimate material removal rates.
- The effect of various process parameters like discharge energy, wire feed and wire tension on machining characteristics is observed. It will help for better process
control in improving the performance of micro WEDM. The feasibility of gas and air assisted machining for improving MRR has been explored.

- A table top near dry micro WEDM setup has been developed using retrofit design concepts. Usage of gas as dielectric is studied and it may lead towards reducing environmental and health hazards. An indigenous machine is developed which is user friendly and is developed in frugal budget.

Organization of the thesis

The primary objective of the present research work is to analyze the micro WEDM process, while processing of difficult to machine materials. Chapter 1 represents introduction to WEDM and Micro WEDM process. Chapter 2 includes detail literature survey considering papers in the field of Micro-EDM/WEDM and development of dry Micro WEDM set up. In Chapter 3 development of thermal model considering micro-scale heat transfer concepts is reported. The pilot experiments performed and the details of experiments undertaken are discussed in Chapter 4. Chapter 5 describes development of a table top near dry micro WEDM setup considering retrofit design concept. The detail experiments to explore capabilities of developed setup and the results obtained by performing experiments using different combinations of dielectric are also discussed in detail in this chapter. The experimental results obtained and allied discussions are represented in Chapter 6 ‘Results and Discussion’. The conclusions drawn from the analysis of the process using existing setup and from the experimentation carried out on new set up are communicated in Chapter 7. Scope for future work is also suggested in the same chapter.