5.11 ELECTROCHEMICAL MICROMACHINING (ECM)

Micro electrochemical machining (ECM) or electrochemical micromachining has become more popular with recent advancements to fulfil the needs of the fabrication of macro and micro components. With rapid developments in the fields of automotive, aerospace, electronics, optics, medical devices and much more, this process finds wide

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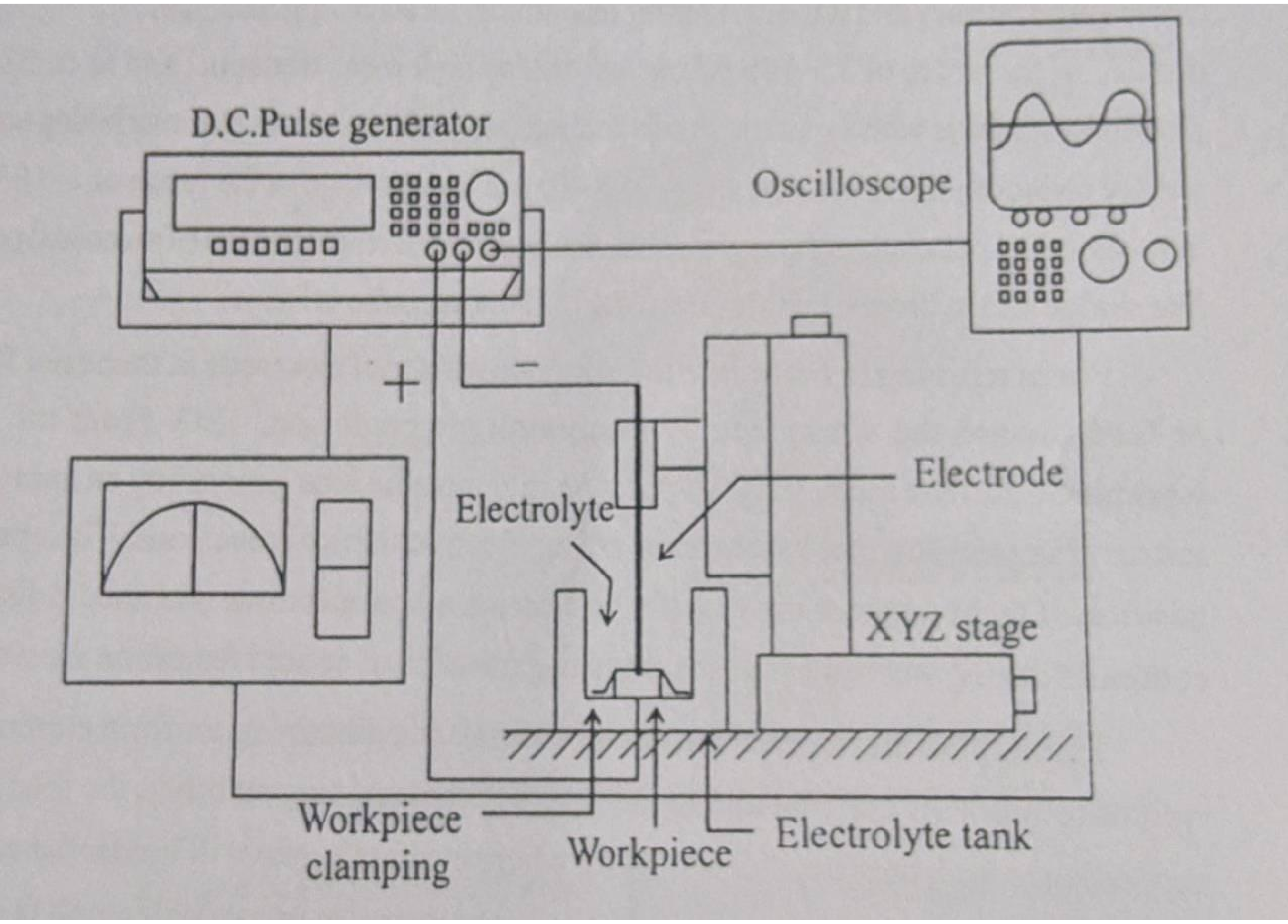
applications in the machining of titanium and titanium alloys, super alloys and stainless steel structures which are difficult to machine and pose many challenges for conventional machining processes.

This process provides added advantages in the shaping of complex features with no thermal stress, burr formation and tool wear and can be implemented on metals regardless of their hardness which facilitates it to execute precision jobs with accuracy in the order of ±1 μm on 50 μm. Governed by the laws of electrolysis of Michael Faraday, this process removes material by the mechanism of anodic dissolution during electrolysis, where it is possible to achieve unit material removal as the size of ions that makes the process extremely useful for machining delicate and complex micro features.

But still, research is needed to explore further opportunities and overcome the challenges in machining different newer materials with greater accuracy for successful generation of more intricate micro features. A schematic diagram of electrochemical micromachining setup is shown in Fig. 5.8.


D.C.Pulse generator
Oscilloscope
+
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Electrode
Electrolyte
XYZ stage
Workpiece
clamping
Workpiece
Electrolyte tank

As discussed earlier, electrochemical micromachining is an electrochemical material dissolution process where both cathode micro tool and anode workpiece remains submerged in proper electrolytic solution separated by narrow inter-electrode gap (IEG). IEG controls the dimensional accuracy as well as resolution of the micro feature to be produced and the lower will be the IEG, the better will be the localization of anodic dissolution.

There are two types of electrolyte available for EMM, one is passivating that contains oxidizing anions which give better accuracy such as sodium nitrate, sodium chlorate, etc. and other one is non-passivating such as sodium chloride which contains aggressive anions. Also, different acid electrolytes such as sulfuric acid, hydrochloric acid, etc. are preferable which does not produces any insoluble reaction products.

The electrolyte needs to be in static condition during operation as introducing high electrolyte flow like conventional ECM may vibrate the micro tool tip and deteriorate the machining accuracy and stability. During machining, for achieving instantaneous high current density in the order of 75–100 A/cm^2 as well as high mass transport and to confine the dissolution process with in micron or sub-micron ranges, for enhancing the machining accuracy and for reducing the IEG in the range of 5–20 μm, low voltage in the range of 1–10 V with ultra-short DC pulse current is applied that also ensures effective removal of machined products like sludge and hydrogen bubbles from the IEG during pulse off time.

For machining to occur, the micrometer scale tool electrode is then feed forward or feed toward the workpiece by maintaining a predefined IEG. From the anodic workpiece, surface metal starts dissolving into metallic ions generating an approximate mirror image of the tool by corresponding electrochemical reactions. The corrupting position of the workpiece varies with the location of tool electrode and anodic dissolution continues during whole the time resulting in generation of desired feature on the workpiece.

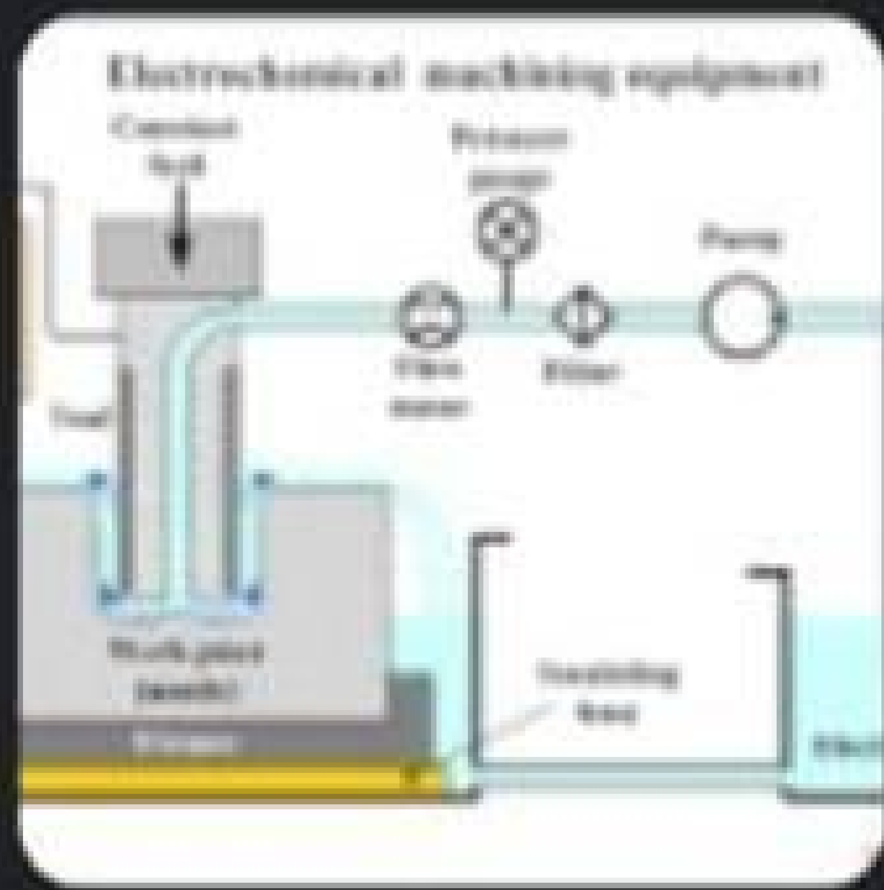
Throughout the material removal process, for maintaining uniform current flow as well as removal of material and to achieve better machining stability, the feed of tool is kept balance with the rate of dissolution, where increase in gap will hinder the machining process by increasing electrolyte resistance and decrease in gap will result in improper flushing and coagulation of reaction products leading to occurrence of frequent short circuits in the machining zone.

However, still during machining, machining products like gas bubbles, sludge, etc. resulting from on-going electrochemical reactions may stick between the micro tool and the workpiece which can clog the small IEG that may lead to formation of micro sparks and deterioration of machining quality and accuracy.

What are the applications of electrochemical machining?

ECM is used to machine work pieces from metal and metal alloys irrespective of their hardness, strength or thermal properties, through the anodic dissolution, in **aerospace, automotive, construction, medical equipment, micro-systems and power supply industries**.

Advantages of electrochemical machining:



- The rate of machining does not depend on the hardness of the work piece material.
- The tool does not wear. ...
- No stresses are produced on the work piece surface.
- No burrs form in the machining operation.
- High surface quality may be achieved.
- High accuracy of the machining operation.

Disadvantages and Limitations of ECM Process:

(i) **All non-conducting materials cannot be machined**. (ii) Total material and workpiece material should be chemically stable with the electrolyte solution. (iii) Designing and making tool is difficult but its life is long so recommended only for mass production.