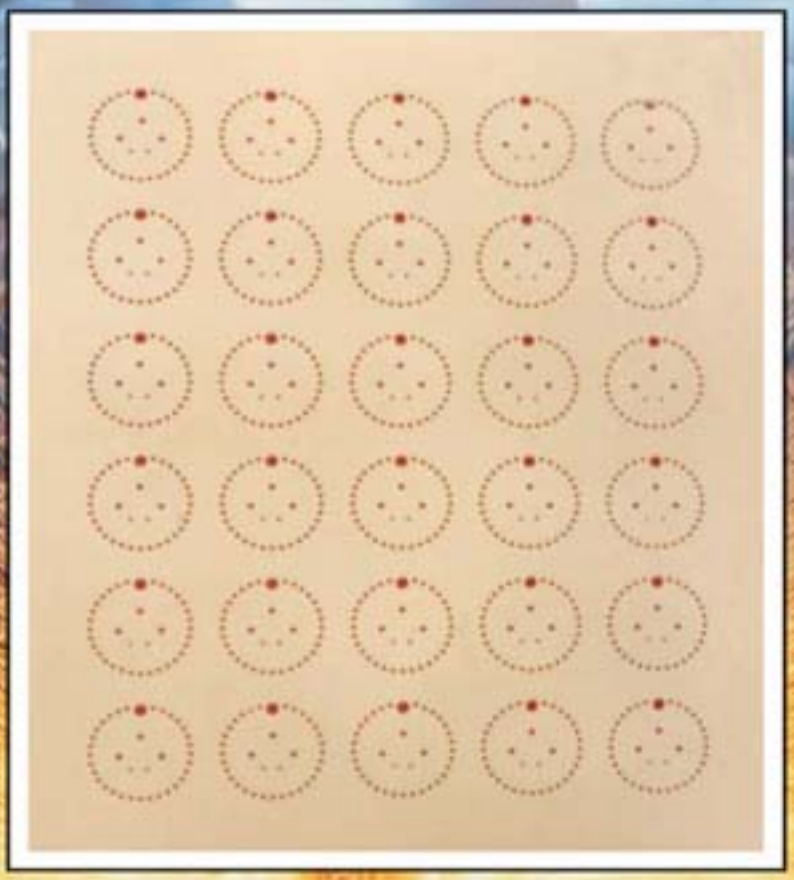
Modern Machining Methods & Machining of Advanced Ceramics

Dr. M. Adithan



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Dr. M. ADITHAN
Professor in Mechanical Engineering and Dean
VIT University
Vellore-632 014, Tamil Nadu

KHANNA PUBLISHERS
4575/15, ONKAR HOUSE, OPP. HAPPY SCHOOL
DARYAGANJ, NEW DELHI-110002
Phone : **2324 30 42 ;** *Fax* : **2324 30 43**
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Preface

Modern Machining Methods which are discussed in this book belong to the category of **Non-Traditional Machining methods**. In the early stages of development, the investigations in the area of "modern machining methods" were almost purely academic in nature. Today, the modern machining methods are no longer mere laboratory processes ; these processes have already entered many production lines.

By modern machining methods, we mean : **Spark erosion machining, ultrasonic machining, chemical machining, electro-chemical machining, electro-chemical grinding, abrasive jet machining, plasma arc machining, electron beam machining and laser beam machining process.** Within a short period of development of these processes, their tremendous advantages and applications have caught up the imagination of the industries and their applications are rapidly increasing in various manufacturing sectors all over the country. These new processes have enabled us to achieve a breakthrough in many manufacturing methods and has given enough stimulus to industries to cut down the imports and increase the exports of quality engineering goods to a much greater extent. Successful applications of many of these processes have given us confidence in our ability to successfully adopt these new techniques and thereby compete with the developed countries of the world.

What are the trends in the engineering field that have been made responsible for the development of these modern machining methods ? Firstly, the need for higher and higher accuracy resulting in the development of machines and equipment of higher and higher precision ; secondly, the need to produce in abundance for the benefit of increasing population which resulted in increased resort to automation in production thereby stimulating the development of newer techniques ; and thirdly, the increasing demand for high strength materials for newer applications which necessitated development of newer machining methods capable of machining these materials which possess high strength and high hardness. It is perhaps, the aero-space field and the demands of this industry that gave birth to unconventional or modern machining methods. The conventional techniques *e.g.,* turning, drilling, milling, etc. as are well known involve the use of mechanical energy between the

workpiece and the tool whereas this need not be the case with unconventional or modern machining techniques. Consequently it is not necessary to use tools harder than the work to be shaped, which means the tool making is made more easy.

Many unconventional machining methods use electrical energy in the working zone to remove the material and hence they are called electrical machining methods.

In the aero-space field, a prime requirement is the very high strength-to-weight ratio of structural components employed. The high strength alloys have to be heat resistant because of the high temperature region in which they have to operate. The material strength tends to decrease with increasing temperature and the creep behaviour of materials becomes very important at high temperature. Conventional machining of high strength materials poses problems because for penetrating into the work-piece, a harder tool has to be used. And with heat resisting materials, there is the added problem that they are poor thermal conductors and hence the heat generated is not dissipated but gets localised in the tool chip zone area thereby increasing the tool wear. For example, Titanium which is used very much in aero-space industry is a very difficult-to-machine material. Even at low speeds of machining, Titanium poses very special problems. But with modern machining techniques, machining of Titanium is made more easier.

The turbine blades at the hot end of a gas turbine have to operate at temperatures of the order of 12,000°C. To operate properly and effectively at such temperatures, nimonic alloys have to be used. These tough materials with very high heat resistance have to be machined to the complex contour of the turbine blade to very exacting tolerances and specifications. Although conventional techniques have been used, **Electro-Chemical Machining (ECM)** has been developed by Rolls Royce in turbine blade manufacture and this technique is extensively used for blade manufacture. ECM is essentially an electrolytic machining process. Fully automatic ECM machines are available for machining of aero-engines' turbine blades for aircraft industries, as well as for machining of turbine blades required for power generation plants.

Another process which is in wide use in machining high strength alloys and hardened die blocks is the **Spark Erosion Machining (SEM) or EDM** as it is sometimes called.

Both these techniques, namely ECM and EDM, have much wider applications than in the aero-space industry, in particular

in the manufacture of dies and moulds ; and in general in the machining of very hard materials.

With the development of special hard materials for various applications, the spark erosion machining is found to be the most efficient method for metal cutting. The chief merit of this process is its capability to handle electrically conductive materials of any hardness and to do such jobs which do not lend themselves to conventional machining. Another advantage is the reproduction of any complicated pattern automatically by the electrode into the workpiece. Other advantages which follow from these are reduced manufacturing cost and better finish on a spark eroded surface. With introduction of EDM, die and tool making is no longer an art, and it is now a standard technique available to any trained operator.

Electrical discharge machines EDM (spark erosion machines) with electro-hydraulic controlled servoheads and with transistorized solid-state power supply units are being manufactured in our country also.

Another unconventional technique used in the aerospace industry is the **Electron Beam Machine** for welding as well as for machining purposes. For example, this technique is used for welding of Titanium fuel tanks in rockets. This technique has the very important advantage of giving a high depth-to-width ratio in welding and permits easy access to complex and intricate components and parts for both machining and for filling up in salvage operations of costly aerospace components. Metals that can be worked with EBM are : Tungsten, Titanium, Tantalum, Nimonics, Stainless Steel and Zirconium. The success of the Concorde is due to the ability of EBM process, to machine precisely and finely the fuel orifices of the reaction bonded silicon nitride (a kind of ceramic) nozzles used in its jets.

Another unconventional technique full of promise and potential is the **laser beam technique.** In fact, laser technology has come up to cater to the need for drilling diamond and watch jewels and for welding the hither-to non-weldable materials. Similarly, rapidly increasing uses of electronics and computers have stimulated the development of many new technological processes.

Techniques like **Chemical Machining CHM** are also used in the aerospace industry. However, it does not mean that all the unconventional machining techniques owe their origin to the demands of the aero-space industry only, for such an impression is certainly wrong. The fields such as nuclear engineering, electronics and modern space technology have also necessitated the

development of unconventional machining techniques. The cite an example, **Ultrasonic Machining USM** has no specific application to the aero-space industry. But this techniques is most ideal to machine materials having the properties of high hardness and impact brittleness such as glass and ceramics. Whereas in both ECM and EDM, only electrically conductive materials can be machined, in ultrasonic machining non-conductive materials such as glass, porcelain and ceramics can be machined easily.

All these modern machining processes are invariably costly. However, adoption of these modern machining methods even when they are costly or expensive is tolerated or justified when we consider their potentialities and capabilities. This may not be true in certain industrial applications, so that cost-benefits analysis have to be properly worked out before embarking on these unconventional techniques.

These modern machining techniques have their own role and importance ; we should not make the mistake of imagining that they are going to throw overboard the many conventional techniques used in the past and today. Modern machining methods are not replacements for conventional methods. Modern machining methods are only complementary to existing methods of machining. While the modern machining techniques will be required for many specific applications and purposes in the new sophisticated areas of technology such as nuclear, aero-space and electronics the conventional machining techniques will continue to have a significant role in the manufacturing processes.

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VIT University
Vellore, Tamil Nadu

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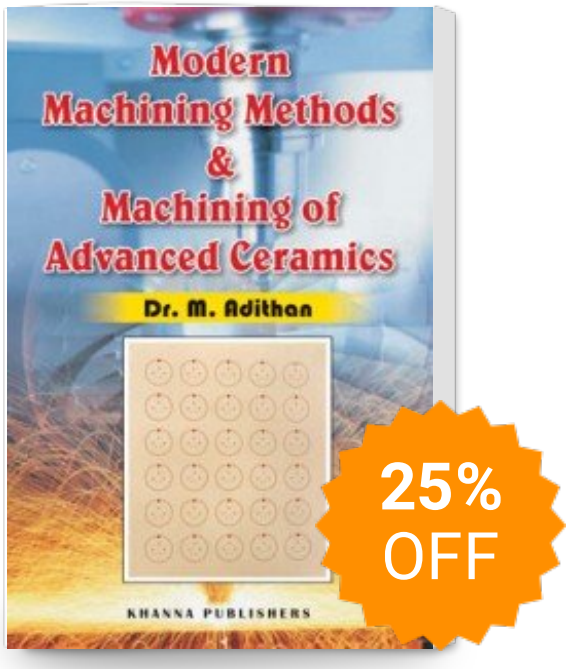

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