Chapter 1

Introduction to Hybrid Machining Technology

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Organization of the presentation

1. Overview of Machining Technology
   (Introduction to Machining Processes, Advances, and New Challenges)

2. Classification of Hybrid Machining Processes
   (Concept and Definition)

3. Major Elements of Hybrid Machining Technology
   (Hybrid Machine Tools, Hybrid Tooling, Hybrid Machining Processes, Metrology System,
   Work Handling System, Process Monitoring Technique)

4. Benefits of Hybrid Machining Technology

5. Challenges and Opportunities

6. Conclusions and Future Research
1. Overview of Machining Technology

Machining operations can be classified into two groups [1]:
(1) Mechanical Machining  (2) Non traditional Machining

- Mechanical Machining
  - Turning
  - Grinding
  - Milling

- Other operations
1. Overview of Machining Technology

Non traditional Machining

- Mechanical Energy Processes
  - Ex. USM
  - WJC

- Electrochemical Processes
  - Ex. ECM

- Thermal Energy Processes
  - Ex. EDM
  - LBM
  - EBM

- Chemical Machining Processes
  - Ex. CHM
  - PCM
1. Overview of Machining Technology

Advances and New Challenges in Machining Processes

Ultra precision machining processes are able to achieve a very high accuracy from 10 nm to 100 nm and material removal rate above $10^{-4}$ mm$^3$/sec.

Highly accurate 3D complex parts are made via variety of separate high precision machining processes. It therefore results in a long process chain and lead time.

**Multifunctional machines/machining centers** are developed by key machine builders like Mazak, DMG Mori, and Okuma to solve this problem. Such centers helps in drastically reducing the machining time.
1. Overview of Machining Technology

Advances and New Challenges in Machining Processes

Traditional Machining Processes

Multifunctional Machining Process

Combining traditional mechanical machining processes with non traditional machining processes can help utilize the advantages of one process and compensate for shortcomings of the other process. **This results in the hybrid machining technology.**
2. Classification of Hybrid Machining Processes

**Definition:** Hybrid machining technology is the integration of traditional and non-traditional machining processes on the same machine platform with the objective to obtain “1+1=3” effect.

Hybrid Machining Processes are classified into 3 groups.

- Assisted Hybrid Machining
- Combined Hybrid Machining
- Controlled application of process mechanisms
2. Classification of Hybrid Machining Processes

**Assisted Hybrid Machining:** The major machining process is superimposed with inputs from one or several types of energy such as ultrasonic vibration, laser, fluid, magnetic field etc. to improve the constituent machining process [2][3].

**Examples:** Laser assisted  
Vibration assisted  
Fluid assisted  
Magnetic field assisted  
Abrasive assisted  
External electric field assisted  
Heat assisted  
Media assisted  
(Cryogenic fluid, gas, carbon nanotube)

![Figure: Laser assisted turning](image)
2. Classification of Hybrid Machining Processes

**Combined Hybrid Machining:** All the constituent machining processes simultaneously contribute to the material removal and affect the machining zone. Such processes have a great potential to produce complex parts with enhanced material removal rate, surface integrity and dimensional accuracy in a relatively short processing time [4][5][6].

**Examples:** Electrochemical discharge  
Laser-electrochemical  
Electrochemical grinding  
Electric discharge grinding  
EDM-ER fluid assisted polishing  
Mechano-electrochemical

![Figure: Electrochemical Spark Machining](image-url)
2. Classification of Hybrid Machining Processes

**Controlled application of process mechanisms:** Material removal process mechanisms of two different processes are simultaneously combined and controlled to achieve desired results [7].

**Examples:** Hybrid abrasive water jet and milling process
Grind hardening process
Electrochemical-Electric discharge milling process

![Electrochemical-Electric discharge milling process](image)
3. Major Elements of Hybrid Machining Technology

Hybrid Platform

- Hybrid Machine Tool
- Hybrid Tooling
- On-Machine metrology system
- Work handling system

Hybrid Machining Process

Process Modelling
3. Major Elements of Hybrid Machining Technology

(A) Hybrid Machine Tool: It can be defined as a power driven machine used for producing a variety of shapes and sizes in metals or other solid materials by removing away redundant work materials through **different hybrid machining processes** [8].

Such machine tools are categorized into three groups.
3. Major Elements of Hybrid Machining Technology

(i) Sequential

Sequential Hybrid Machines

These machines are built under the philosophy of integrating sequential machining processes in one machine platform, where machining processes take place one after the other. All the machining processes occur in one coordinated system, there is no need to transfer the workpiece from one machine to another.

Ex. Hybrid μ-EDM Machine DT-110
3. Major Elements of Hybrid Machining Technology

(ii) Assisted

These machines are used to implement hybrid machining process. Ultrasonic hybrid machine is the most popular and commercially successful machine tool. It is particularly useful for machining hard-to-machine materials. For example, in turning operation, conventional tool post is replaced by a ultrasonic tool post [9].
3. Major Elements of Hybrid Machining Technology

(iii) Combined

Combined Hybrid Machines

These machines combine material removal mechanisms of two different machining processes under one platform to perform simultaneous machining. Such hybrid machines are used for achieving combined material removal rate higher than rates of individual machining process.

Ex. Mechano-Electrochemical Milling (MECM, developed by KU Leuven University)
3. Major Elements of Hybrid Machining Technology

(B) Hybrid Tooling: The Hybrid tooling combines two or more established processing modules into one tooling device in order to achieve desirable material removal effect. Some examples are as follows:

- Laser Assisted Turning Tool Holder
- Laser Micro-Jet Tooling
- Ultrasonic Assisted Turning Tool Holder
- Ultrasonic Assisted Milling-Grinding Tool Holder
3. Major Elements of Hybrid Machining Technology

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(C) On-Machine Metrology System: On machine monitoring (OMM) is very important in hybrid machining processes as it can avoid time-consuming realignment operations and possible damage during the transportation between machine tool and measurement platform. It can therefore further enhance machining accuracy and efficiency [11].

Two major tasks for OMM are:

(i) **Dimensional Metrology.**
(ii) **Surface Metrology.**

In the above mentioned two tasks, both contact metrology and non-contact metrology play key roles.
3. Major Elements of Hybrid Machining Technology

(i) Contact Metrology

Parallel Kinematics Probe: Uses linearly movable styli and flat probe tips. It uses incremental sensors to measure the displacement of each stylus. The lines of measurement of the probes are typically arranged orthogonal to each other and perpendicular to the sphere surface. The three measurement line passes approximately through the center of the sphere. This probe demonstrates repeatability of less than 0.5 μm and an error range of less than 2 μm throughout the large measurement range of the probe [1].
3. Major Elements of Hybrid Machining Technology

(ii) Non-Contact Metrology

Optical methods of metrology are the fastest and most reliable methods of OMM applications. Optical techniques can operate effectively over scales ranging from few nanometers to few meters meaning that there is a high level of applicability across many types of manufacturing.

Due to working volume constrictions and cost implications, a single-point optical method, namely dispersed reference interferometry is used in online monitoring for hybrid machines [1].

Example: NanoCam from 4D Technology
3. Major Elements of Hybrid Machining Technology

(C) Work Handling System

Hybrid Machining requires automated handling of the workpiece. Use of robotic handling systems have become a commonplace in recent years. These standard workpiece handling robots are fully automated and usually have tech-in functions for different workpieces which provide great flexibility for different operations.

As in hybrid machines, multiple processes are integrated on one machine platform, the workpiece handling system needs to be within and as a part of the hybrid machine [1].
4. Benefits of Hybrid Machining Technology [1][12][13]

1. Hybrid Machining makes it possible to machine hard-to-machine materials that may not be possible by conventional approach. For instance, diamond turning tools will experience severe thermochemical tool wear when machining ferrous metals. Applying ultrasonic assisted diamond turning, an optical quality surface (Ra < 5nm) can be achieved on hardened steel for mould manufacturing.

2. Improving the existing process capabilities in terms of improved surface finish, surface integrity, tool life etc. For example, compared with conventional diamond grinding, a 30 % improvement of machined surface finish has been achieved along with a defect free subsurface in dry LAM of Si₃N₄ and Al₂O₃.

3. Reducing machining time and production cost. As hybrid machining takes place on the same machine bed, there is no need to transfer and reposition the workpiece at different times. The setup time is therefore reduced.
4. Benefits of Hybrid Machining Technology [1][12][13]

4. Gaining significant benefits of interactions of different process energies. For example ECDM combines electrochemical and electric discharge process energies.
5. Challenges and Opportunities [1]

There are two types of challenges in Hybrid Machining Processes:
(a) Scientific Challenges  (b) Technical Challenges

(a) Scientific Challenges:
1. **Machining mechanism of Hybrid Machining:**
Understanding fundamental material removal and surface generation mechanisms is very important to improve the machining accuracy and efficiency.

2. **Multi-scale and Multi-physics modelling:**
Hybrid machining is a complicated machining process. The working zone is usually under the actions involving mechanical, electrical, thermal or chemical energies.
5. Challenges and Opportunities

3. Online metrology for surface integrity
One of the benefits of Hybrid machining is to improve surface integrity. However, currently there is no method to realize on line measurement of surface integrity. It therefore, needs a new reliable measurement approach.

(b) Technical Challenges

1. Hybrid machining system integration:
The integration of a number of machining systems into one compact machine platform proposes a big technical challenge in terms of kinematic design and dynamic design.

2. Hybrid system control:
The material removal in hybrid machining is through not only mechanical motion but also other electrical or thermal processes. Controlling the complex system, therefore, becomes another technical challenge for implementation.
5. Challenges and Opportunities

3. Online metrology: Implementing the surface sensor in a real production floor will need to overcome influences from environmental vibrations, thermal deformations, humidity, and obstacles from cutting chips, fluids, etc.
6. Conclusions and Future Research

Hybrid machining technology offers great potentials in obtaining high quality products with great efficiency productivities, accuracy, and energy efficiency. The future research and development focus for hybrid machining technology is envisage in the following aspects [14]:

1. Development of specific multi-axis hybrid machine tools.

2. Opportunities for improving process monitoring techniques.

3. Development of on-machine tool fabrication and metrology techniques.

4. Establishment of noble processes.

5. Cost effectiveness study.

6. Industrial implementation.
References


References


Thank You