Introduction to Non-Traditional Machining BME405A

ATME College of Engineering

GOLD QS I-GAUGE INDIAN COLLEGE RATINGS

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DEPARTMENT OF MECHANICAL ENGINEERING -ATME-

Introduction to Non-Traditional Machining

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COURSE SYLLABUS

Course Code	BME405A	CIE Marks	40
Number of Lecture Hours/Week	03 Hours	SEE Marks	60
RBT Levels	L1, L2, L3	Exam Hours	03
Credits – 03			

Course Objectives:

- To learn various concepts related to modern machining processes & their applications.
- To appreciate the differences between conventional and non-conventional machining processes.
- To acquire a functional understanding of non-traditional manufacturing equipment.
- To know about various process parameters and their influence on performance and their applications.
- To impart knowledge on various types of energy involved in non-traditional machining processes.

Syllabus of Non-Traditional Machining (NTM)

MODULE 1 - INTRODUCTION

Introduction to Non-traditional machining, Need for Non-traditional machining process, Comparison between traditional and non-traditional machining, general classification Non- traditional machining processes, classification based on nature of energy employed in machining, selection of non-traditional machining processes, Specific advantages, limitations and applications of non-traditional machining processes.

MODULE 2

Ultrasonic Machining (USM): Introduction, Equipment and material process, Effect of process parameters: Effect of amplitude and frequency, Effect of abrasive grain diameter, effect of slurry, tool & work material. Process characteristics: Material removal rate, tool wear, accuracy, surface finish, applications, advantages & limitations of USM.

Abrasive Jet Machining (AJM): Introduction, Equipment and process of material removal, process variables: carrier gas, type of abrasive, work material, stand-off distance (SOD). Process characteristics-Material removal rate, Nozzle wear, accuracy & surface finish. Applications, advantages & limitations of AJM.

Syllabus of Non-Traditional Machining (NTM)

MODULE 3

ELECTROCHEMICAL MACHINING (ECM)

Introduction, Principle of electro chemical machining: ECM equipment, elements of ECM operation, Chemistry of ECM. ECM Process characteristics: Material removal rate, accuracy, surface finish.

Process parameters: Current density, Tool feed rate, Gap between tool & work piece, velocity of electrolyte flow, type of electrolyte, its concentration temperature, and choice of electrolytes. ECM Tooling: ECM tooling technique & example, Tool & insulation materials.

Applications ECM: Electrochemical grinding and electrochemical honing process. Advantages, disadvantages and application of ECG, ECH

CHEMICAL MACHINING (CHM)

Elements of the process: Resists (maskants), Etchants. Types of chemical machining process- chemical blanking process, chemical milling process.

Process characteristics of CHM: material removal rate, accuracy, surface finish, advantages, limitations and applications of chemical machining process

Syllabus of Non-Traditional Machining (NTM)

MODULE 4

ELECTRICAL DISCHARGE MACHINING (EDM)

Introduction, mechanism of metal removal, EDM equipment: spark erosion generator (relaxation type), dielectric medium-its functions & desirable properties, electrode feed control system. Flushing types; pressure flushing, suction flushing, side flushing, pulsed flushing. EDM process parameters: Spark frequency, current & spark gap, surface finish, Heat Affected Zone. Advantages, limitations & applications of EDM, Electrical discharge grinding, Traveling wire EDM.

PLASMA ARC MACHINING (PAM)

Introduction, non-thermal generation of plasma, equipment mechanism of metal removal, Plasma torch, process parameters, process characteristics. Safety precautions. Safety precautions, applications, advantages and limitations.

Syllabus of Non-Traditional Machining (NTM)

MODULE 5

LASER BEAM MACHINING (LBM)

Introduction, generation of LASER, Equipment and mechanism of metal removal, LBM parameters and characteristics, Applications, Advantages & limitations.

ELECTRON BEAM MACHINING (EBM)

Introduction, Principle, equipment and mechanism of metal removal, applications, Advantages & limitations.

Course Outcomes

1. **Describe** non-traditional machining process and **compare** with traditional machining process. **Recognize** the need for Non-traditional machining process
2. **Describe** the constructional features, performance parameters, process characteristics, applications, advantages, and limitations of USM and AJM .
3. **Characterize** the need of Chemical and electro-chemical machining process along with the constructional features, process parameters, process characteristics, applications, advantages, and limitations.
4. **Illustrate** the constructional feature of the equipment, process parameters, process characteristics, applications, advantages and limitations EDM & PAM.
5. **Elucidate** the LBM equipment, LBM parameters, and characteristics. **Describe** EBM equipment and mechanism of metal removal, applications, advantages and limitations LBM & EBM.

CO –PO Mapping

Subject Code:	BME405A	TITLE: Non-Traditional Machining					Faculty Name: Dr. Chethan S				
List of Course Outcomes	Program Outcomes										
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO-1	2	3	-	-	-	-	-	-	-	-	2	2
CO-2	2	3	-	-	-	-	3	-	-	-	2	2
CO-3	2	3	-	-	-	-	3	-	-	-	2	2
CO-4	2	3	-	-	-	-	3	-	-	-	2	2
CO-5	2	3	-	-	-	-	3	-	-	-	2	2
CO Avg	**2.00**	**3.00**	**-**	**-**	**-**	**-**	**3.00**	**-**	**-**	**-**	**2.00**	**2.00**

Module 1

INTRODUCTION

Non-traditional Processes Definition

A group of processes that remove excess material by various techniques involving mechanical, thermal, electrical, or chemical energy (or combinations of these energies) but **do not use a sharp cutting tool** in the conventional sense

Non-traditional Machining Processes

Manufacturing processes can be broadly divided into two groups:

primary manufacturing processes : Provide basic shape and size

secondary manufacturing processes : Provide final shape and size with tighter control on dimension, surface characteristics

Material removal processes once again can be divided into two groups

Conventional Machining Processes

Non-Traditional Manufacturing Processes or non-conventional Manufacturing processes

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition

Conventional Machining

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition

The major characteristics of conventional machining are:

1. Generally macroscopic chip formation by shear deformation
2. Material removal takes place due to application of cutting forces – energy domain can be classified as mechanical
3. Cutting tool is harder than work piece at room temperature as well as under machining conditions

Major characteristics of Non-conventional machining

1. Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level.
2. In NTM, there may not be a physical tool present. For example in laser jet machining, machining is carried out by laser beam. However in Electrochemical Machining there is a physical tool that is very much required for machining.
3. In NTM, the tool need not be harder than the work piece material. For example, in EDM, copper is used as the tool material to machine hardened steels.
4. Mostly NTM processes do not necessarily use mechanical energy to provide material removal. They use different energy domains to provide machining. For example, in USM, AJM, WJM mechanical energy is used to machine material, whereas in ECM electrochemical dissolution constitutes material removal.

Traditional vs Non Traditional Machining

	Conventional Process	Non-Conventional Process
1	The cutting tool and work piece are always in physical contact with relative motion with each other, which results in friction and tool wear.	There is no physical contact between the tool and work piece, In some non-traditional process tool wear exists.
2	Material removal rate is limited by mechanical properties of work material.	NTM can machine difficult to cut and hard to cut materials like titanium, ceramics, nimonics, SST, Composites materials.
3	Relative motion between the tool and work is typically rotary or reciprocating. Thus the shape of work is limited to circular or flat shapes. In spite of CNC systems, production of 3D surfaces is still a difficult task.	Many NTM are capable of producing complex 3D shapes and cavities.
4	Machining of small cavities, slits, blind holes or through holes are difficult	Machining of small cavities, slits and Production of non-circular, micro sized, large aspect ratio, shall entry angle holes are easy using NTM

Traditional vs Non Traditional Machining

	Conventional Process	Non-Conventional Process
5	Use relative simple and inexpensive machinery and readily available cutting tools	Non-traditional processes requires expensive tools and equipment as well as skilled labour, which increase the production cost significantly
6	Capital cost and maintenance cost is low	Capital cost and maintenance cost is high
7	Traditional processes are well established and physics of process is well understood	Mechanics of Material removal of Some of NTM process are still under research
8	Conventional process mostly uses mechanical energy	Most NTM uses energy in direct form For example : laser, Electron beam in its direct forms are used in LBM and EBM respectively
9	Surface finish and tolerances are limited by machining inaccuracies	High surface finish(up to 0.1 micron) and tolerances (25 Microns) can be achieved
10	High metal removal rate.	Low material removal rate.

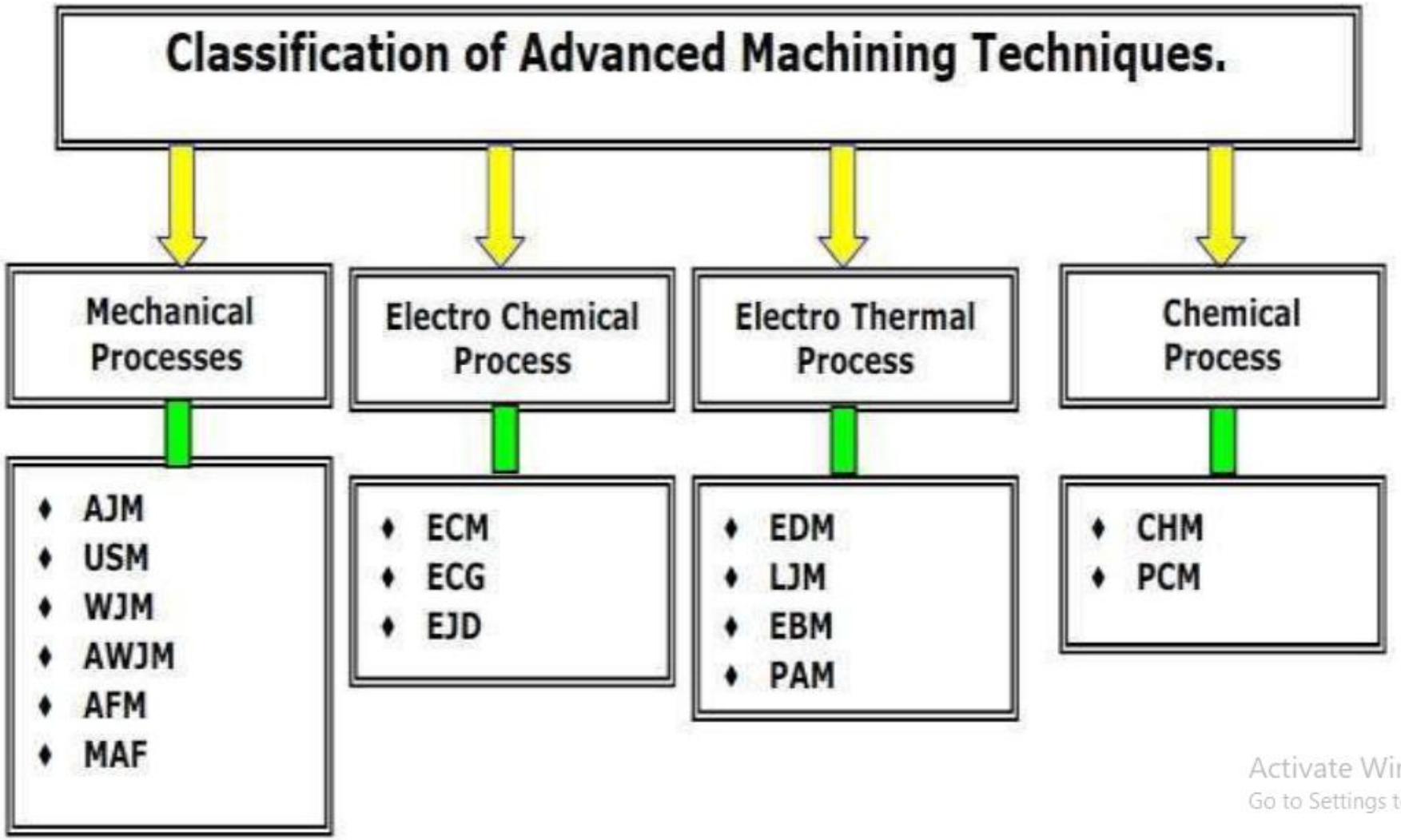
Classification of unconventional machining process

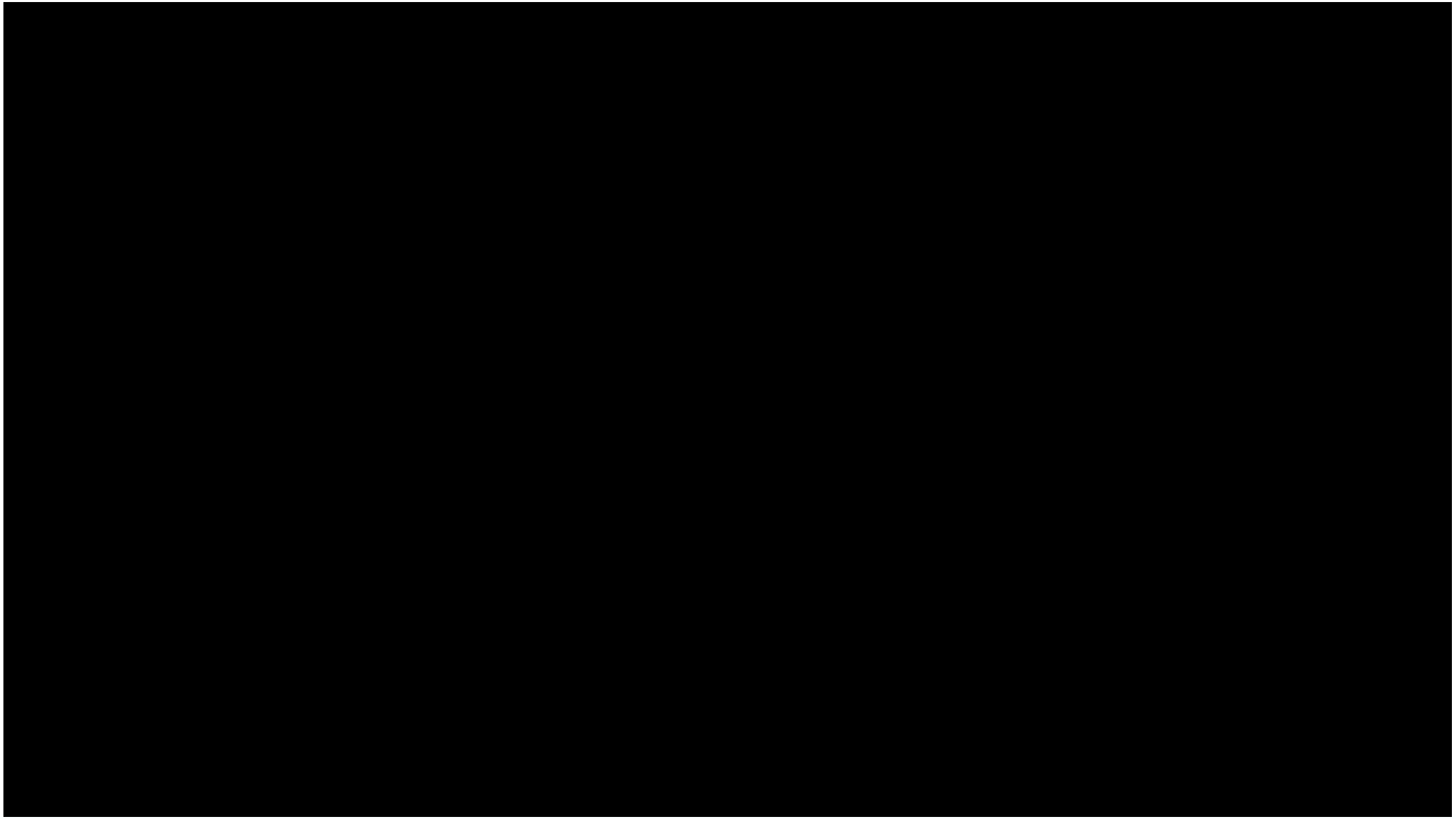
1. Mechanical - erosion of work material by a high velocity stream of abrasives or fluid (or both) is the typical form of mechanical action
2. Electrical - electrochemical energy to remove material (reverse of electroplating)
3. Thermal – thermal energy usually applied to small portion of work surface, causing that portion to be removed by fusion and/or vaporization
4. Chemical – chemical etchants selectively remove material from portions of workpart, while other portions are protected by a mask

Classification of Unconventional Machining Process

1. Mechanical Processes
   - Abrasive Jet Machining (AJM)
   - Ultrasonic Machining (USM)
   - Water Jet Machining (WJM)
   - Abrasive Water Jet Machining (AWJM)
2. Electrochemical Processes
   - Electrochemical Machining (ECM)
   - Electro Chemical Grinding (ECG)
   - Electro Jet Drilling (EJD)
3. Electro-Thermal Processes
   - Electro-discharge machining (EDM)
   - Laser Jet Machining (LJM)
   - Electron Beam Machining (EBM)
4. Chemical Processes
   - Chemical Milling (CHM)
   - Photochemical Milling (PCM)

Classification of Unconventional Machining Process



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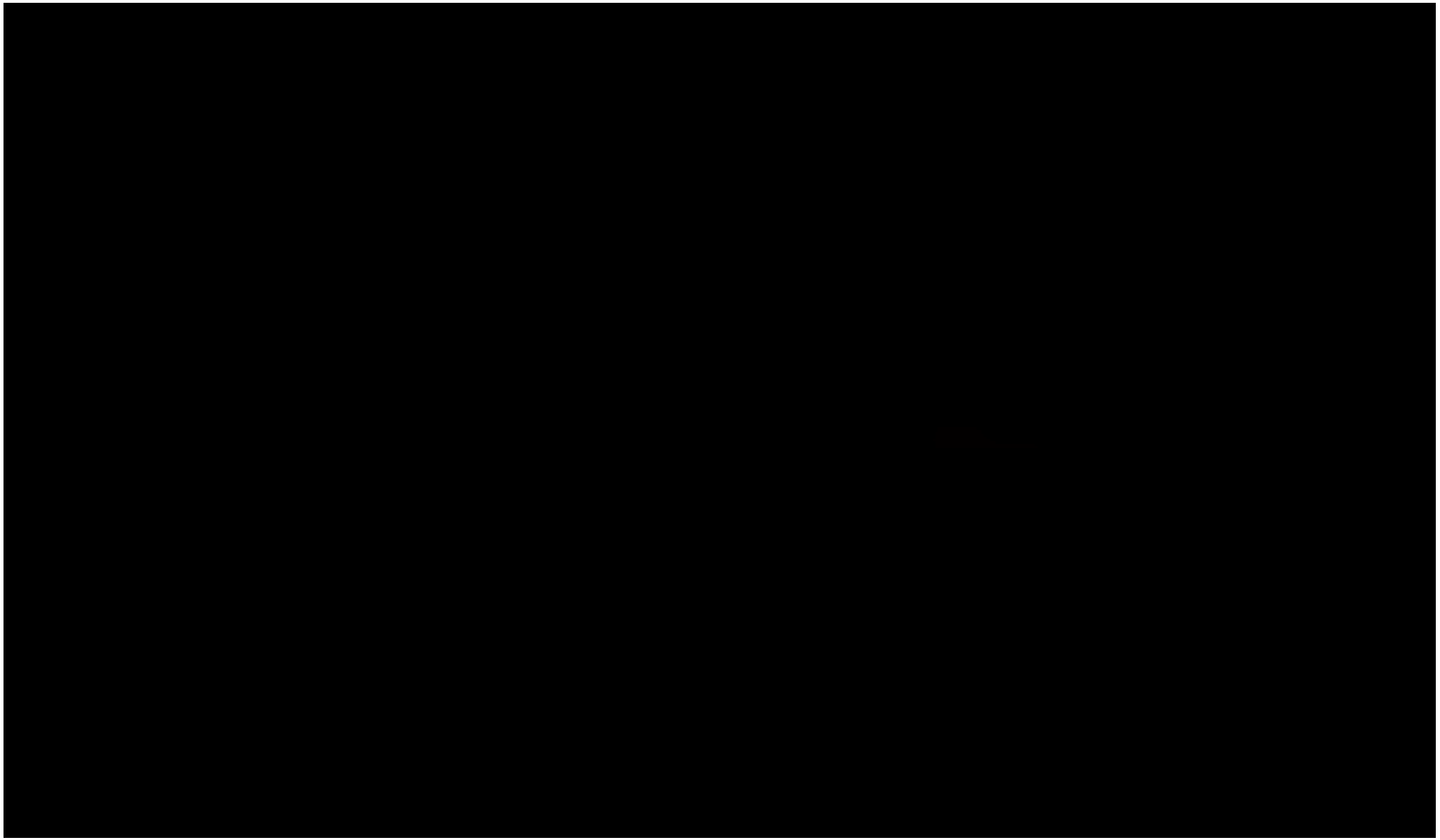
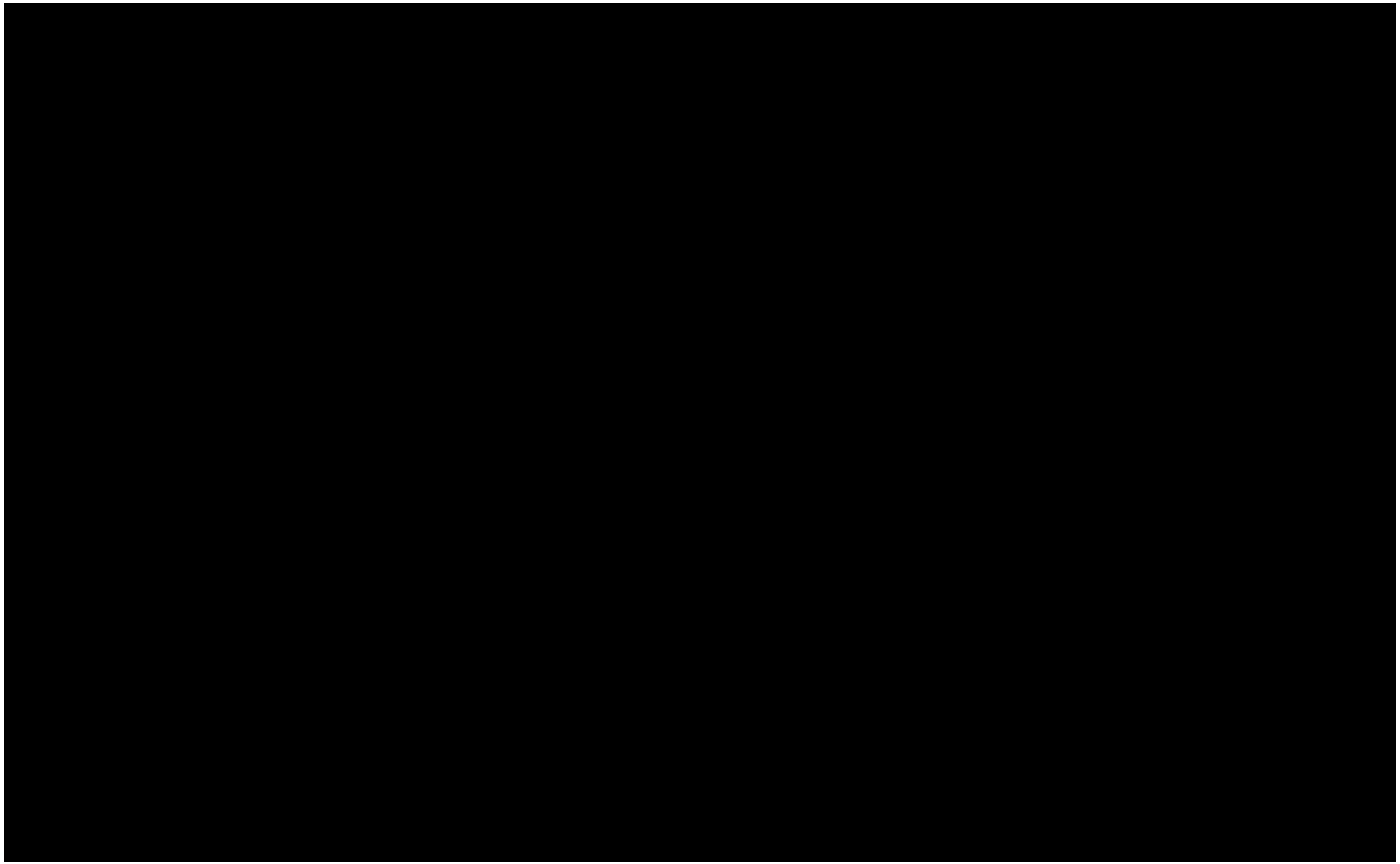


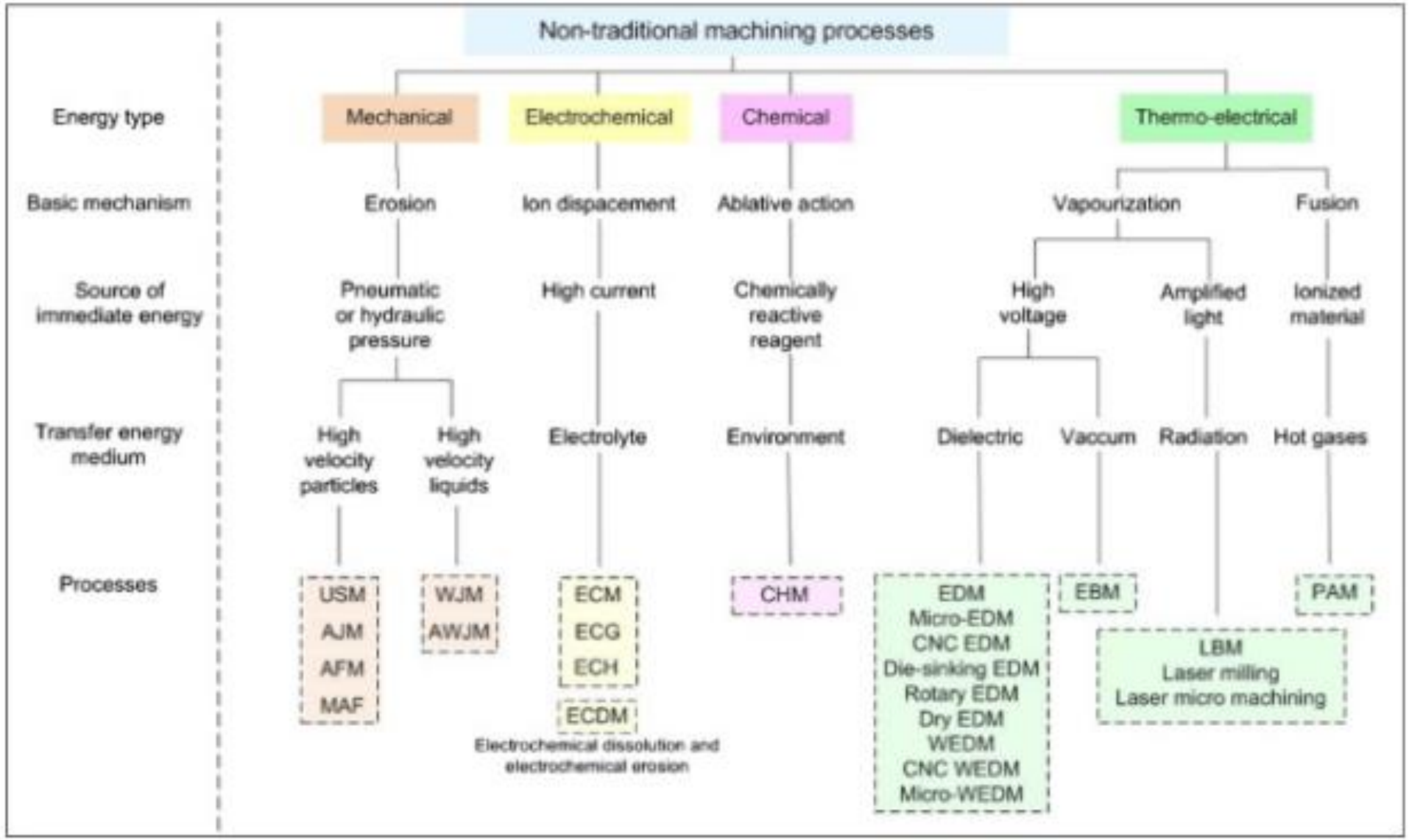


Classification of unconventional machining processes:

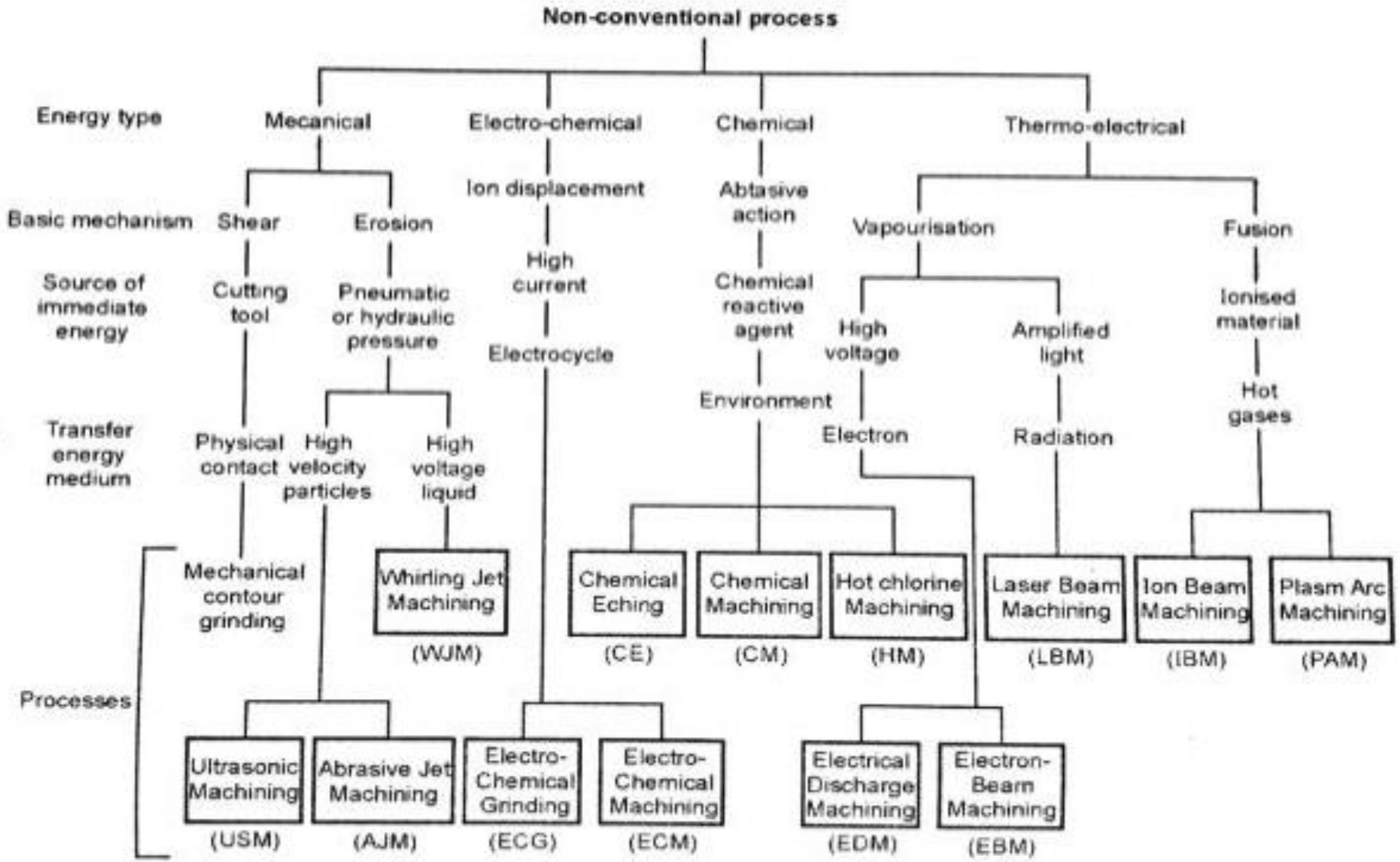
Unconventional machining processes can be broadly classified into several types based on four main criteria. The classification of unconventional machining processes is given below:

1. Based on the type of energy used
    1. Mechanical Energy based Unconventional Machining Processes
    2. Electrical Energy based Unconventional Machining Processes
    3. Electrochemical Energy based Unconventional Machining Processes
    4. Chemical Energy based Unconventional Machining Processes (e.g. Chemical Machining)
    5. Thermo-electrical (or Electro-thermal) Energy based Unconventional Machining Processes
2. Based on the source of energy
    1. High Current density
    2. High Voltage
    3. Hydraulic Pressure
    4. Pneumatic Pressure
    5. Ionised Particles
    6. Light energy
3. Based on the mechanism of material removal
    1. Erosion
    2. Ion Displacement
    3. Melting and Vapourisation
    4. Chemical Etching
    5. Blasting
4. Based on the medium of energy transfer
    1. Electrons
    2. Atmosphere
    3. Ions
    4. Electrolyte
    5. Pressurized gas
    6. Water
    7. Ultrasonic waves
    8. Plasma
    9. Laser
    10. Chemical reagent
    11. Radiation

Classification of NTM Process



Classification of NTM Process



Classification of Non-conventional processes

Classification of Non Traditional Machining Process

Mechanical Metal removal Processes

It is characterized by the fact that the material removal is due to the application of mechanical energy in the form of high frequency vibrations or kinetic energy of an abrasive jet.

1. Ultra sonic Machining (USM).
2. Abrasive Jet Machining (AJM).
3. Water Jet Machining (WJM).

Electro-Chemical

It is based on electro-chemical dissolution of materials by an electrolyte under the influence of an externally applied electrical potential.

1. Electro-Chemical Machining (ECM).
2. Electro-Chemical Grinding (ECG)
3. Electro-Chemical Drilling (ECD)

Thermal Method

The material is removed due to controlled, localized heating of the work piece. It result into material removal by melting and evaporation. The source of heat generation in such cases can be widely different.

1. Electric Discharge Machining (EDM).
2. Plasma Arc Machining (PAM).
3. Electron Beam Machining (EBM)
4. Laser Beam Machining (LBM0

Need for Non Traditional Machining

1. Extremely hard and brittle materials or Difficult to machine materials are difficult to machine by traditional machining processes.
2. When the workpiece is too flexible or slender to support the cutting or grinding forces.
3. When the shape of the part is too complex.
4. Intricate shaped blind hole – e.g. square hole of 15 mmx15 mm with a depth of 30 mm
5. Deep hole with small hole diameter – e.g. φ 1.5 mm hole with l/d = 20
6. Machining of composites.

SELECTION OF PROCESS

1. Physical parameters of the process
2. Shape to be machined
3. Process capability
4. Economics of the processes

Physical parameters of the process

Physical Parameters of the Modern Machining Processes

Parameters	*USM*	*AJM*	*ECM*	*CHM*	*EDM*	*EBM*	*LBM*	*PAM*
Potential (V)	220	220	10	—	45	150,000	4500	100
Current (Amp)	12 (A.C.)	1.0	10,000 (D.C.)	—	50 (pulsed D.C.)	0.001 (pulsed D.C.)	2 (average 200 peak)	500 (D.C.)
Power (W)	2400	220	100,000	—	2700	150 (average 200 peak)	—	50,000
Gap (mm)	0.25	0.75	0.20	—	0.025	100	150	7.5
Medium	Abra-sive in water	Abra-sive in gas	Electrolyte	Liquid chemical	Liquid dielectric	Vaccum	Air	Argon or hydro-gen

Physical parameters of the process

Parameters	ECM	EDM	EBM	LBM	PAM	USM	AJM
Potential, V	5 – 30	50 – 500	200×10^3	4.5×10^3	250	220	220
Current, A	40,000	15 – 500	0.001	2	600	12	1.0
Power, KW	100	2.70	0.15	20	220	2.4	0.22
Gap, mm	0.5	0.05	100	150	7.5	0.25	0.75
Medium	Electrolyte	Dielectric Fluid	Vacuum	Air	Argn or hydrogen or nitrogen	Abrasive grains & water	N_2 or CO_2 or Air
Work Material	Difficult to machine materials	Tungsten Carbides and electrically conductive materials	All materials	All materials	All materials which conduct electricity	Tungsten Carbide, Glass, Quartz	Hard and brittle materials

Shape to be machined

Shape Applications of Modern Machining Processes

Process	Holes: Precision small holes: Dia <.025 mm	Holes: Precision small holes: Dia >.025 mm	Holes: Standard: Length <20 Dia	Holes: Standard: Length >20 Dia	Through cavities: Precision	Through cavities: Standard	Surfacing: Double contouring	Surfacing: Surfaces of revolution	Through cutting: Shallow	Through cutting: Deep
USM	—	—	A	C	A	A	C	—	C	—
AJM	—	—	B	C	C	B	—	—	A	—
ECM	—	—	A	A	B	A	A	B	A	A
CHM	B	B	—	—	C	B	—	—	A	—
EDM	—	—	A	B	A	A	B	—	C	—
LBM	A	A	B	C	C	C	—	—	A	B
PAM	—	—	B	—	C	C	—	C	A	A

Note
A Good B Fair C Poor

Shape to be machined

For producing micro holes	LBM is best suited
For producing small holes	EBM is well suited
For deep holes (L/D>20) and contour machining	ECM is best suited
For shallow holes	USM and EDM are well suited
For precision through cavities in work pieces	USM and EDM are best suited
For honing	ECM is well suited
For etching small portions	ECM and EDM are well suited
For grinding	AJM and EDM are best suited
For deburring	USM and AJM are well suited
For threading	EDM is best suited
For clean, rapid cuts and profiles	PAM is well suited
For shallow pocketing	AJM is well suited

Material Applications

Materials Applications

Process	Material							
	Aluminium	*Steel*	*Super alloys*	*Titanium*	*Refractories*	*Plastics*	*Ceramics*	*Glass*
USM	C	B	C	B	A	B	A	A
AJM	B	B	A	B	A	B	A	A
ECM	B	A	A	B	B	D	D	D
CHM	A	A	B	B	C	C	C	B
EDM	B	A	A	A	A	D	D	D
EBM	B	B	B	B	A	B	A	B
LBM	B	B	B	B	C	B	A	B
PAM	A	A	A	B	C	C	D	D

Note

A Good Application B Fair C Poor D Not Applicable

Material Applications

Sl.No.	Material	Methods of Machining
1.	Non Metals like ceramics, Plastics and glass	USM, AJM, EBM, LBM
2.	Refractories	USM, AJM, EBM, EDM
3.	Titanium	EDM
4.	Super alloys	AJM, ECM, EDM, PAM
5.	Steel	ECM, CHM, EDM, PAM

Process capability

Process Economy

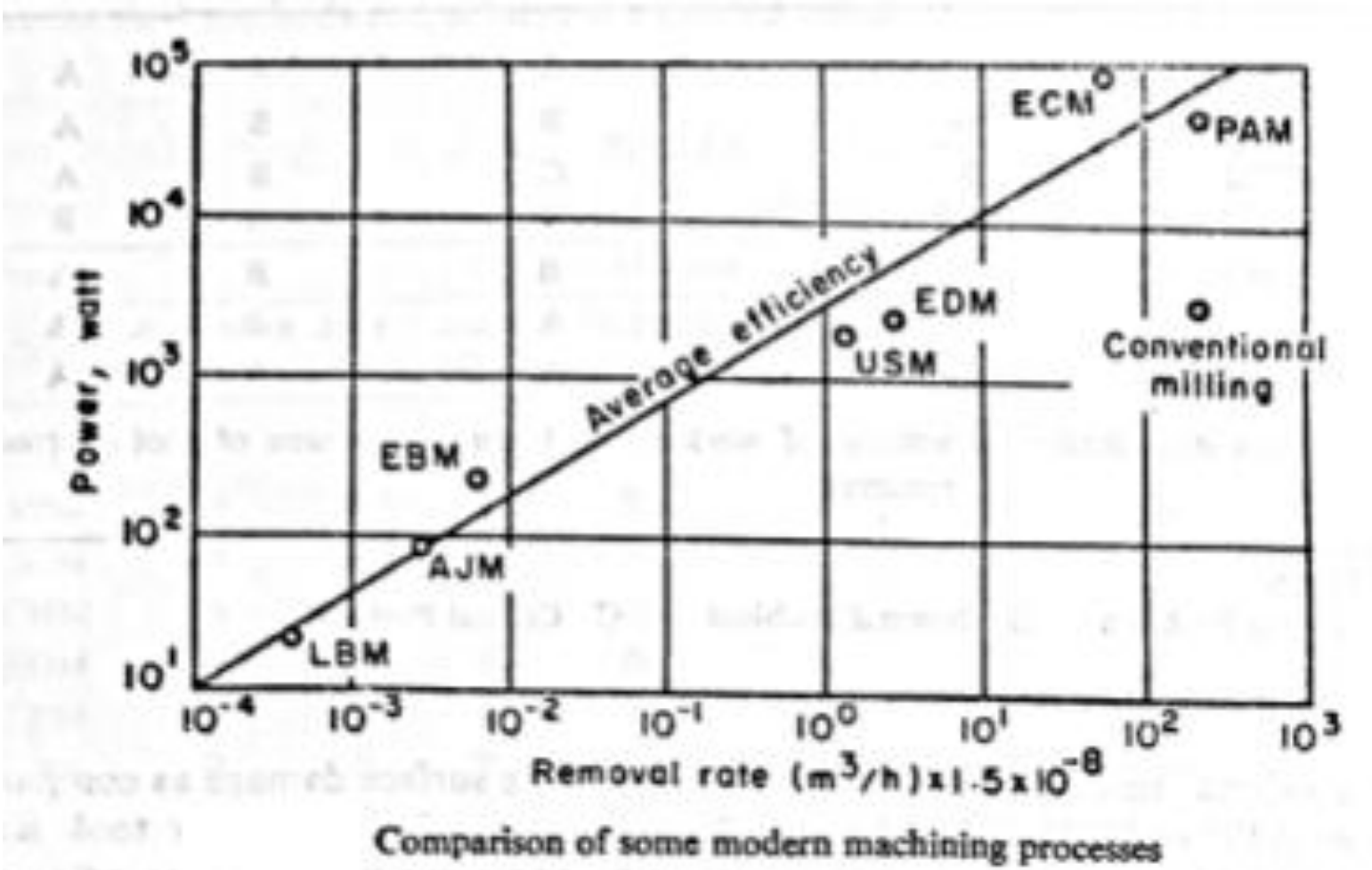
Process	Capital investment	Tooling and fixtures	Power requirement	Efficiency	Tool consumption
USM	B	B	B	D	C
AJM	A	B	B	D	B
ECM	E	C	C	B	A
CHM	C	B	D	C	A
EDM	C	D	B	D	D
EBM	D	B	B	E	A
LBM	C	B	A	E	A
PAM	A	B	A	A	A
Conventional machining	B	B	B	A	B

Notes
A Very Low Cost B Low C Medium D High E Very High

Process capability

Process	Process Capability			
	Material Removal Rate (mm^3/s) MRR	Surface Finish (µm, CLA)	Accuracy	Specific Power ($KW/cm^3/min$)
LBM	0.10	0.4 to 6.0	25	2700
EBM	0.15 to 40	0.4 to 6.0	25	450
EDM	15 to 80	0.25	10	1.8
ECM	27	0.2 to 0.8	50	7.5
PAM	2500	Rough	250	0.90
USM	14	0.2 to 0.7	7.5	9.0
AJM	0.014	0.5 to 1.2	50	312.5

Economics of the processes



Comparison of some modern machining processes

Economics of the processes

Process	Capital Cost	Tooling and	Power requirement	Efficiency	Total Consumption
EDM	Medium	High	Low	High	High
CHM	Medium	Low	High	Medium	Very low
ECM	Very High	Medium	Medium	Low	Very Low
AJM	Very Low	Low	Low	High	Low
USM	High	High	Low	High	Medium
EBM	High	Low	Low	Very High	Very Low
LBM	Medium	Low	Very Low	Very High	Very Low
PAM	Very Low	Low	Very Low	Very Low	Very Low
Conventional Machining	Very low	Low	Low	Very Low	Low

Advantages of Non-conventional machining

- High accuracy and surface finish
- Less/no wear
- Tool life is more
- Quieter operation

Disadvantages of Non-conventional machining

- High cost.
- Complex set-up.
- Skilled operator required.