Advanced Machining Processes

ME312: Manufacturing Technologies - II
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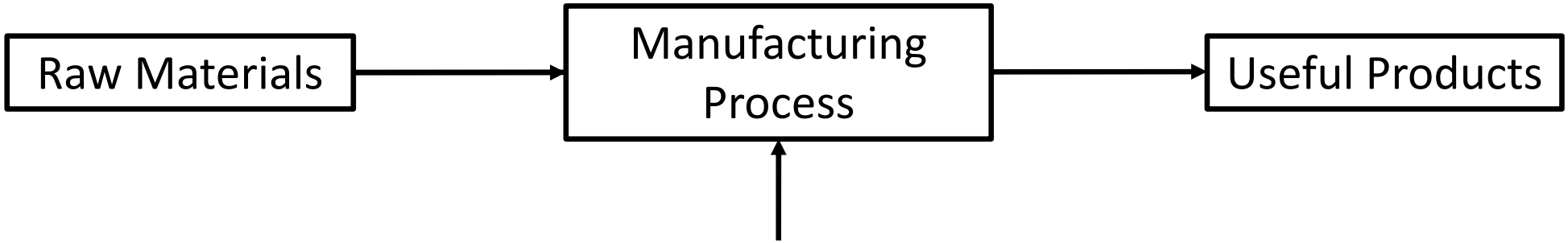
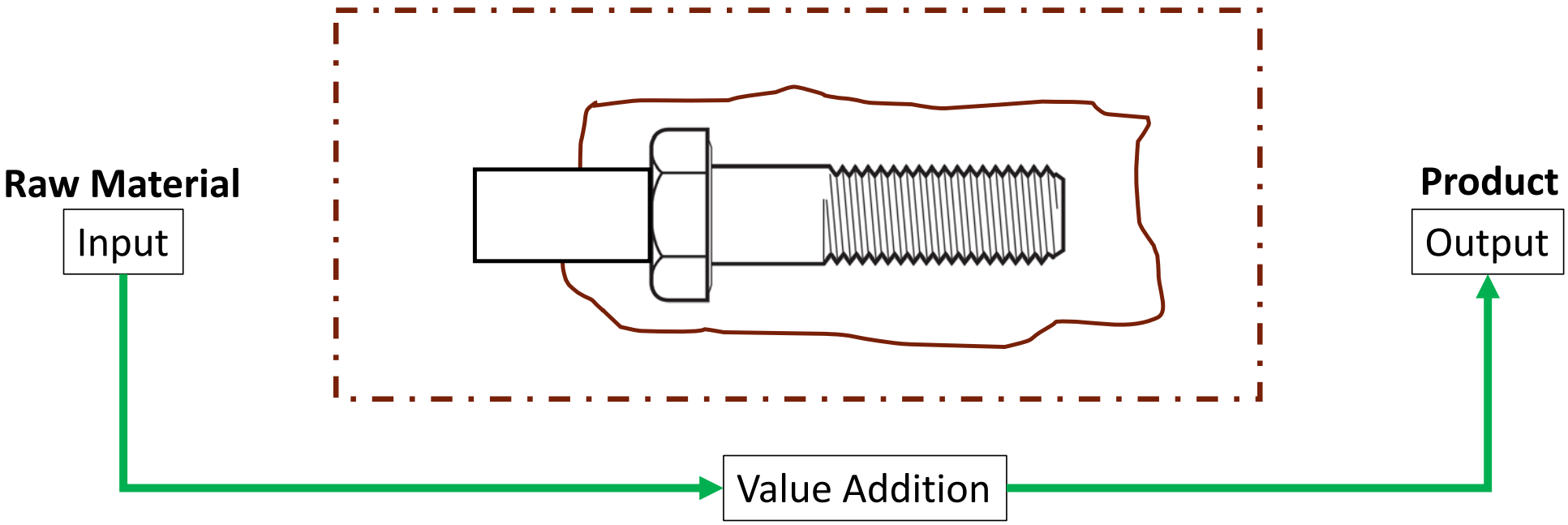
What is Manufacturing?

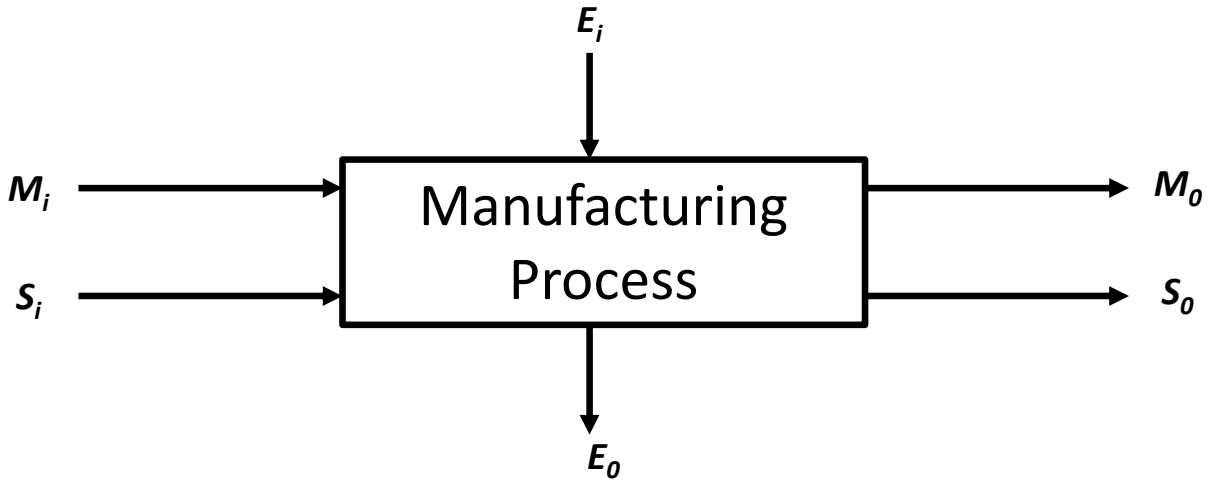
- Derived from the Latin word manufactus
- manus = hand, factus = made
- Practical definition: process of converting or processing raw materials into usable products.



Manufacturing Processes



Classification of Manufacturing Processes



- Based on:
  - process type e.g., shaping vs. non-shaping
  - state of workpiece material e.g., solid or liquid
  - processing energy e.g., mechanical, electrical,…

Classification of Manufacturing Processes

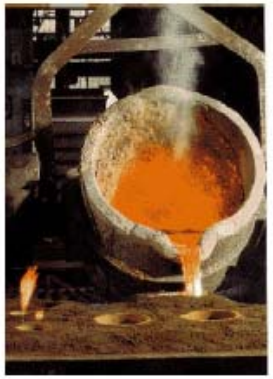
- Shaping process classification
  - Mass conserving, dM ~ 0

    examples: casting, bulk forming, powder processing
  - Mass reducing, dM < 0

    examples: conventional and unconventional machining
  - Mass adding, dM > 0

    examples: joining processes

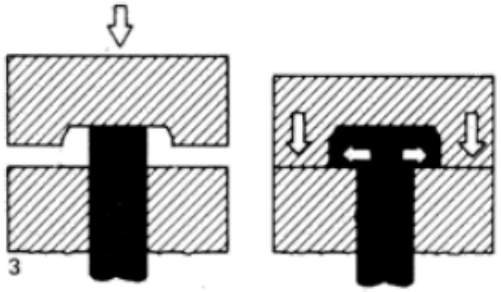
Further sub-classification is possible based on processing energy and workpiece state considerations



Casting ($dM \sim 0$)

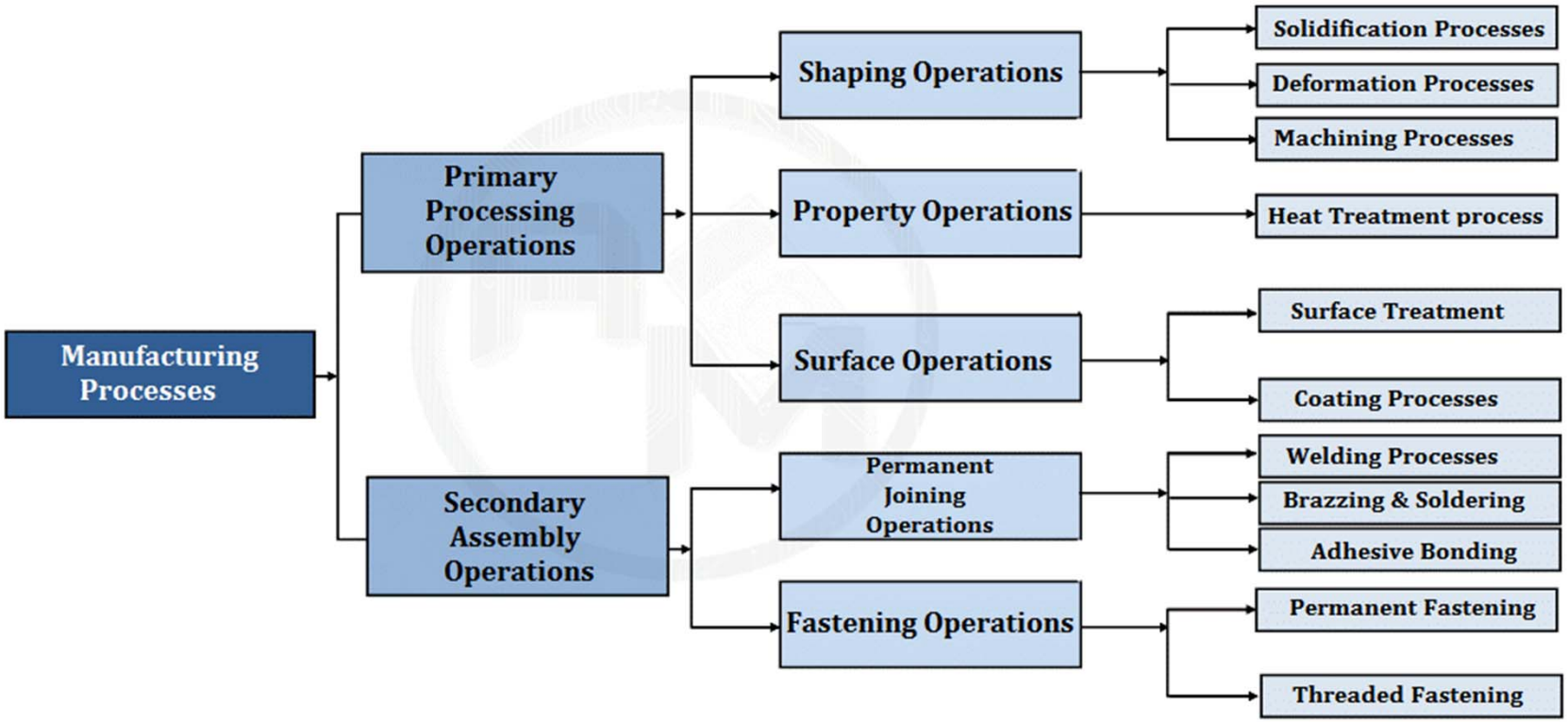
Cutting ($dM < 0$)

Welding ($dM > 0$)



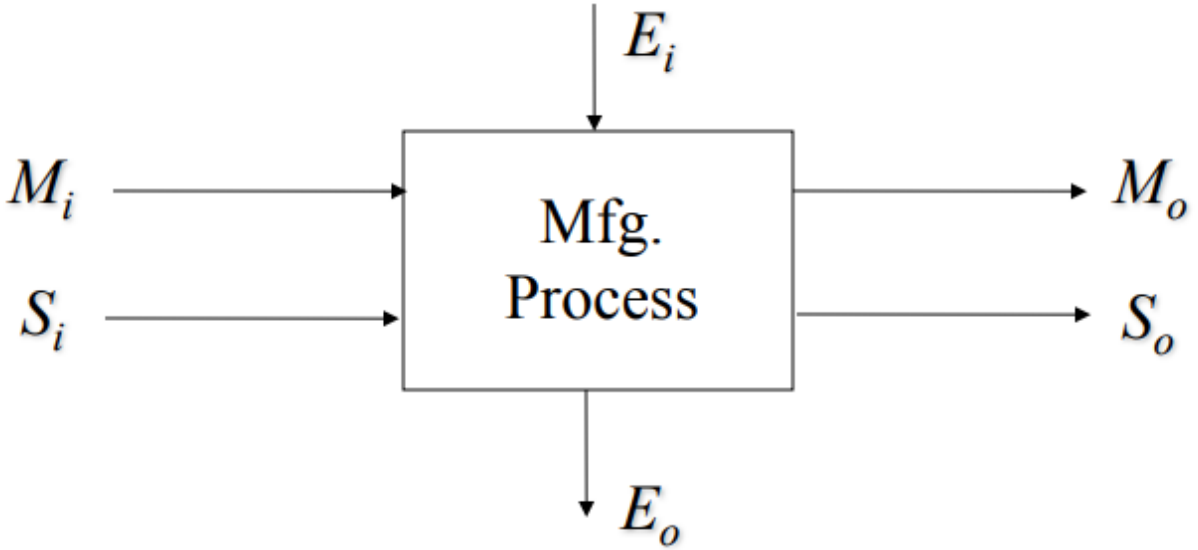
Forging ($dM \sim 0$)

Manufacturing Processes



What is Machining?

- Material Removal Process
- Mass reducing, dM < 0
- Also called subtractive manufacturing



Definition of Machining

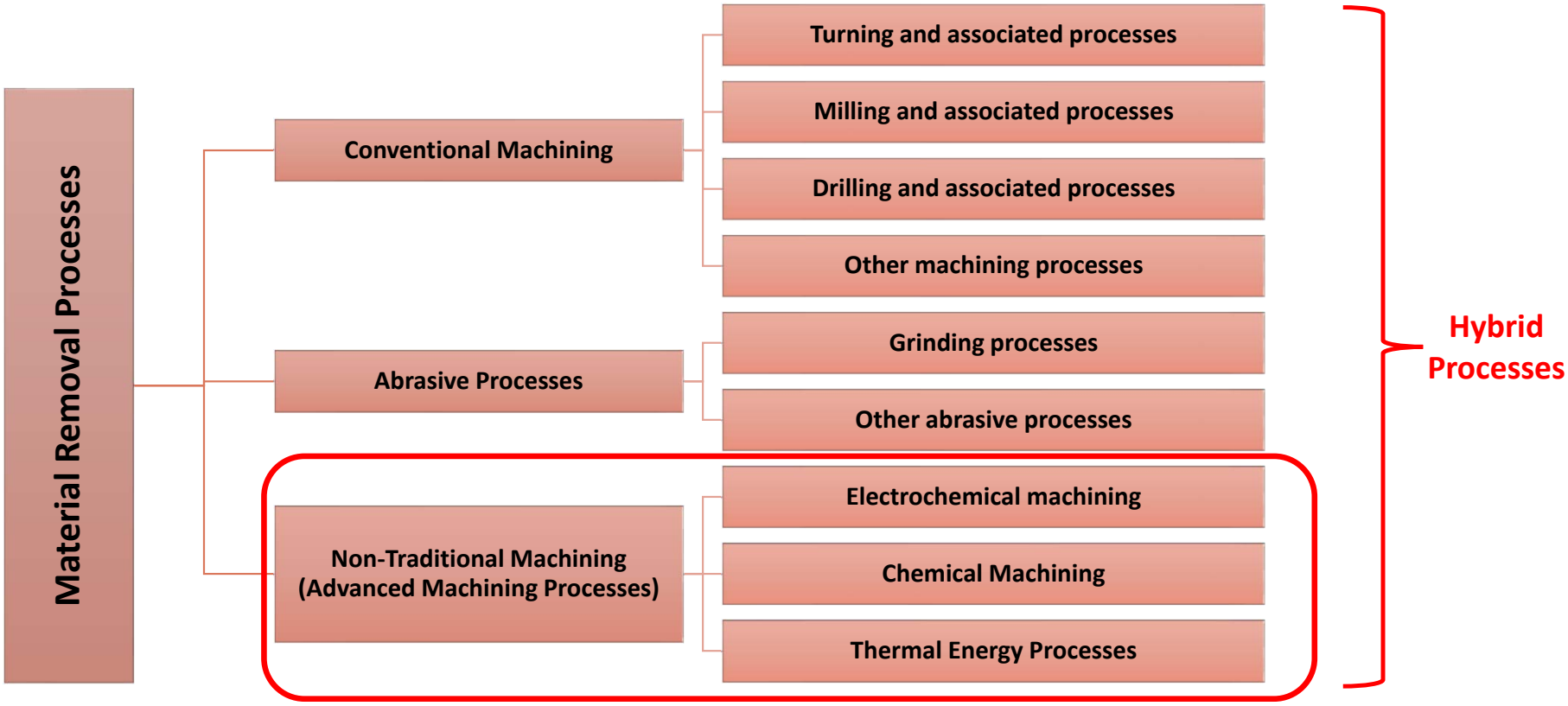
"Machining involves the removal of some material from the workpiece (machining allowance) in order to produce a specific geometry at a definite degree of accuracy and surface quality"

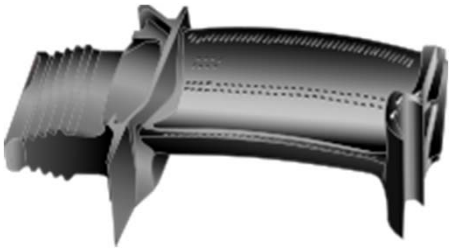
Turning

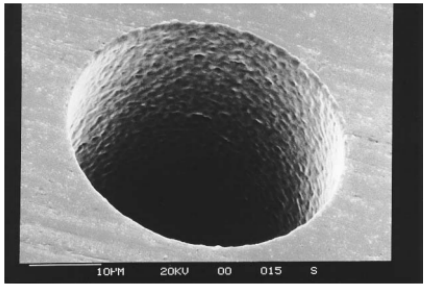
Drilling

Milling

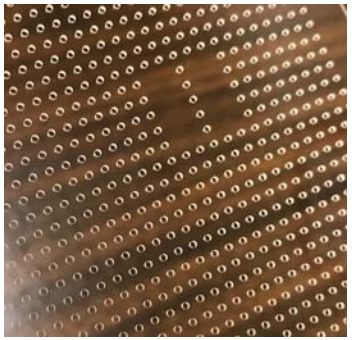
Material Removal Processes







Ceramics (bullentech.com)



Holes in Glass (swiftglass.com)

Nontraditional Machining

- A machining process is called non-traditional if its material removal mechanism is basically different than those in the traditional processes
- Processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies
- These processes do not use a sharp cutting tools as those need to be used for traditional manufacturing processes
- Also called advanced machining processes

Why Nontraditional Machining?

- Engineering Materials
  - Metals and Alloys
  - Plastics and Composites
  - Ceramics

} Getting more popularity and have advantages over others

- Demand of materials with ultrahigh strength, hardness, very high temperature resistance in industries
- The greatly improved thermal, chemical, and mechanical properties
- The high cost of machining of ceramics and composites and the damage generated during machining are major obstacles

Solution: Advanced Machining Process (AMP)

Why Nontraditional Machining?

- Product Requirement
  - Complex shapes
  - Machining in inaccessible areas
  - Low tolerances (less than 10 microns)
  - Better surface quality (no defects such as microcracks)
  - Increase demand of miniaturization of components

Solution: Advanced Machining Process (AMP)

Why Nontraditional Machining?

- Situations where traditional machining processes are unsatisfactory or uneconomical:
  - Workpiece material is too hard, strong, or tough.
  - Workpiece is too fragile to resist cutting forces or too difficult to clamp.
  - Part shape is very complex with internal or external profiles or small holes.
  - Requirements for surface finish and tolerances are very high.
  - Temperature rise or residual stresses are undesirable or unacceptable.

Characteristics of Advanced Machining Processes

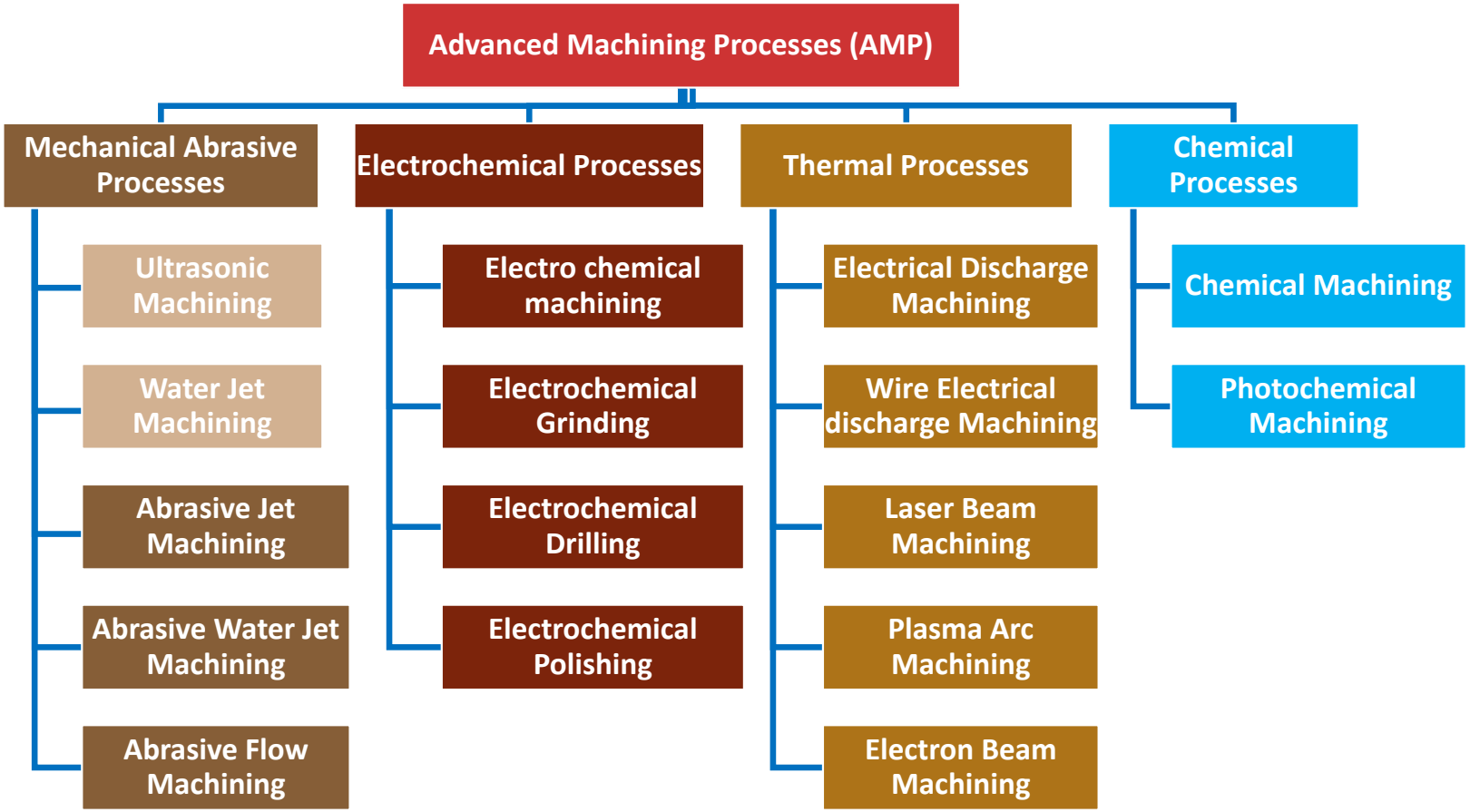
- Performance does not depend on the workpiece strength/hardness
- Performance depends on thermal, electrical or/and chemical properties of workpiece/tool material
- The hardness of tool materials can be significantly lower than that of workpiece materials
- The material can be processed directly using energy such as electric energy, electrochemical energy, sound energy or light energy.
- Mechanical forces are not apparent during the machining and the workpiece seldom produces mechanical and thermal deformation, which are helpful to improve machining accuracy and surface quality of the workpiece.

Low MRR but Better Quality

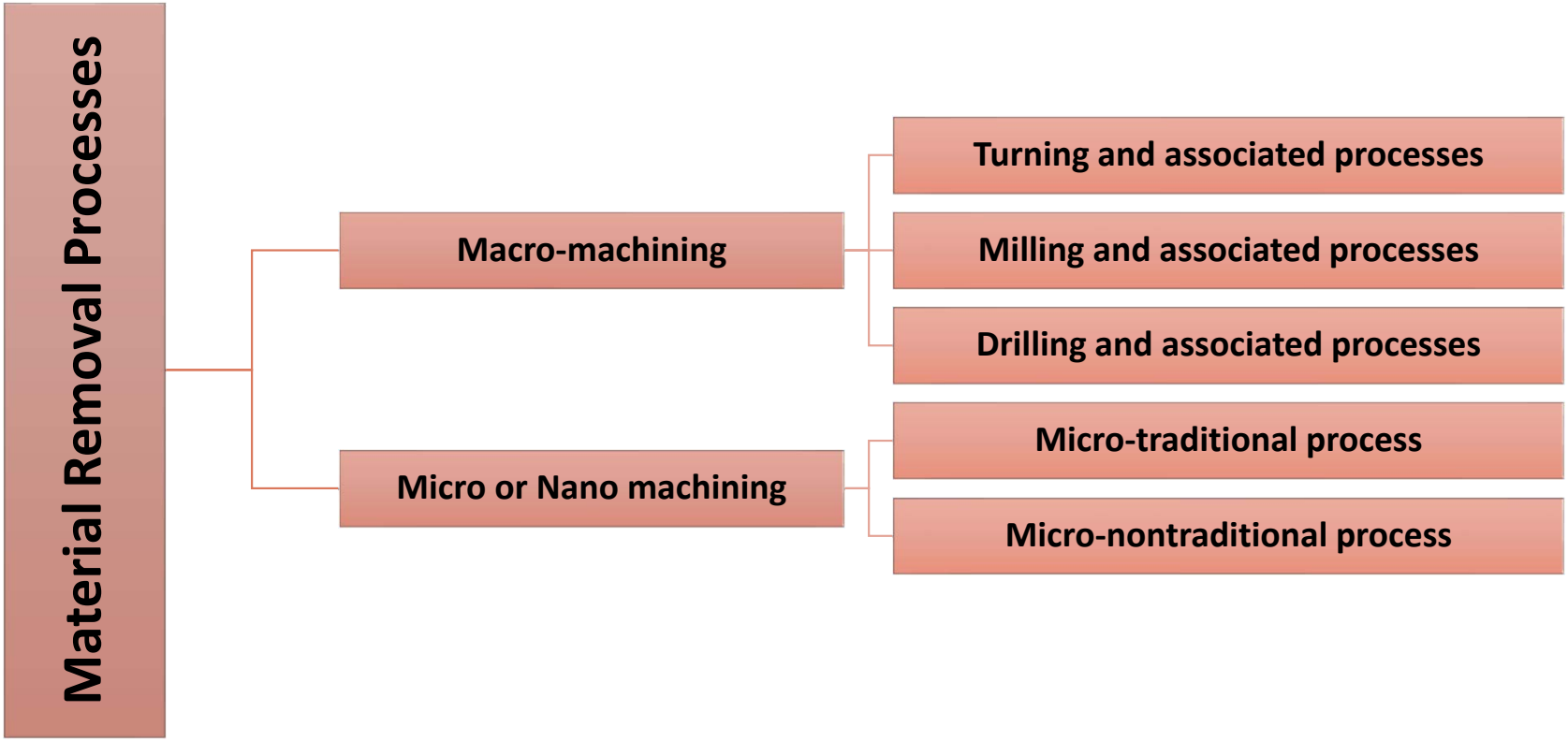
Classification of Advanced Machining Processes

- Based on the source of energy which is used to generate machining action
- Mechanical: Erosion of the work material by a high velocity stream of abrasives or fluids (or both)
- Thermal: The thermal energy is applied to a very small portion of the work surface, causing that portion to be removed by fusion and/or vaporization of the material. The thermal energy is generated by conversion of electrical energy.
- Electro-Chemical: Mechanism is reverse of electroplating.
- Chemical: Most materials (metals particularly) are susceptible to chemical attack by certain acids or other etchants. In chemical machining, chemicals selectively remove material from portions of the workpart, while other portions of the surface are protected by a mask.

Classification of Advanced Machining Processes

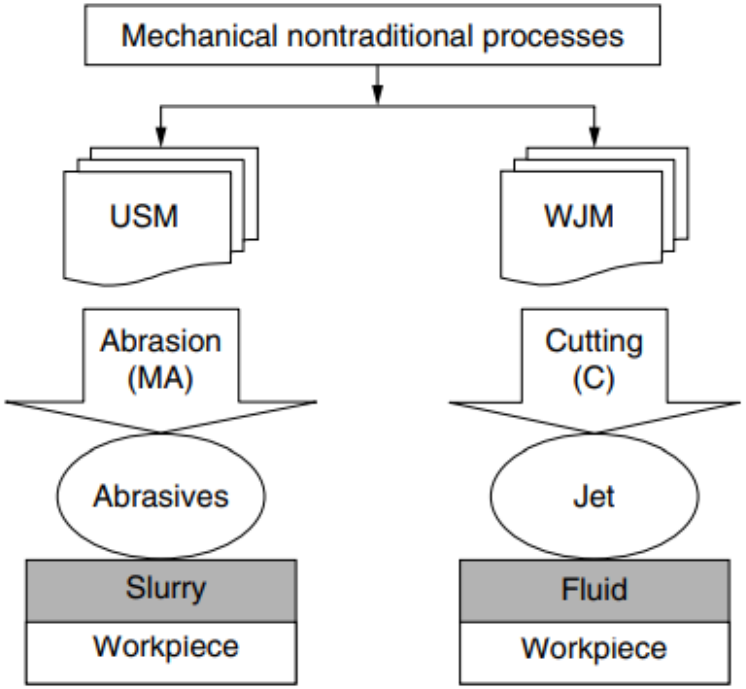


Classification based of Scaling of Process



Mechanical Machining

- Ultrasonic Machining (USM) and Waterjet Machining (WJM) are typical examples of single action, mechanical nontraditional machining processes.
- The machining medium is solid grains suspended in an abrasive slurry in the USM, while a fluid (water) is employed in the WJM process.
- The introduction of abrasives to the fluid jet enhances the machining efficiency and is known as abrasive water jet machining. Similar case happens when ice particles are introduced as in Ice Jet Machining.



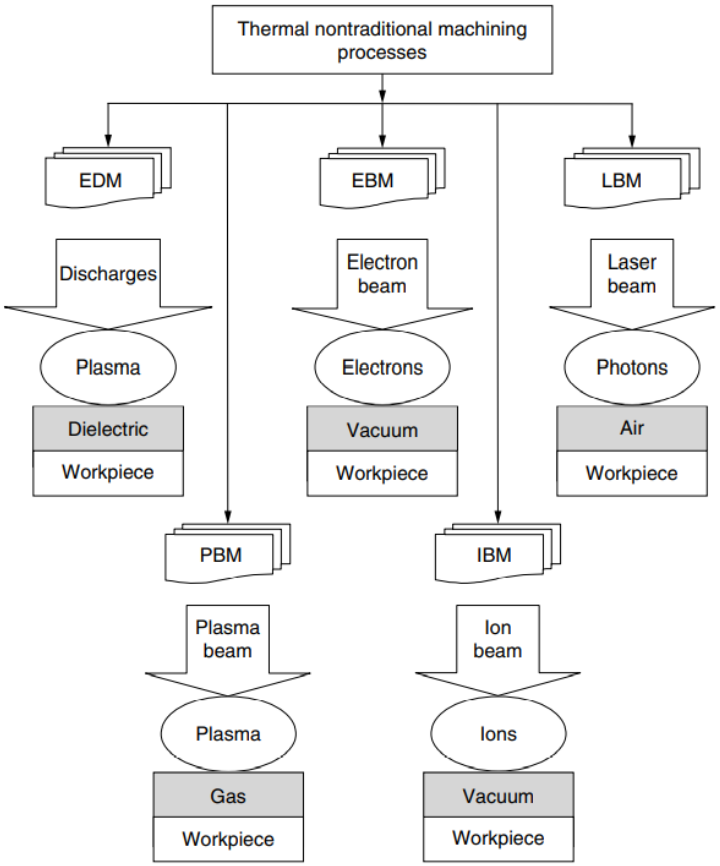
Examples in nature??

Thermal Machining

- Thermal machining removes materials by melting or vaporizing the work piece material.
- Many secondary phenomena occur during machining such as microcracking, formation of heat affected zones, striations etc.
- The source of heat could be plasma as during EDM and PBM or photons as during LBM, electrons in EBM, ions in IBM etc.

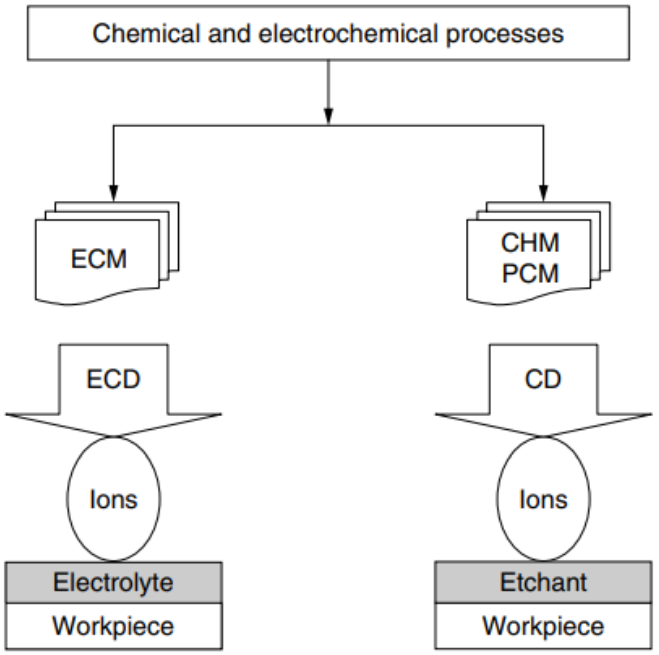
Examples in nature related to laser??

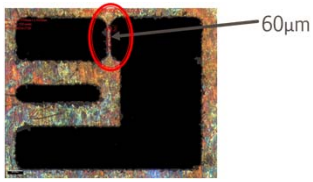
Thermal and Electro-Thermal Machining

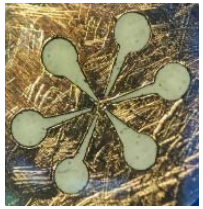


Chemical and Electro-Chemical Machining

- Chemical milling and photochemical machining or photochemical blanking all use a chemical dissolution action to remove the machining allowance through ions in an etchant.
- Electrochemical machining uses the electrochemical dissolution phase to remove the machining allowance using ion transfer in an electrolytic cell.



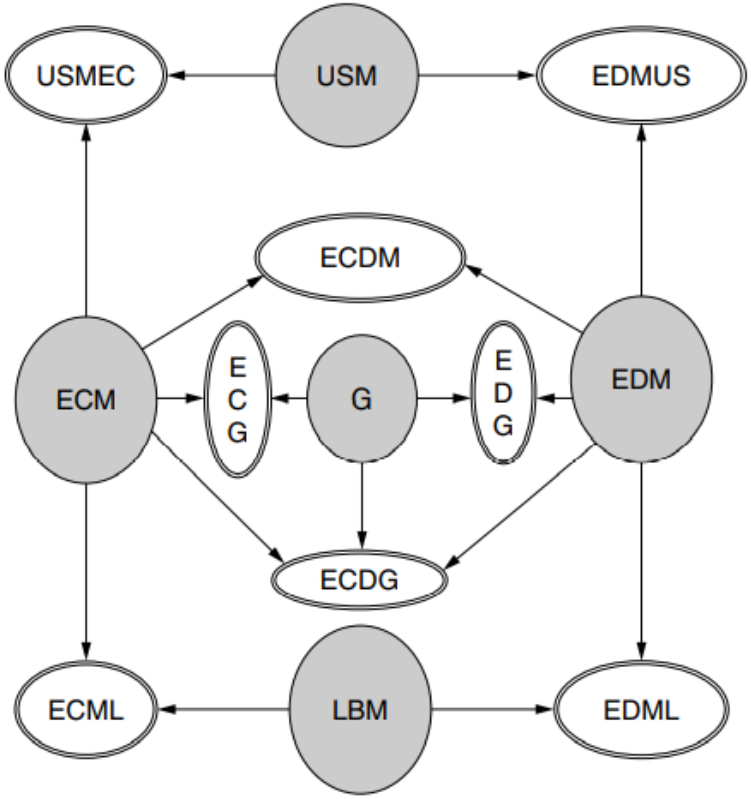


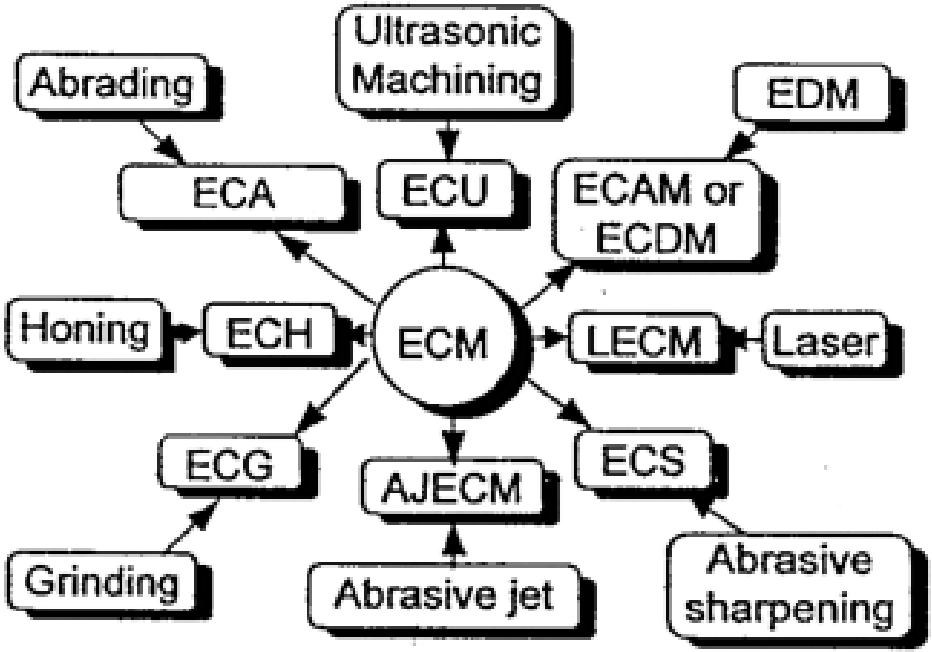


Hybrid Machining

- Development of a hybrid machining process is mainly to make use of the combined advantages and to avoid or reduce some adverse effects the constituent processes produce
- The performance characteristics of a hybrid process are considerably different from those of the single-phase processes in terms of productivity, accuracy, and surface quality
- Combination of AMP+AMP or AMP+Traditional
- Hybrid chemical and electrochemical processes
- Hybrid thermal machining.

Hybrid Machining Processes





References

- V. K. Jain, Advanced Machining Processes, Allied Publishers,2009
- Hassan El-Hofy, Advanced Machining Processes, McGraw-Hill Prof Med/Tech, 2005
- Helmi Youssef, Non-Traditional and Advanced Machining Technologies, CRC Press, 2020