Chapter

A Review on Advanced Manufacturing Techniques and Their Applications

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Abstract

Advancement in manufacturing processes has drawn preeminent interest from researchers and industry, it makes the process of manufacturing more productive and capable of high efficiency. Advancement of technology has been done by several approaches to combine different manufacturing processes with similar objectives of increasing material removal rate, improving surface integrity, reducing tool wear, reducing production time, and extending application areas. A combination of different processes has been called 'Hybrid' processes by various researchers, engineers, and industry expert. Hybrid processes open new opportunities and applications for manufacturing various components that are not able to be produced economically by processes on their own. This review report starts with the classification of current manufacturing processes based on the nature of the processing. The main part of this report is reviews of existing and widely used manufacturing processes that recently reported in a decade. Purpose of this report to produce an overview of these different processes by reviewing various research papers.

Keywords: manufacturing processes, advancement of technology, hybrid processes, economic processes, recent manufacturing process

1. Introduction

In the present manufacturing industry developed a new approach to manufacture products. Generally conventional manufacturing processes which has been widely adopted are computer numerical control (CNC) machining, transformative processes such as forming, joining and dividing operations, for example, welding and sawing. Also, additive manufacturing has been adopted in many sectors of industries.

Conventional manufacturing processes, however, have their inherent drawbacks which cannot be eliminated. In other words, due to their technological constraints, they are not always feasible to produce various components in terms of geometry, dimension, and strength, etc. CNC machining can have difficulties in machining complex shapes due to tool accessibility. High temperature and tool wear are other considerations while machining hard materials. As compared to CNC machining, Rapid prototyping is still restricted because of long production time and low accuracy. Limited materials' formability and spring-back effect confine the development of forming processes. In welding processes, furthermore, dimensional precision is hard to completely control.

In view of the issues referenced above, a combination of two or more manufacturing processes with different manufacturing principle is a new topic for many researchers, such processes are called hybrid manufacturing. The main driven idea to develop such process is to minimize individual manufacturing limitation and enhance their advantages by combining two or more manufacturing processes. The combination of CNC machining and additive processes may provide a new substantial solution to the limitations of additive processes due to the high accuracy and machining speed that machining processes offer. Moreover, the combination of laser heating and forming reduces spring back behavior. The combination of drilling and ultrasonic vibration can reduce the tool wear rate and cutting force. The involvement of laser drilling and electrochemical machining (ECM) significantly removes the recast layer and heat affect zone.

Hybrid manufacturing has enormous potential to produce more complex parts, provide more tolerance of flexibility while maintaining high accuracy in relatively lower production time. This is now becoming trend among researchers to develop hybrid processes for enhancing processes capabilities, minimizing their limitations and broadening application areas.

The major topic contains in this book chapter are classification of existing manufacturing processes and its technologies based on their nature of operation; simplification of different strategies and terms used by researchers; define, identify and classification of hybrid manufacturing processes.

2. Need and significance of advance manufacturing

2.1 Major drivers of advanced manufacturing

As shown in **Figure 1** Advance Manufacturing has three major driver's material driver, process driver and operational driver. A development in new materials which are hard to machines are categorized under material driven processes, while process driver is due to specific product necessities such as precision, high accuracy,

Figure 1.
The major drives of advanced manufacturing processes.

Figure 2.
Manufacturing philosophy wise the trends.

high quality etc. The operation driver is responsible for shrinking time to market requirements which led to high production rate, apart from that its attributed to produce products cost effective by cutting manufacturing costs.

2.2 Manufacturing philosophy wise the trends

Over a last few decade's manufacturing theory wise the trends can be observed in **Figure 2** and those are as follows, In the 1960's a measure trend for manufacturing processes were cost-driven. Then it became quality driven in 1980. However recently cost quality and time to market are the most important drivers in manufacturing industries.

The need for advanced manufacturing can be attributed to the following.

a. Limitations in conventional methods.

b. Rapid improvements in material properties.

c. High tolerance requirements, product requirements.

Some major advantages of advanced manufacturing processes

a. Production with low cost

b. Automated data transmission

c. Miniaturization

d. Precise and ultra-precession Finishing

3. Classification of advanced manufacturing techniques

3.1 General classification of advanced manufacturing techniques

A general classification is described in **Figure 3**. Techniques like ultrasonic machining, water jet machining, abrasive water jet machining, abrasive jet machining, abrasive flow machining, magnetic abrasive flow machining are classified under Mechanical category. Plasma earth machining, laser beam processing, electron beam processing, electric discharge machining, ion beam machining etcetera

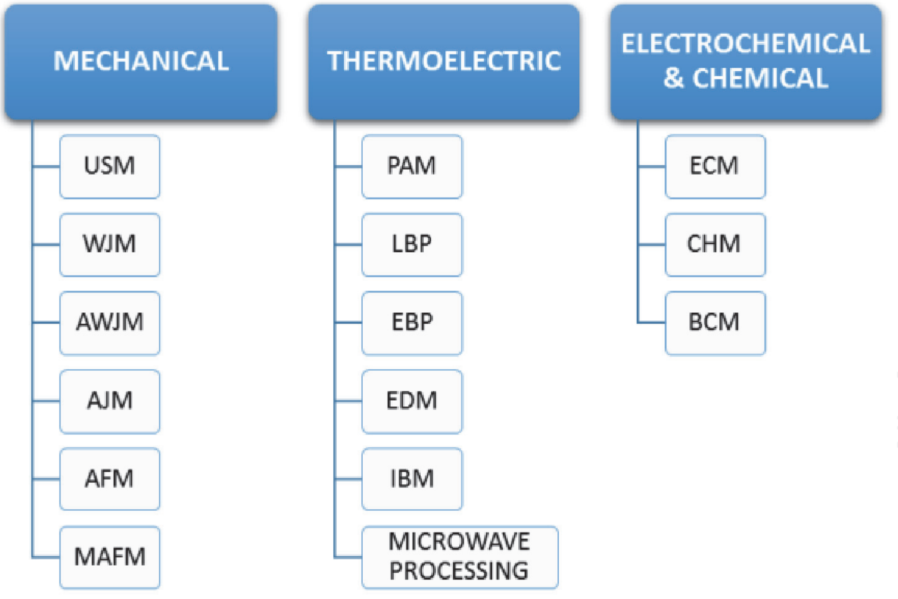

Figure 3.
General classification of advanced manufacturing techniques.

are classified under Thermoelectric category. One new process is emerging in this category, this is microwave processing. Microwave processing of materials have been extensively used, especially in polymeric and ceramic material processing [1].

The new trend in advanced manufacturing is hybridization of two or more than two manufacturing processes. The International Academy for Production Engineering (CIRP) has suggested two definition based on its nature of Hybrid Manufacturing.

i. "A hybrid manufacturing process combines two or more manufacturing processes into a new combined set-up whereby the advantages of each discrete process can be exploited synergistically" (Open definition).

ii. "A hybrid manufacturing process comprises a simultaneous acting of different processing principles on the same zone" (Narrow definition).

3.2 Broad classification of hybrid manufacturing techniques

A classification has been done based on process nature and further its categorized in **Figure 4**. A classification by Kalpakjain and Schmid (2010) is as follows.

i. Joining Technology: Include processes which allowed two or more workpieces to join and to form a new workpiece. Examples are welding and assembly.

ii. Dividing Technology: Contain processes which are the opposite to the joining processes, for instance, sawing and disassembly.

iii. Subtractive Technology: Contains operation which are responsible for material removal, in an order to make new workpiece materials has removed from a single workpiece, all machining operations are the examples of subtractive technology.

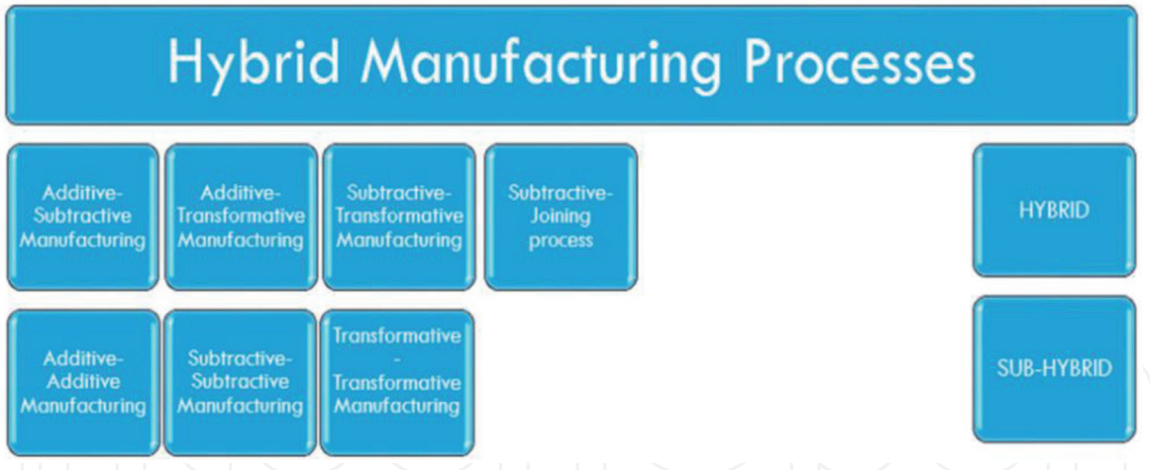

Figure 4.
Classification of hybrid and sub hybrid manufacturing processes.

iv. Transformative Technology: Without changing its mass a workpiece is transformed to create another new workpiece. Examples of transformative processes are forming, heat treatment and cryogenic cooling.

v. Additive Technology: To build a new workpiece material must be added to an existing workpiece which result in an increment in the mass of the final workpiece. The existing technology such as rapid prototyping processes, injection molding and die casting are the example of additive manufacturing processes.

Based on above classification a sub-categorization of hybrid and sub-hybrid processes are mentioned in **Figures 5** and **6** respectively.

3.3 Sub categorization of hybrid manufacturing processes

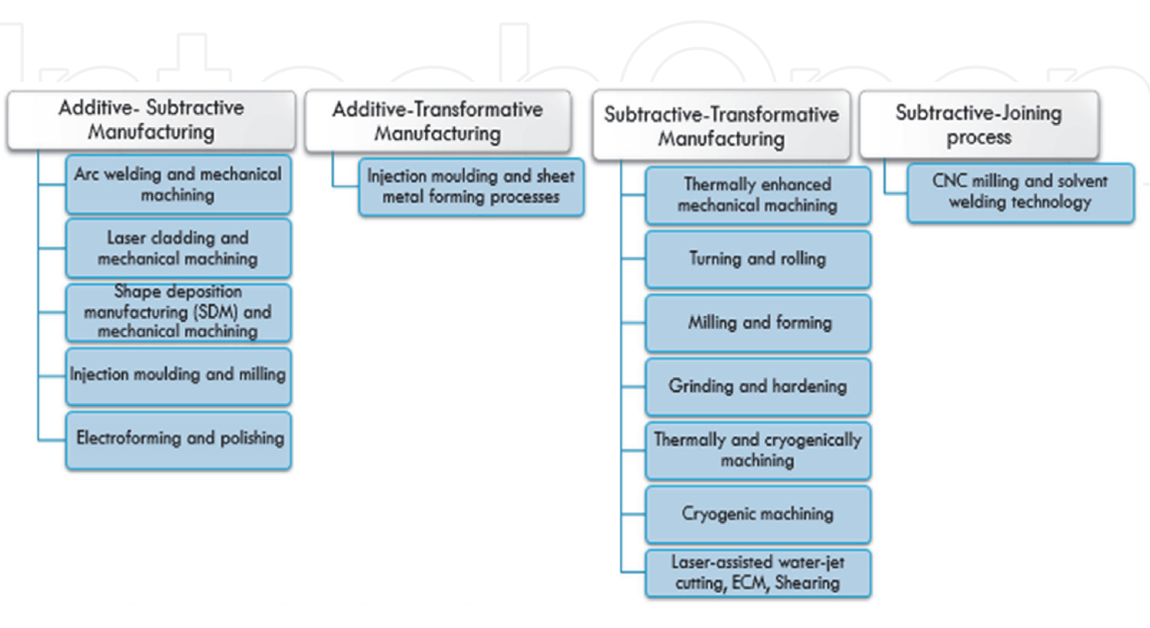

Figure 5.
Sub categorization of hybrid manufacturing processes.

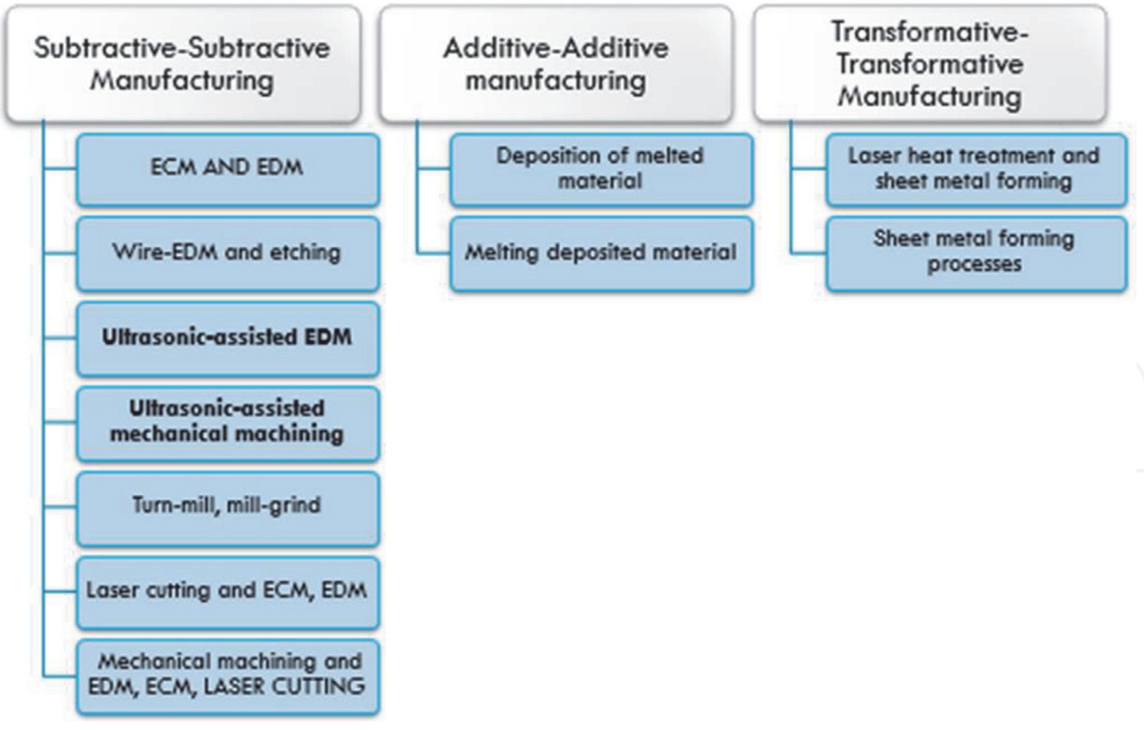

Figure 6.
Sub categorization of sub hybrid manufacturing processes.

4. Overview of processes (setup, procedures, manufacturing)

4.1 Additive subtractive manufacturing processes

4.1.1 Arc welding & mechanical machining

In this process a 3D welding is used as an additive manufacturing process while milling process is used as a material removal process, single beads of welding is deposited side by side by using conventional gas metal arc welding. By controlling the welding parameters mainly speed and power, the thickness of bead can be set in a range between 0.5 and 1.5 mm. After deposition of a bead layer, surface of layer is machined by using milling to achieve a smooth surface with defined thickness for

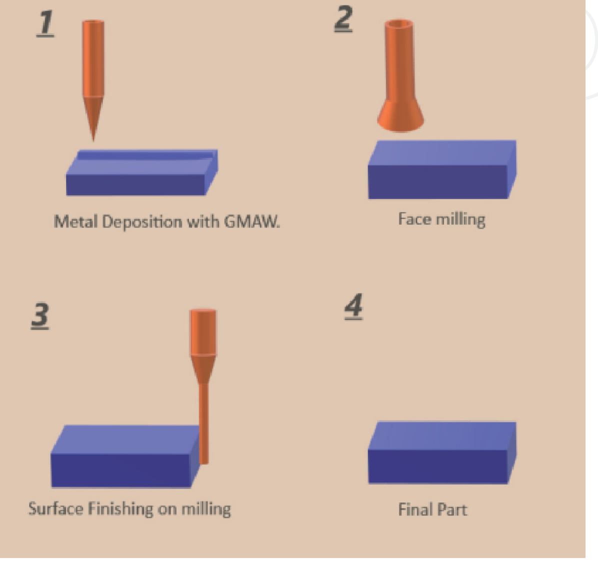

Figure 7.
Gmaw and milling operation [2].

next weld bead deposition, as shown in **Figure 7**. The combination of this process of welding pass and with face milling offers a advantage in controlling layer thicknesses range between A0.1 and A1 mm. After the sequence of weld bead deposition and face milling is finished, surface finishing operation is take place on same machining setup in order to subtract the left stair steps pattern on the surface of the machining part and to improve the accuracy of the near-net shape metal part [2–5].

4.1.2 Laser cladding and mechanical machining

The combination of selective laser cladding (SLC) and milling process result in a hybrid process and its design and construction is shown in **Figure 8**. By laser cladding a layer of material is deposited on the workpiece, and then subsequently milling operation was introduced to smooth the deposited clad surface. After the cladding operation, the engaged focal point of the laser was moved away and the workpiece was moved to the position beneath the milling head. Then, to achieve the desired accuracy and a smooth surface, the top surface of the workpiece with the deposited clad profile was machined in order to make the surface ready for the next cladding operation [6–10].

4.1.3 Shape deposition manufacturing (SDM) and mechanical machining

One of the variations of Shape Deposition Manufacturing is a Mold SDM and various process steps can be seen in **Figure 9**. SDM is a process which include additive and subtractive manufacturing process which is used to manufacture a various metal based and polymer-based parts. Almost every layer deposition technique breaks down the model into moderately thin and uniform thickness layers. However, in the process of shape deposition manufacturing layers are 3D, also it can be of arbitrary thickness and it has not compulsion to be planar. Such a decomposition in additive process allows the quantity of layers to be limited which is leads to reduction in processing time. In Mold based Shape Deposition Method molds are constructed using SDM process, afterwards these are used to cast a various part material. For illustration, the Mold Shape Deposition Methods construct succession for a basic part with three layers**.** The shape of the mold cavity is defined by the support material segments. The mold itself is formed by the support material which are constructed around by the segments of mold material. In initial step the mold is constructed up layer by layer by Deposition Methods techniques. In later step support material is removed which allowed a mold ready for casting**.** In subsequent

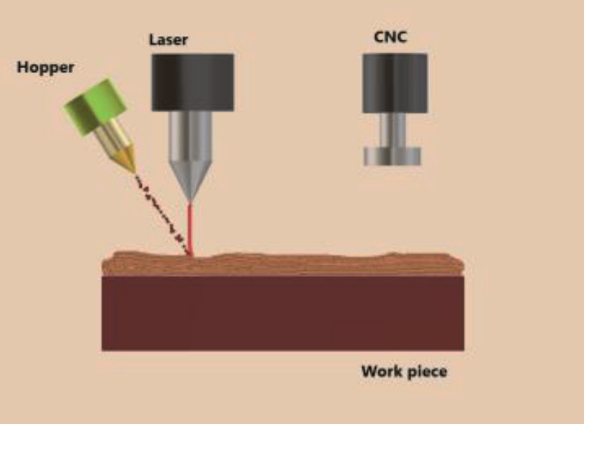

Figure 8.
Laser cladding and mechanical machining [6].

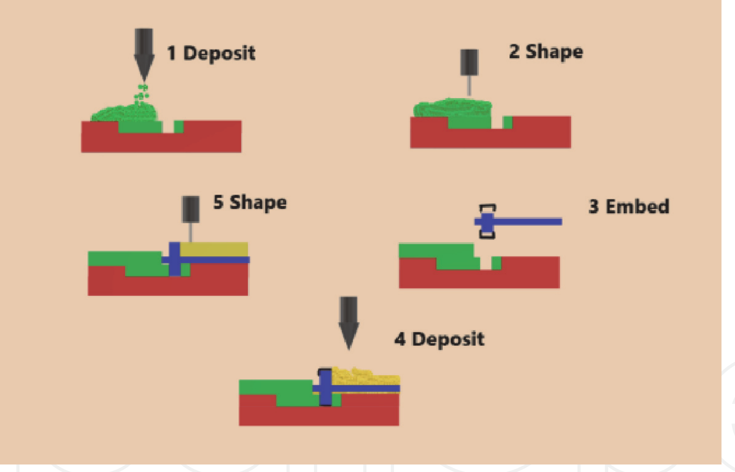

Figure 9.
SDM and machining.

stage after part material cured it removed from the mold and finishing operation take place, for example removal of gates and runners. An alternative method also can be applicable in which the mold material is used as a fixturing during finishing operations and then it can be remove in later stage [11–14].

4.1.4 Injection molding and machining

Klelkar et al. developed a re-configurable molding process by using movable pins, as shown in **Figure 10**, to generate a cavity in the mold, the process has limitation as a part surface is only approximated. According to the change of product design the pins can be re-positioned, and a required mold cavity can be produced. Kelkar and Koc introduced multiaxis machining in re-configurable mold tooling. Multi-axis machining was used to improve the surface accuracy of the part after a part is molded. The both process was carried on same setup and make it suitable for a batch production [15, 16].

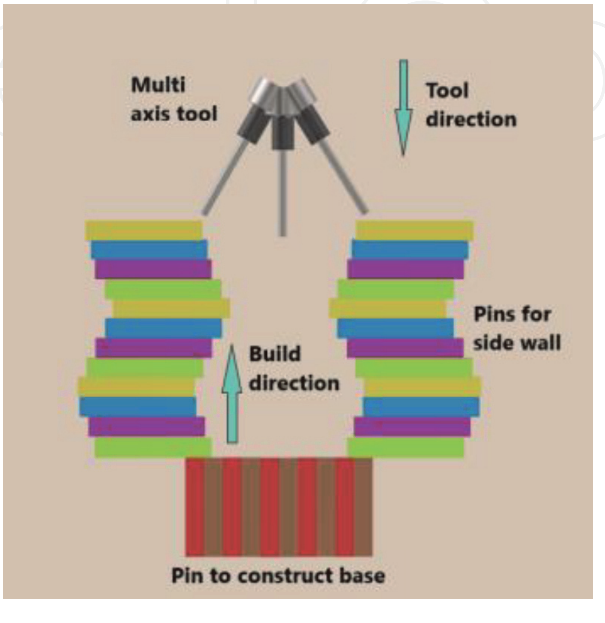

Figure 10.
Injectioun molding and machining.

4.2 Additive and transformative manufacturing processes

4.2.1 Injection molding and sheet metal forming

Polymer Injection Forming (PIF) is a one-operation manufacturing technique and a novel approach to manufacture sheet metal/polymer macro-composite. During the process, the pressure which is exerted by the injection of the molten polymer is used to shape a metal sheet inside an injection mold. In the same step permanent bond between the metal sheet and polymer creating a fully finished product is carried out in only one manufacturing step. The Polymer Injection Forming manufacturing is a combination of the metal forming and injection molding processes. The process sequence can be seen in **Figure 11**.

i. Between the open halves of a mold a metal sheet is inserted.

ii. When the mold closes, the metal sheet is cut down to the defined blank size. During the same operation and on same apparatus the blank can be shaped by bending the sheet or by deep drawing metal into the basic product shape.

iii. The polymer is injected into the remaining cavity when the mold is completely closed and a second, hydrostatic, deformation step is applied to shape the metal sheet into its definite form. In this phase of the PIF process, the physical adhesion between the metal sheet and the injected polymer is obtained.

iv. Finalizing the production cycle, the product is ready and is removed from the mold.

4.3 Subtractive and transformative manufacturing processes

4.3.1 Thermally enhanced mechanical machining

In the process of thermally enhanced mechanical machining externally heat sources is applied to heat the metal locally in front of the cutting tool. The heating effect changes the microstructure of the workpiece and it softened the material which allowed reduction in hardness, cutting forces and tool wear during material removing process on conventional machines. The frequently used external heat sources are laser beam and plasma. Laser assisted mechanical machining has been considered as an alternative process for machining of high-strength materials, such as high-temperature alloys, metal matrix composites, ceramics [18–21].

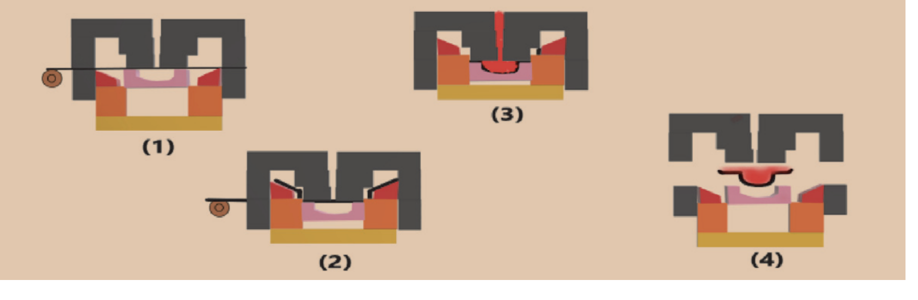

Figure 11.
Polymer Injection Forming process sequence [17].

4.3.2 Grinding and hardening

The grind-hardening process shown in **Figure 12** used to surface harden steel parts. This process is using greater depth of cuts, up to 1 mm, and slower work-piece speeds. Rotating grinding wheel generate a heat at contact by which the surface temperature of material raised above that of authentication. Also by introducing self-quenching for heat dissipation by using coolant, martensitic phase transformation takes place [22, 23].

4.4 Subtractive joining process

A configuration of schematic diagram of Solvent Welding Freeform Fabrication Technique (SWIFT) process is shown in **Figure 13**. In initial stage a standard size solvent weldable thermoplastic sheets placed loaded into a sheet feeder. The most frequently used solvent weldable thermoplastics materials are polystyrene, polycarbonate, PVC, and ABS. A pair of pinch rollers are used to fed sheets forward. Forwared sheet passes through a solvent masking which assist to prevent unwanted welding in desired areas. Solvent has been applied to the underside of the sheet at solvent masking station. Sheets are feeding continuous until it is positioned over the build platform. A platen is used to apply pressure on the sheet which is positioned over the stack of previously assembled sheets. In the process the new sheet placed on the top surface of the previously applied sheet, then the applied solvent between

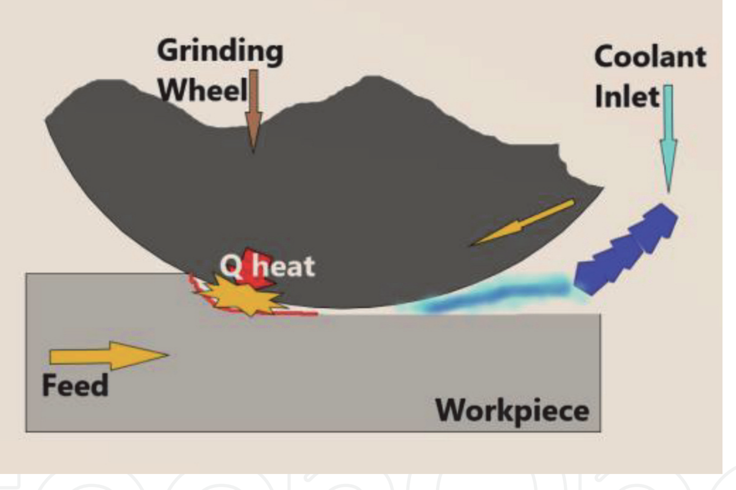

Figure 12.
Grind hardning process.

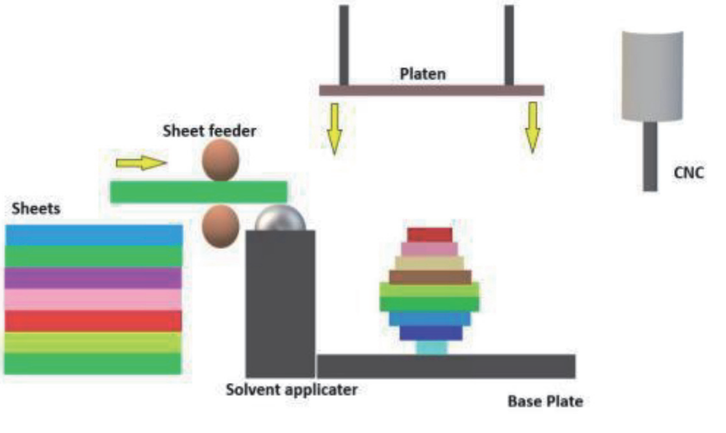

Figure 13.
Swift process configuration.

the two sheets at the interface dissolves polymer chains. After a while as solvent evaporates or absorbed it result in an interface weld and a solid part, which allows new molecular bonds between the two sheets to be established. This process is very rapid, and in practical, the platen apply pressure for only 5 seconds. Then by a CNC milling machine the cross-sectional contour cut down with a small diameter end mill cutter. As the machined sheets are preassembled prior to machining, process does not have any requirement of post assembly or special registration. Final product is completed after every layers has been added to the assembly and machined, the part can be removed from the build platform for the post processing as per the requirement [24, 25].

4.5 Additive manufacturing processes

4.5.1 Melting deposited material

Plasma laser deposition manufacturing working principle is shown in **Figure 14**. Powder is continuously feeding by control system into molten pool where powder is melted due to the focused laser beam and it result in re-solidification. The coatings thickness and 3D CAD model part must be predefined. To reduce oxidation, the whole operation is carried out under inert gas argon environment. The worktable is controlled by the control system. The material is deposited side by side with a defined amount of overlap. After deposition of an entire coating layer, the beam height of laser and plasma considerably keep away from the surface. The variables in the process such as power of combine plasma and laser beam, velocity of beam movement, feeding rate of material are controlled as per requirement of part to manufacture a final product.

This proposed PLDM process offers several advantages over conventional surface coatings techniques [26, 27]:

i. The traditional spray coating process can only used for thin coatings; The proposed PLDM process can allow to deposit thick layer coatings and it surfaces coating thickness can be controlled according to their requirements.

ii. The PLDM also allows material with a higher melting point such as alloys and refractory materials to directly fabricating different materials coatings.

iii. The PLDM process also offers comparatively high-quality microstructure and other mechanical characteristics.

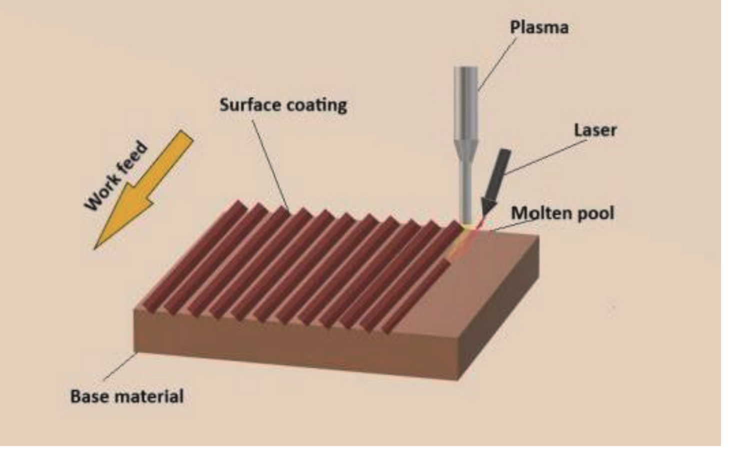

Figure 14.
Plasma laser deposition manufacturing.

iv. The PLDM process is widely adopted metal based rapid prototyping and tooling requirements.

4.5.2 Deposition of melted material

The laser deposition is one of the widely used metal deposition processes. This process offers a several advantages over other conventional solid deposition techniques. The advantages such as robust deposition with more accuracy in placement of the deposited material and provide in ease of disposition for many functional materials by using its' powder form. This proposed process shown in **Figure 15** is similar in working principle to laser welding and laser cladding in which using laser beam to form a melt pool and subsequently powder injected. The powder which is injected is deposited and fused onto the substrate because of the scanning from the laser. As the whole process is driven by the laser, so by controlling its beam and travel speed part can be manufacturing very accurately and it is become easy to mange other variables of the process and material waste as well as manufacturing time reduced [28].

4.6 Transformative manufacturing process

4.6.1 Sheet metal forming processes

Incremental forming process in one of the novel approaches of forming. Its basic working techniques shown in **Figure 16** is entirely different than traditional forming processes. A Single Point Incremental Forming (SPIF) uses a small tool which deformed the sheet metal and generate the shape of the final geometry. This process is different because in the process dies are not required to generate the shape. Below following set of relevant advantages is mentioned of SPIF [29]:

i. Process does not have any setup cost.

ii. A CNC is responsible for tool movement: a three-axis milling machine is sufficient for the requirement.

iii. Process offers very high flexibility: change in part program is very easy to do

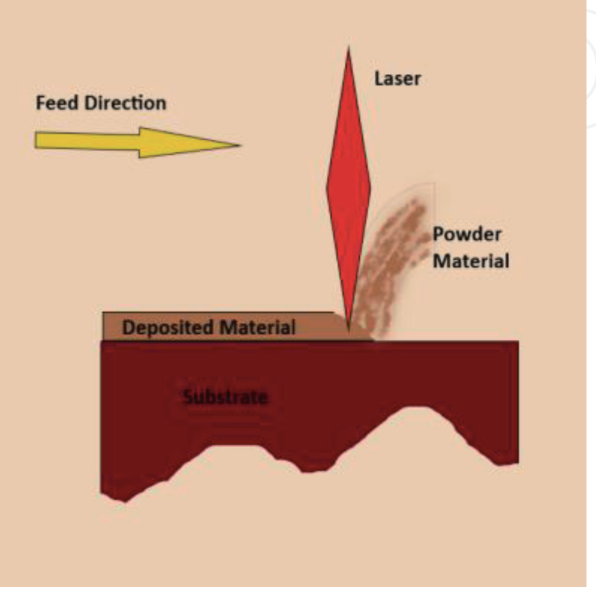

Figure 15.
Laser deposition system.

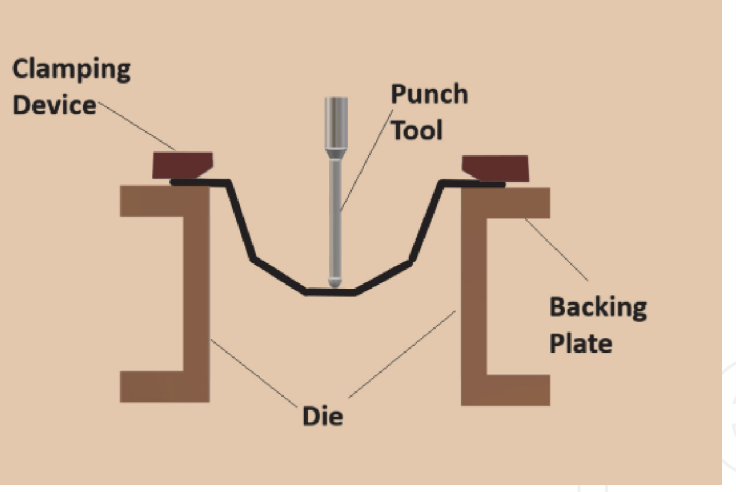

Figure 16.
Single point increment forming.

iv. The process is good alternative for rapid prototyping; the process is also very suitable to produce deform parts, especially old automobile body parts whose die is outdated and no longer available.

v. In comparison to conventional stamping processes, it provides a high formability. This characteristic of the process is due to the local deformation produced by the punch.

Some of the limitation of the product is listed below:

i. SPIF is comparatively slow process. The deformation is gradually done locally by the punch which travel on predefined ttrajectory to form complex shapes. Although advance machines operate at high tool feed, and it takes a time to form the sheet metal.

ii. The accuracy from the process is very limited. The effect of spring back can not be easily predicated, and operation need to be done on trial-and-error basis.

Incremented forming with die can be implied for specific requirement that is very hard to deformed by AISF. As one can see in the **Figure 17**, process has combination of two action AISF and SF. In result this process provides more uniform distribution of thickness. In both process stage AISF and SF induce same thickness across the sheet. After as per requirement less thinning can be generated by SF. If there is any pocket in the geometry it will help to form accordingly as material would be available to fill the pocket [30, 31].

4.6.2 Laser heat treatment and sheet metal forming

It is evident that the laser beam is provide a heat energy to change the microstructure and mechanical properties of the material, which result in ease of metal forming process. In the process shown in **Figure 18** a laser is utilized to heat sheet metal which eventually increasing the formability of the sheet and allows more effectiveness in single point incremental forming process SPIF. A laser beam is passed in front of the forming tool to heat the metal and to assist the forming process. A deep drawing process with laser assistance has been investigated. Prior to the deep drawing process energy of laser beam is used to heat the material locally, which allows the

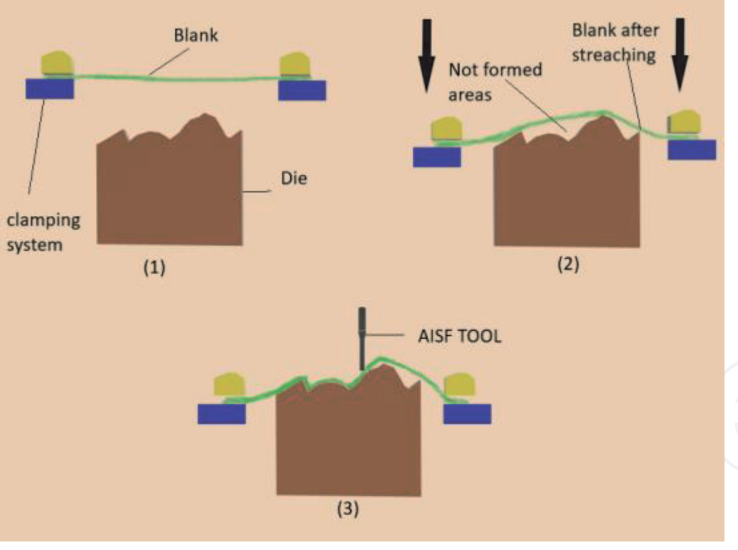

Figure 17.
Incremental forming with die.

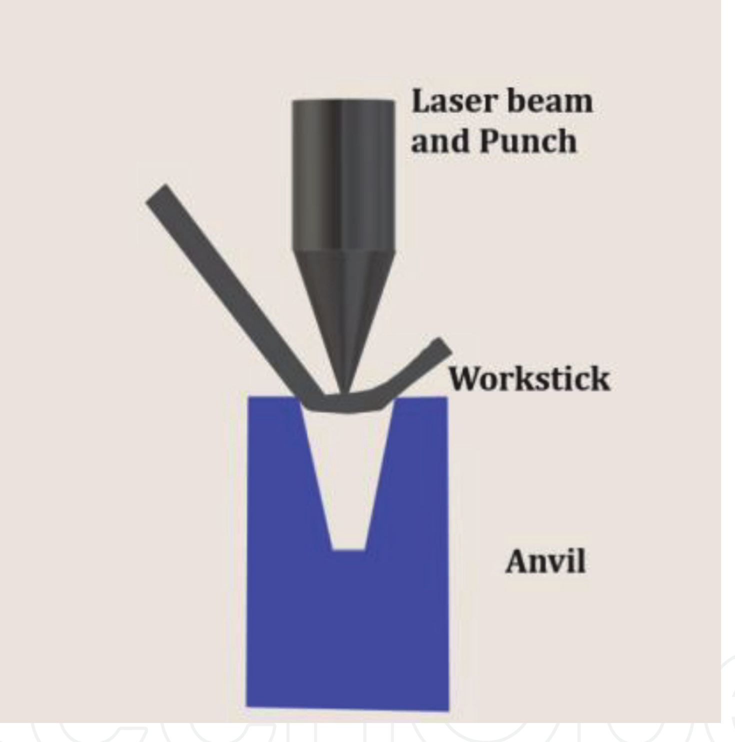

Figure 18.
Laser assisted V bending.

comparatively less drawing force, also it is responsible for lower number of forming steps and shows high productivity than the conventional deep drawing [32–35].

4.7 Subtractive manufacturing process

4.7.1 Mechanical machining and ECM

Figure 19 shows schematic view of the proposed hybrid process. The material removal process is driven by the combination of electrochemical machining and mechanical machining, a coated diamond abrasives spherical rod act as cathode and it rotates in pilot hole with certain speed in order removes material. The pilot hole is machined with a small diameter than the final hole diameter. In the process abrasives must be nonconductive while the tool core is electrically conductive. During

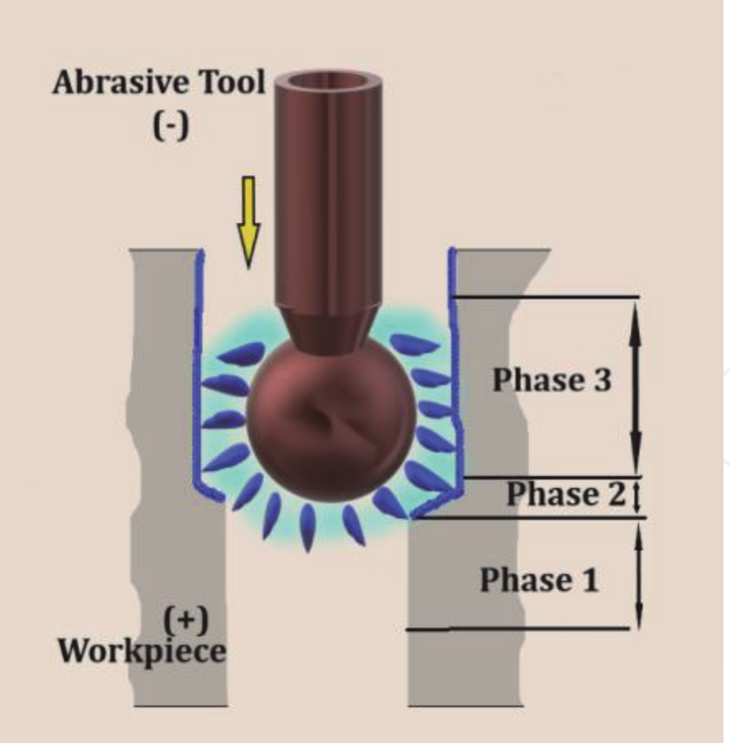

Figure 19.
ECM removing and grinding.

the operation, negative node is set on tool whereas positive end is set on workpiece. The diamond particles, which are abrasive particles of the tool are inserted before the nickel layer which is the conductive surface. This arrangement allows a gap between the conductive surface layer and wall inside the hole. In ECMG material removing action occurs in two stage, as it can be seen in **Figure 19**. Initially Electrolytic action start as soon as electrolyte filled the gap while during the process electrical charge supply to the tool. Step 1 of the process is entirely driven by electrochemical material removal action. Passive electrolyte NaNO3 is used in step 1 which allows passivation of the metal surface inside the hole. Step 2 of material removal process is a hybrid process which is combine action of electrochemical and mechanical material removal. As the tool advances inside the hole a gap between tool and material surface is decreases. The abrasive grains on the tool is responsible for removal of the soft and non-reactive passivation layer. In result of this step a fresh metal layer is become expose for another electrolytic reaction. During the process the electrolyte is stored between tools' diamond particles while the metal forms small cells of electrolytic, and that is how the dissolution of materials occurs. At the end of step 2 diameter of hole is enlarged and at its maximum limit. To manufacture highly accurate hole and sharp edges, insulated tool is used during the process. During step 3 only electrochemical dissolution occur which result in taper hole and no material removal is take place during the last stage [36].

4.7.2 Mechanical machining and EDM

In electrochemical grinding, demonstrate in **Figure 20**, allows material to remove by combination of abrasive action and electrochemical reaction; there are many variants of this process and abrasive wire ECM is one of them. Another variant of the process is allowing abrasive-laden air jet to directed towards the melt pool, and introduction laser milling/grooving processes has shown potential enhancement in the material removal rate (MRR) while almost eliminating the roughness and minimizing the heat affected zone of the generated surface. It is

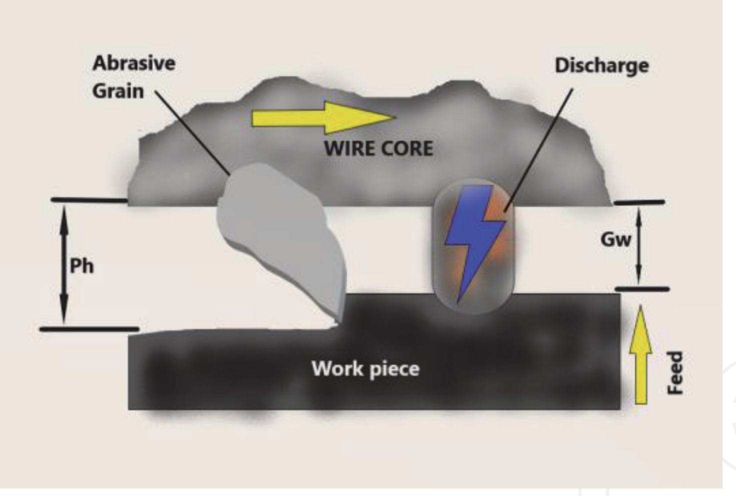

Figure 20.
EDM and mechanical machining.

evident that the hybridization in manufacturing processes is generally driven by the need that emerge due to technological limitations inherent to conventional manufacturing processes. Many hybridization in manufacturing processes applied abrasion removal machining process as one of the mechanisms by which material is removed. In electrochemical grinding process the combination of the abrasive action, which continually removes the surface material layers, and electrochemical material removal also contribute in removal of the material [37].

4.7.3 Laser jet and ECM

Electro chemical machining jet and laser drilling machining (JECM-LD) is not similar to laser drilling. It has combination of two different sources, energy of photons (laser drilling) and energy of ions (ECM), of energy simultaneously. The major purpose of combining a laser beam with a jet electrolyte is to achieve high quality machining by reducing the spatter and recast layer which is produced in simple laser drilling. As shown in **Figure 21** the focused laser beam is co-axially

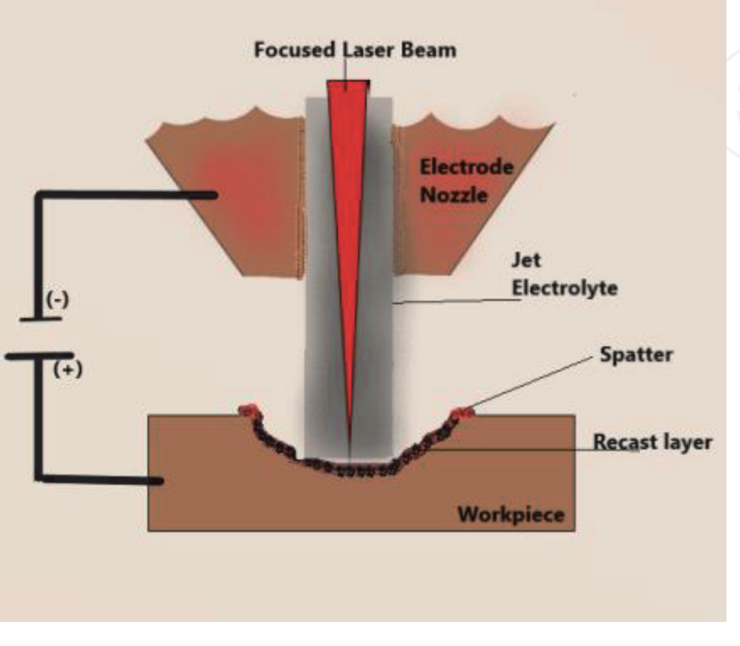

Figure 21.
Laser cutting and EDM.

aligned with a focused laser beam and tool this-electrode is not in contact with the material. The jet electrolyte and the laser beam are focused at a same time on the same location of workpiece. In JECM-LD manufacturing process, laser drilling is more responsible for material removing process and jet electrolyte effects is responsible to overcome the defects as it provides electrochemical reaction with materials, transporting debris and effective cooling to workpiece [38].

4.8 Ultrasonic assisted manufacturing process-(UAM)

Figure 22 illustrate the fundamental approach in ultrasonic assisted manufacturing processes and most potentially effective processes are mention below.

i. Ultrasonic assisted turning

ii. Ultrasonic assisted milling

iii. Ultrasonic assisted drilling

iv. Ultrasonic assisted grinding

v. Ultrasonic assisted EDM

vi. Ultrasonic assisted FSW

4.8.1 Ultrasonic assisted turning

Ultrasonic-assisted turning (UAT) is a novel approach of machining operation which generate a vibration by an ultrasonic system. **Figure 23** shows basic setup for UAT and tool behavior during cutting operation. The ultrasonic system generates high frequency and low-amplitude vibrations. Main purpose of this method is to avoid continuous contact with the workpiece. Most desirable benefits can be

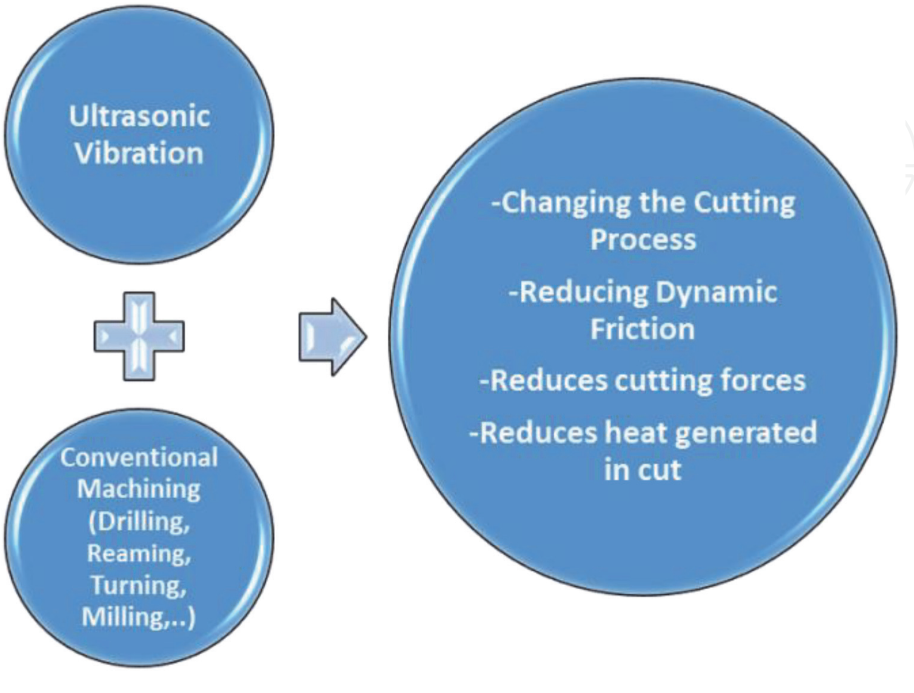

Figure 22.
Ultrasonic assisted process.

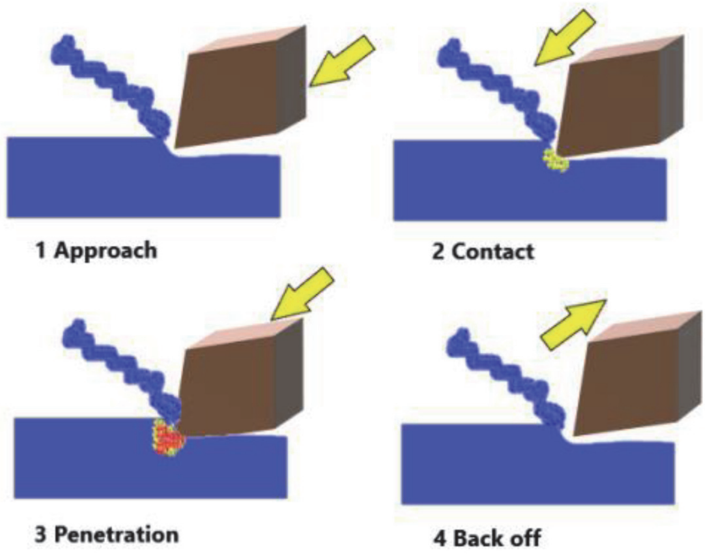

Figure 23.
Detailed view of ultra sonic turning process, 1–4 stages of the ultrasonic-assisted machining process.

achieved such as enhanced surface quality, reduced cutting forces, and lower residual stresses in a workpiece compare to conventional turning. Ultrasonic assisted is also advantageous for the machining equipment as it allows considerable life extension of the cutting tools because of lower requirements of cutting force. Ultrasonic Assisted Turning, however, is more efficient at lower cutting speeds compared to conventional turning. Ultrasonic-assisted machining effects decrease by increasing speed of cutting [39–43].

4.8.2 Ultrasonic assisted EDM

The combination of USM and EDM has the potential to reduce tool wear and electrode deflection in EDM of micro-holes and grooves. The mechanical signal was generated and transmitted to the tool-electrode, which was applied to remove material. The tungsten carbide workpiece was being vibrated while the EDM process was carried out. To remove the burrs formed on the exit region of a drilled hole ultrasonic vibration assisted dry electrical discharge machining process is used. The result of the study proves that in lower pulse durations the performance of novel ultrasonic vibration assisted dry EDM process is better compare to dry EDM process. The positive effects of applying ultrasonic vibrations to electrode at EDM process are because of both cavitation effect of the working fluid and also the vibrational action of the electrode itself [44–46].

Electrical discharge machining (EDM) is the process which is developed to remove conductive materials in the form of small craters. Such removal of materials are ranging from several to tens of microns. Process used electric sparks between a tool, electrode, and a workpiece which is submerged in a dielectric fluid. The sparks are strictly coordinated to control material removal rate. The micro-EDM process mechanism and EDM process mechanism is fundamentally same, the only notable differences are discharge energy supplied, tool dimensions and the resolution of the axis's movement. The gap between the tool and the electrode called spark gap, the series of sparks in a controlled spark gap is responsible for material removal, a small amount of material in the form of crater were removed from the workpiece as a spark strike the material. A pulse duration [μs], series of sparks within a certain time period, which is followed by a interval [μs], define as a pause for certain time duration in the sparking process. Each discharge cycle consists of pulse interval and

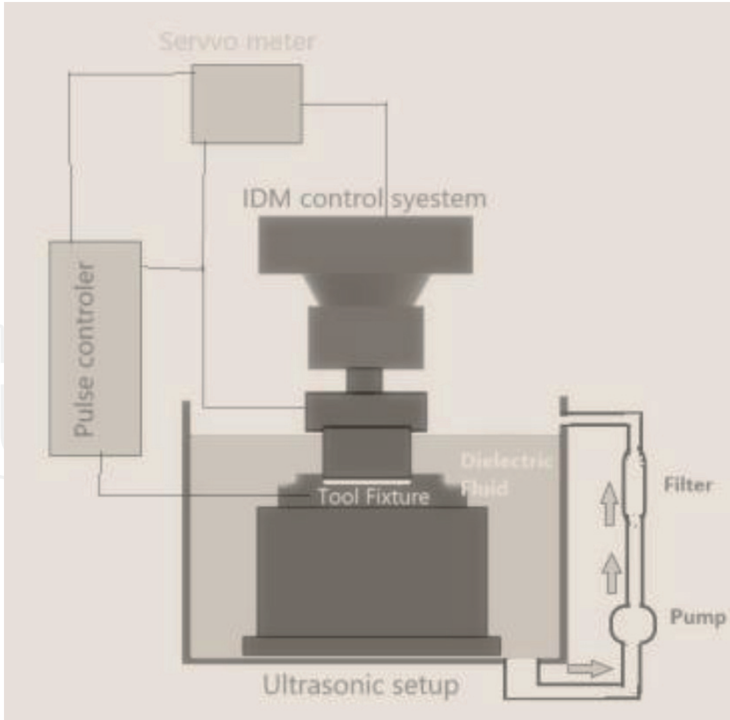

Figure 24.
Schematic diagram of ultrasonic assisted EDM.

pulse duration. The number of cycles which could run in a second control the discharge frequency. The pulse generator is used to control the discharge energy for a single pulse based on the requirement of machining conditions, such as finishing or semi-finishing, roughing. To maintain and to modify the spark gap and to control the movement of electrode respect to workpiece a servo control system is used. The EDM/micro-EDM system consist built in apparatus such as pump, filter, and dielectric reservoir to maintain the fresh dielectric flow in the spark gap which also flushing out the debris from the machined zone. **Figure 24** shows the basic sschematic diagram of ultrasonic assisted EDM/Micro-EDM system [45, 47–52].

5. Conclusions

It is observed tremendous amount of innovation and hybridization in advance manufacturing technologies. There are many researcher and universities are constantly working on innovative ideas and new technology. It can be observed that by hybridization of two manufacturing technology, more beneficial result can be achieved, and individual drawback of same process can be eliminated. Many of these innovations are potentially transformative, and not simply evolutionary. The subtractive processes and its combinations are mainly associated with the material, especially superalloys and ceramic, which are difficult to machine on the material removal processes such as milling, turning, drilling and grinding. The major contributors to material removal are EDM and other mechanical machining as such processes provided the high surface quality. Advance assisted processes such as ultrasonic vibration or laser cutting and its combination with conventional machining processes result in lower tool wear, higher surface integrity and shorter production times. Laser processing is still trending and attract many researchers to work on it in hybrid subtractive and transformative processes. It is important to be noted that the laser does not participate in actual materials removing process but introduction of it prior to the machining change the microstructures of the materials. It allows higher material removal rate as it become easy for conventional machining operations to remove the material in terms of the lower cutting forces which also beneficial as it results in longer tool life. However, flexibility of the processes is the limitation in a such type of combinations, therefore, to achieve freedom of flexibility and high dimensional accuracy rapid prototyping technology has been employed by various researchers to flexibly build components with arbitrary shapes. Future research advances, need to be addressed, namely, integration with other processes; need for new process-planning., modeling representations of hybrid process capabilities, additional standards, A.I. implementation (Machine learning) [44].

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