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Alternative Manufacturing Processes

FOREWORDS

Manufacturing processes are vital for both developed and developing countries of the world. Developed economies depend heavily on manufacturing industries for their revenues and, as a result, different kinds of manufacturing processes have been developed over the years. Engineers are always in search for effective manufacturing processes in order to make life easy and better for mankind. One of the most effective manufacturing processes is alternative manufacturing processes which employ different measures from conventional manufacturing processes to create real objects. Examples of such manufacturing processes include electro discharge machining (EDM), 3D printing, Design for Manufacturing and Assembly (DFMA) and many others. Sormaz & Khoshnevis (2003) argued that the process of incremental plan generation could help in providing cost feedback in real time to the designer. Designer can do a design modification due to the provision of the availability of alternative manufacturing process. With alternative manufacturing process in place, production schedules can be augmented and also production resources would be more efficiently used with improved delivery schedules (Nonaka, et al., 2013). This report discusses the mechanisms, processes, uses and fundamental features of the above-mentioned alternative manufacturing processes as well as their relevance in the manufacturing industry.

ELECTRO DISCHARGE MACHINING (EDM)

Electro discharge machining (EDM) is a machining process used in the removal of metals through electric spark erosion. Krar (2007) called it a controlled metal-removal process and SME, (1999) labeled it a thermal erosion process. A series of regularly occurring electrical discharges between the electrode and the work-piece causes the thermal erosion to occur. However, it should be considered that the workpiece in an EDM must be conductive and also there must be a dielectric fluid for the process to occur.

History of EDM

The history of electrical discharge machining is rooted to electric discharge mechanism dated as far as the early 18th century. Descoeudres (2006) showed that early EDM was in the form of devices using electric arcs for lightening purposes. According to IDS machining, the first person to investigate into the early EDM is Joseph Priestly in 1770 and the machine was seen as a failure because it was not precise. However, the modern EDM began in the 1943 when the principles of operation of the machine were invented by Russian scientists, Boris, and Natalya Lazarenko. They proved that EDM erosive effects could be controlled and therefore effectively employed in manufacturing purposes (IDS machining).

Although the performance of the machine was still limited at this time, a lot of researches, and progresses were made to understand its functionality and improvement. The erosion phenomenon of EDM was an aspect of the machine in which effort was made to understand. The development of semiconductor in 1960 brought about an astounding improvement in EDM machines. Other developments between the 1960s and 1990s made EDM machines more precise and improved. Such developments included the introduction of numerical positioning that made the electrode movements more precise, computer numerical controlled system (CNC) which enhanced the machines overall performance. With these developments, both die-sinking machines and wire-cutting machines became reliable and produced the required surfaces with exceptional qualities (Rajesh, & Anand,. 2012; Shanmugam et al. 2013). Further improvement in technology led to the development of newer methods for the operation and processes of EDM machines.

How It Works?

Prior to discussing the working processes or principles of EDM, it would be imperative to consider that both the work-piece material and the electrode material of the machine must be conductors of electricity. Krar (2007) mentioned that EDM processes can be opted in two different ways. The first is a pre-shaped tool made of copper or graphite, and it is shaped in the form of a cavity that is to be reproduced. The tool is vertically downward fed and eroded in reverse shape into the solid work-piece. Another way for an EDM process can be used in a vertical wire electrode continuously traveling and with a very small diameter. The electrode or tool follows a programmed path, controlled by a computer and can be directed to cut through a workpiece so as to produce the required shape.

Source: Adopted from Descoeudres, 2006

The working principles of an EDM machine can be better evaluated by understanding the classification of the machine. EDM machine:

- In a conventional EDM process, having RAM or sinker machining as a part, electric spark is used to cut the work-piece. The work-piece then takes an opposite shape to the electrode after being cut. During the cutting process, both the electrode and the workpiece are submerged in a dielectric fluid such as light lubricating oil. In addition, the electrode and the workpiece are restricted to come in contact with each other and are be separated by a distance of about a human hair thickness with a servomechanism.
- Wire EDM is also known as spark EDM process, and it involves electrothermal production mechanism. In this process, a particular thin single-strand metal wire is used together with de-ionized water and the use of heat from electrical sparks, it allows the wire to cut through metal. This EDM process is essential because it can be employed in machining precision components and complex parts from hard conductive materials.
- Sinker EMD Machining process is another interesting process in which two metal parts are immersed in an insulating liquid and are connected to a current source. They are switched off and on depending on how the controller is set. The operation of the machine in this process depends on whether the controller is switched on or off (IDS machining).

In the operation of the EDM, materials are removed from the work-piece by stationary and timed electrical pulses. The machine tool containing the dielectric holds the electrode and work-piece. The intensity and timing of the electrical charges, as well as the movement of the electrode regarding the work-piece, is controlled by the power supply. A discharge occurs where the electric field is strongest, and then the accelerated electrons and positive charges form an ionized channel which conducts electricity. Electron collision occurs at this point between the particles because of current flow. A bubble of gas is developed creating a plasma zone which reaches very high temperatures of between 8000oC and 12, 000oC and therefore some amount of the materials at the surface of the conductors are melted. The eroded materials solidify, and it all happens without the electrode touching the work-piece. Hence, EDM is a non-contact machining process. Better finish and improved quality is produced in this process (Mercatech, 2004).

Uses and Applications of the Processes

EDM and Micro-EDM have wide industrial applications today. For instance, EDM is rather used than conventional methods in producing complex shapes because the machine is easier to program. Moreover, the tool that one is using has constant dimension and not miller cutters with lots of different diameters. EDM is also used in order to reduce the cost because it uses lower chip/work-piece mass ratio. One can reuse slugs produced from wire EDM, but the only way to recover and reuse chips from conventional machining methods is through recycling process. EDM is a manufacturing process with a lot of edges over the conventional process (Mercatech, 2004).

EDM is used in manufacturing varieties of tools such as diesel injector with seven holes, diesel injector with eight holes, and diesel injector with nine holes. In addition, it facilitates in aerospace components, speaker die for care stereo system, side burn and so forth.

Advantages and Limitations

Electrical discharge machining has several advantages over conventional machining processes, but it also has some demerits or limitations. The benefits of the manufacturing process are as follows. It does not generate any cutting force because it is a non-contact process. Therefore, it is possible to produce small and fragile materials through the machining process. The edges produced do not have burr as well as it is possible to ensure intricate details and superior finishes in this process. It is possible to produce intricate parts that have low operator intervention with EDM machines that have built-in process knowledge.

Despite the above-mentioned advantages, a few limitations can be experienced with an EDM machine. These include: in comparison to chip machining process, the rate of metal removal in this manufacturing process is low; to ensure that the shapes of the electrodes are consumable and specific, one needs lead time.

Figure 2 Classification for main research areas in EDM (Adopted from: Rajesh & Anand, 2012).

3D PRINTING

Additive technology is an innovative technology that is expected to revolutionize the manufacturing sector in the 21st century. 3D printing is one of the top notch additive manufacturing processes. According to ELI (2012), it is the method of producing an object with the aid of a machine that builds upon materials layer by layer in a three-dimensional structure. It follows the instruction supplied by a computer program until the required shape is produced. It is also known as rapid prototyping and usually the 3D printer used for the printing is small. This technology is quite interesting because of its efficiency, cost and time-saving benefits and so forth. The object produced with 3D printer can be designed with a special computer program, usually a kind of the CAD program. In some cases, the object is rather scanned with a 3D scanner before printing (Tyagi, 2011; Komoto, & Tomiyama,, 2010).

History of 3D Printing

Charles Hull developed the technology for 3D printing from digital data in 1984. However, he called the process Stereo Lithography, for which he got it patent in 1986. A variant but very similar technology to the Stereo Lithography was patented by Massachusetts Institute of Technology (MIT) in 1993. This technology took after the 2D Printers inkjet technology, and it was known as 3 Dimensional Printing Techniques. Subsequently, a number of products were released from different corporations such as Stratasys, Z Corporation, and 3D Systems. In 2005, the groundbreaking high-definition color 3D printer was launched by Z Corporation. This led to a lot of revolutions in the development and manufacturing processes of the 3D technology (CSC Leading Edge Forum, 2012).

Z Corporation, (2009) pointed out that 3D printing technology has gone through three generations that include the first generation, corresponding to 3D printing arrival between 1995 and 2000. Examples include Z402, Z402C, and Z406 while second generation enhanced the performance, affordability and color of the printers during period of 2000- 2005. The examples include ZPrinter 310, Spectrum Z510 and lastly the third generation which focused on ease of use between 2005 and 2010. It includes ZPrinter 450, ZPrinter 650, ZPrinter 350 and others.

Figure 3 Sequence of first, second and third generation of 3D Printing (Adopted from Z Corporation, 2009).

How It Works?

This process needs to be provided a model for the 3D printer in order to create the 3D object. This model can be provided either by scanning an existing object with a 3D scanner or by creating the model having specification for model in a 3D modeling application (ELI, 2012). To create the specification with a computer system, one need to create the model with a software tool that would export it as files in standard formats for 3D printing. The formats could be. PLY,. STL, . ZPR, . 3DS, . WRL and so forth. Most importantly, the exported files must be a mesh or triangles in space that encloses the volume of the 3D object. In addition, it is important for the mesh to be solid and water tight. That is to say; the design should not just be abstract, meant specifically for a computer. It must be ready to exist in the real world. Examples of CAD software used in producing 3D files include 3D Studio Max, 3D Studio Viz, Alias, and AutoCAD. In addition, it includes MicroStation, Mimics, Pro/ENGINEER, Raindrop GeoMagic, Bentley Triforma, RapidForm, Blender, ResMol and so forth. (Campos, Lovisolo, & de Campos, 2014; Z Corporation, 2009).

Once the object is created in the CAD software and ready. One has to launch the printer software in the computer. One can send the specification to an extrusion printer which uses plastic filaments or any other material to create the needed object layer by layer in three-dimensional form. In most cases, the completed object has one color but with improved technology, variant color 3D printed objects are now being produced (ELI, 2012).

Figure 4 Different processes of 3D Printing, (Adopted from Z Corporation, 2009).

Uses/Application of 3D Printing

3D printing technology is now employed in manufacturing a number of things. CSC Leading Edge Forum, (2012) pointed out that the developed lifecycle of materials can be reduced by rapidly printing prototypes. 3D printing in the past was only concerned with printing prototypes but today it is also concerned with direct part production which is also known as direct digital manufacturing. Some of the areas in which 3D printing technology is employed include defense where it is used in producing strong, durable and reliable military equipment. It is also used in aerospace to produce lightweight but strong materials. In addition, it is used in automotive, healthcare, construction industries, manufacturing industries and so forth. The automotive industry has been employing 3D printing that is used to create prototypes. But recently, the first 3D printed car was developed by Urbee, and it is shown in the figure below.

Figure 5 3D Printing of Prototype car (Adopted from CSC Leading Edge Forum, 2012)

Advantage and Limitation of 3D Printing

3D printing technology has lots of advantages. Firstly, 3D printing saves time and cost. It is additive manufacturing process, and therefore materials are not wasted, unlike other printing techniques. With 3D printing, one can print materials at the comfort of his home. This facilitates by curtailing the movement from one manufacturer to another. The technology allows the easy creation of complex objects that hitherto would have been difficult, and the object would be created with much accuracy. Furthermore, such complex object which would have taken substantial amount of time to produce via conventional manufacturing process would be printed in a very short time. A good example is the 3D printed race car that was printed in four minutes with high precision at the Vienna University of Technology (CSC Leading Edge Forum, 2012).

However, 3D printing has a few limitations and these limitations hinges on the fact that it is still an evolving technology. Firstly, the printers often use liquid polymers in printing objects in layers. This may not be practical to use the printers in printing large objects. Objects created with 3D printing technology have surface finishes that are rough and ribbed, and the end products often have an unfinished look. The cost of purchasing 3D printers and its accessories are very high (Stein).

DESIGN FOR MANUFACTURING AND ASSEMBLY (DFMA)

Design for Manufacturing and Assembly (DFMA) are a series of techniques used for design and process improvement in order to reduce the cost of production. It is imperative to consider that DFMA is a combination of two processes namely; design for manufacturing and design for assembly. Both processes are targeted at ensuring cost-effectiveness, as well as the design and process improvement. The manufacturing process is often employed in the manufacturing industry, and the result is improved efficiency (Di et al., 2014).

History of DFMA

The development of this process named Design for Manufacturing and Assembly stream from the long developing period. It avoids the high cost, unguaranteed quality, poor characteristics in manufacturing, assembly and maintenance and lots of other flaws of the conventional manufacturing process (Xie, 2003).

Its research and development were first conducted in the 1970s by Geoffrey Boothroyd and Peter Dewhurst, and they had DFMA as their company's trademark (Porter, 2005; Xie, 2003). The company formed by Geoffrey Boothroyd and Peter Dewhurst developed DFMA software and also created the concept behind its operation. The software is used in most production process of DFMA today.

How does it work?

- Design for Manufacturing (DFM) is a method of design that is targeted at making manufacturing easy of the collection of parts that would form the product after it has been assembled. In other words, this process is simply aimed at improving the manufacturing process (Stienstra, 2013).
- Design for Assembly (DFA) is a tool of design to make assembly of the parts and system easy and effective.

Before DFMA

After DFMA

Figure 6 New Development and design of reticle Assembly (Adopted from Porter, 2005)

While design for manufacturing is concerned with reducing overall production cost, design for assembly is concerned with reducing assembly cost alone. The combined use of these particular processes is usually referred to as a single method known as DFMA (Stienstra, 2013). The sequence of operation of this design is first the design for assembly and then design for manufacturing that then leads to the detailed design. It is imperative to consider that the assembly and manufacturing process must follow certain processes.

Uses/Application of DFMA

DFMA is widely used in the manufacturing processes. Products designed with this technology have higher quality and reliability than those developed through conventional methods. Also, the design process is faster. It is used by most companies that also use solid modeling such companies include Hewlett-Packard, Texas Instrument, Ford, General Motors, Toy Manufacturers and so forth. DFMA can be used in the fabrication, assembly and installation of pilot instrument panels, fasteners and a wide range of products (Porter D. K, 2003; Michalos, et al., 2014).

Advantages and Limitation

The advantages of DFMA are numerous that include the following: Firstly, the design method helps to minimize waste because up to 75 percent of the product cost can be determined during the engineering phase. (Porter, 2003). It also helps to reduce inefficiency in the product design; it helps to save cost while improving efficiency of the final product; the time involved in the production process is also reduced with DFMA.

Some of the limitations of DFMA include: Firstly, it has very little scientific base. The method has insignificant effort at the conceptual design stage; in case of unsuitable design, one cannot provide redesign suggestions so as to modify shapes.

Figure 7 Comparison between cost of assembly & manufacturing (Adopted from Stienstra, 2013).

CONCLUSION

The report discussed three innovative alternative manufacturing processes including electro discharge machining (EDM), 3D printing and Design for Manufacturing and Assembling (DFMA). These alternative manufacturing products all help to create improved products with enhanced efficiency. Another important feature that is common with these alternative manufacturing processes is involvement of time in manufacturing products that shortened it compared with the conventional manufacturing process. The operational processes of these manufacturing processes have been discussed above, and it was also noted that they have both benefits and disadvantages or limitations.

3D printing is perhaps the most revolutionary of the three alternative manufacturing processes discussed above. It is an additive manufacturing technique which can be used in printing real three-dimensional objects with a 3D printer. It is imperative to consider that the future holds great prospect for these alternative manufacturing processes. For instance, 3D printers are projected to be used in printing rocket parts; liquid metal parts; houses; trees, leather, meat and any food. It also helps in personal medicine, human tissue, and complex organs; soil and flowers; spare parts in space and moon base and many more. Likewise the other alternative manufacturing processes namely, EDM and DFMA will also find a lot of wonderful applications in the future.

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