Study of Ultrasonic Additive Manufacturing

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Abstract: Over the past 20 years, additive manufacturing (AM)technology are comes in word and contributed such as 3D printer used for rapid photography and other is sterendithography (i.e. it is STL file used to convert the 3D CAD into the create a parts or object). An ultrasonic consolidation is a technology which comes in word in 1999 and it consist of a manufacturing of rapid tooling process. In which the tooling is done in single operation. The AM technology comes in many sectors of manufacturing to reduce working time, waste of raw material, waste of energy. Ultrasonic additive manufacturing (UAM) is done with by using conventional manufacturing processes. An UAM is a manufacturing process which can do without tools in which only one tool is used which is "sonotrode". In UAM the metal is joined layer by layer by using of an ultrasonic wave welding at a solid state of work piece. Included is an outline of the definition of UAM, A review of the commercially available and under development technology of metal fabrication, possibilities and overall assessment of process characteristics and formation of bond. As broad view on future research opportunities are so many available.

Keywords *— UAM (Ultrasonic Additive Manufacturing), Sonotrode, CNC, Milling, Trimming, Welding, CAD.*

I. INTRODUCTION

The UAM is a sheet metal working process which are used to the sheet metal by using ultrasonic wave welding. It consist of three steps such as first is the joining of material, after that the CNC trimming or milling machining is required to remove excessive material. In which the Duct tape is used to fill the gap as a material saving element. The size of duct tape is 0.150 mm thick and 25 mm wide does however result in saving of material. Milling machining can do after each layer putting or after that the whole process depends upon our specific applications.

The UAM process or technology broadly used in many type of fabrication applications of many metallic or non metallic object of engineering materials such as nikel base alloy, composite alloy, stainless steel, copper, titanium and fiber like as silicon carbide (Sic), etc. the UAM can be fabricate an object with low temperature and allows for internal geometries to be created.

The UAM have main advantage is the it is process which bond different material and requires less amount of energy by using a ultrasonic waves and pressure.

II. ABOUT ULTRASONIC ADDITIVE MANUFACTURING

UAM is also known as ultrasonic consolidation is a low temperature additive manufacturing or 3D printing technique for metals. This process work by scrubbing metal sheets are together with ultrasonic vibrations under pressure in continuous fashion i.e. sheet lamination classified in additive manufacturing. Metal melting is not the formation mechanism. Instead, metal joining is in the solid state. Via disruption of the surface oxide Layer between the metals i.e. UAM is metal welding mechanism. CNC counter milling process is used to trim or remove the excessive material or unbound material from the object. UAM have the ability to join different type of multiple metals type together. An UAM done at very low temperature i.e. the temperature sensitive material at relatively low temperature. Typically less than the

50% of the metal matrix melting temperature. UAM can be used at the metal fabrication industries where as the different type of the material foils are joined together with low temperature process.

The Ultrasonic Consolidation or Ultrasonic Additive Manufacturing process was invented and patented by Dawn White. In 1999, White founded Solidica Inc. to sell commercial UAM equipment formation machine suite. Apart from this, the conceptual as well as experimental study of the ultrasonic consolidation was under research since much longer period. In 1971, Joshi has presented the paper on the bond formation between two metal surfaces under effect of surface oxide layers. Daniels led the path of ultrasonic welding principle in 1965 and in year 1977, Kreye studied the metal melting during bond formation in ultrasonic consolidations. These all thesis built the base for invention of UAM. In 2011, Fabrisonic LLC was formed to commercialize the improved UAM process Sonic Layer machine suite.

III. PROCESS OF UAM

UAM is also known as ultrasonic consolidation (UC).it work by use of an ultrasonic wielding process to join permanently foils of metal together fabrication of an object by one foil or sheet of material.

UAM is sticks strips of metal material by use of ultrasonic wielding. It is a solid state welding process that of by using of high frequency ultrasonic acoustic vibration locally to work piece being join together by use of pressure to generate solid state weld that is meaning of process a bond is created without the melting of the material.

In traditional wielding the brittleness found between the layers. But in case of UAM is neglected due to a low temperature fabrication process and different metals are bounded after that the CNC machine is used to trim or remove the excessive material and complete the desired or required object. Then the object is fabricated one layer at a time by repeating the above same process. The main or ideal special application and UAM is to join the different type of materials and different type of combination of metals with tight bonds.

The material feedstock are defines the layer thickness and this process and can be as thin as 200 um. The use of an UAM is to fabricated object from different material such as titanium, molybdenum, tantalum, silver, aluminum, stainless steel etc and other alloys. It have a main advantage of this method is the ability to change fabrication material during the fabrication process.” Smart structures” are created by use of UAM where additional component becomes part of the finished product. It is for example to embed electronics into a sealed internal cavity during the printing process.

The ultrasonic additive manufacturing consists of following major steps:

i. Preparing CAD file of component
ii. Setting up the machine
iii. Two step hybrid additive-subtractive process
   a) Metal addition & ultrasonic joining
   b) Trimming
iv. Repetition of process until completion
v. Finished Product

In these specified steps, the ultrasonic consolidation takes place.

A. preparing cad (.stl) file of component

Figure 1) Significance Of .stl File

B. TWO STEP HYBRID ADDITIVE-SUBTRACTIVE PROCESS

UAM is a bond-then-form process that directly produces metallic components from a 3D model by successive use of low-temperature ultrasonic welding followed by CNC trimming of metal layers. Parts are built up from bottom to top on a heated substrate, with temperatures ranging from room temperature to

~200C. Each layer is typically deposited as a combination of foils laid side by side rather than a single large sheet, as is typically practiced in sheet lamination processes. These layers are then trimmed using CNC milling to form the desired accuracy and geometry. This process works well with metals having low deformation resistance.

a) STEP1:METAL ADDITION & ULTRASONIC SEAM WELDING

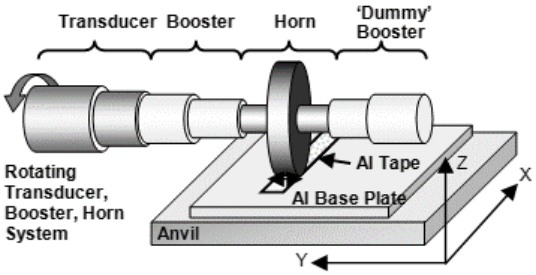

Figure 2) Metal Addition And Welding Operation [6]

During UAM, a rotating sonotrode travels along the length of a thin metal foil (typically 100–150μm thick). The foil is held closely in contact with the base plate or previous layer by applying a normal force via the rotating sonotrode. The sonotrode oscillates transversely to the direction of motion, at a constant 20 kHz frequency and user-set oscillation amplitude. This procedure is repeated until a complete layer is placed. The next layer is bonded to the previously deposited layer using the same procedure.

b) STEP2:CNC MILLING (TRIMMING)

Typically four layers of deposited metal foils are termed one level in UAM. After deposition of one level, the CNC milling head shapes the deposited foils/layers to their slice contour (the contour does not need to be vertical, but can be a curved or angled surface, based on the local part geometry).

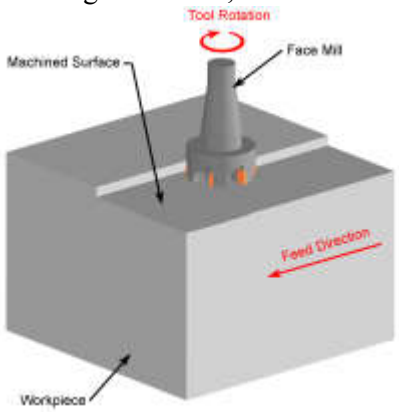

Figure 3) CNC Trimming Operation [5]

The general manufacturing process is: A base plate is placed onto the machine anvil and fixed into place. Metal foil is the drawn under the sonotrode, which applies pressure through a normal force and the ultrasonic oscillations, and bonded to the plate.

C. FINISHED PRODUCT

Finished product of the UAM is the ready to use part comprising of numerous metal foils stacked over each other and joined by means of the ultrasonic welding effect. This part is almost free from any kind of residual stresses and seldom requires post finishing as it is already machined with the CNC milling head.

IV. ADVANTAGES OF UAM

- Low surface roughness and high dimensional accuracy CNC machining eliminates the stair-stepping effects found in other AM processes. The final products show low surface roughness and

high dimensional accuracy that is independent of the foils layer thickness. In short, the UAM process manufactures the ready to use part as almost no post machining operations are required.

- UAM is a great environmentally friendly and cost-effective metal forming technology. This process combines low temperature ultrasonic bonding and additive-plus-subtractive processing to create complex, multifunctional 3D parts, including objects with complex internal features or embedded sensors etc.
- It is a low temperature process which produces temperature only about 50% as that of the melting point temperature. This low temperature generation imparts the plus points of not having any kind of thermal distortion or inducing of residual stresses in the manufactured component. Also the lower working temperature promotes the comfortable working environment and longer machine tool life.
- UAM is a solid-state manufacturing process in which materials are machined and bonded in the solid phase itself. The conventional methods such as casting, molding are liquid or semi-liquid state processes in which the material is subjected to melting. This causes the excess energy input and prolonged production time. On the contrast, UAM consumes less power, around 10% as that of conventional processes. Also the time span of the UAM is short as compared to the conventional methods as it have 250-500 cm^3/hour material deposition rate.
- Product part of any customized composition can be manufactured easily which not possible in case of casting or forging. The composites of metal-metal, metal-fiber-metal, ceramic reinforced metal are manufactured easily. One only need to change the foil of metal to change the composition of the workpiece being manufactured.

V. APPLICATIONS OF UAM

A. Functionally Graded Materials

UAM can manufacture the FGM are used for the applications where high level mechanical as well as physical properties are required such as aerospace vehicle shields, rocket nozzles where the temperature reaches up to 2000’ C. Other applications are the heat exchanger plates, lightweight armor plates for defense applications, heat engine components.

B. Structurally Embedded Electronic Systems

In current industrial applications, the electric systems embedded in a solid enclosure or part are becoming essential so as to facilitate the portability, robustness and flexibility in the functioning. Thus UAM provides a single stroke method to produce better electrical applications such as embedded sensors and RFID, tamperproof electronics.

C. Fiber Reinforced Metal Matrix Composites

UAM can be used to manufacture the MMC in which the matrix is a metal where as another component is fiber of Silicon Carbide (SiC) reinforced in the metal matrix. These fiber reinforced MMC manufactured by UAM are used I the applications such as airplane wing frames where the low weight and higher strength is expected. The F-16 Falcon fighting plane uses silicon carbide fibers in titanium matrix for structural components of the jet’s landing gear. Apart from these, other applications are golf clubs, fishing rods, brake parts, biological prosthetics etc.

VI. CONCLUSION

From the detailed study of the ultrasonic additive manufacturing (UAM), also known as ultrasonic consolidation. It can be concluded that UAM is an emerging field of rapid prototyping which facilitates the manufacturing of metal components almost similar to that of 3D printing technology and covers the vast area of applicability. It can be used to produce the complex geometrical shapes and composite material parts with ease and least affecting properties. Although the UAM technology is advantageous in many aspects, its uses are limited to the certain fields because of constrained research in its research and

development. Only special applications such as aerospace technology, composite heat transfer members are being manufactured by UAM nowadays. The further expansion of this technology might lead to the revolutionary changes in the manufacturing section and hence the UAM offers wide chances of future development.

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