Design and Fabrication of 3D metal printer using Fused Deposition Modeling.

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Abstract

Three-dimensional printing is the method wherein the object is printed as a 3D net shape product with the aid of laying of additive layers of the material. It is the part of Rapid Prototyping where a mechanized technique is employed to manufacture 3D objects in a quicker manner. The blueprints for the object are to be printed are stored on the personal computer which is connected to the 3D printer. Now an entire model can be created in a unique process by the usage of 3D printing. We have created a 3D printer that can be used to print metal objects by using soft metals. 3D parts can be made through the melting of metal wires at sufficient temperature by using a Coil Heater. This paper describes about 3D printing through the Fused Deposition Modeling technique. The 3D printer is extensively used in a variety of industries like Engineering, Construction, Medical industries, Aerospace, etc.

Keywords: *Metal Printing, Aluminium, Coil Heater, Fused Deposition Modeling.*

1.Introduction

Fused Deposition Modeling is also termed as Fused Filament Fabrication process. The principle behind FDM is that a filament of continuous spool form is fed through the nozzle of a 3D Printer with the aid of an extrusion head. The nozzle is elevated to a temperature by using a heating coil, and a motor is used to feed the wire filament through a nozzle. The printer head is actuated by the respective stepper motors in one or more coordinates.

The deposited material solidifies and builds the part over the print bed. It is a layer by layer sequential printing of the required part. This method of building a 3D part is continual, and eliminates secondary operations. In this method, the production material is fed to the extrusion nozzle which melts the material into semi-liquid-state and drops it across the layer as per the geometry of the prototype [3]. The FDM process utilizes an easy mechanism which consists of building a physical component by the addition of fused material of layers by the help of adhesion [13]

The 3D printing procedure prints the three-dimensional object from a 3D model of “stl” format and prints layer by layer of the model, which is referred as additive manufacturing that is no longer like traditional machining processes like casting and forging in which the material is eliminated from a stock item like subtraction of material or poured into a mold and shaped by dies, presses, and hammers.

"3D printing" includes many processes within which materials are blended or solidified underneath the managing of a computer to make a three-dimensional object, with the product being added collectively together with liquid molecules or powder grains being joined collectively, layer by layer. In the early 1990s, 3D-printing techniques were accepted in the field of manufacturing more effectively for practical purpose and a relevant name for it was rapid prototyping. One of the key benefits of 3D printing is the potential to supply very complicated shapes for printing any 3D printed part is by the usage of a digital 3D file. 3D printing has various techniques like Electron beam melting, selective laser melting, etc.

3D Metal Printing Technology and Metal Additive Manufacturing Processes like Powder Based Fusion and Direct Energy Deposition are detailed along with the applications, advantages, and disadvantages of AM. The economics of 3D Printing Technology, Technology Selection were also discussed [1]. The influence of hybrid Laser MIG Welding experiment performed on AISI 304 SS Plates, and the analysis of the results along with determination of real influence of each parameter, [2]. The various techniques to Enhance FDM based 3D Metal Printing, cost Analysis of FDM and SLS Technology and finding easy way to manufacture the printing device and advantages, disadvantages are listed [3].

The Comprehensive assessment of 3D Printing and contains qualitative assessment of 3D Printing induced sustainability and model calculations [4]. The detailed comparison of different types of 3D Printing technologies were discussed along with the general introduction to the concept of 3D Printing, different types of 3D Printing Technologies with their pros and cons [5]. FDM 3D Printer with Three Nozzle extrusion mechanisms, provides detailed design aspects to improve the shortcomings of the current 3D Printer as well as its working mechanisms of 3D Printer [6].

FDM Technologies with different RP materials such as ABS, Nylon, Wax, Resins, etc and their characteristics were elaborately illustrated. [7]. The method of Designing and Manufacturing 3D Printer based on FDM Technology, the results of this process with ABS, PLA Materials and the techniques to achieve, geometric accuracy of the given product were clearly provided [8]. Micro structural level analysis were carried out over the 3D Printing part using Fused Deposition Modeling of Metals [9].

A modified system to enhance a prescribed amount of deposition of eutectic and non-eutectic Bismuth and Tin for making parts like Jigs and Fixtures, Tools and dies. The Metal/Polymer composites were combined to manufacture a 3D Product and various performance tests were also done on them [11]. Experimentation, Analytical Modeling, and Numerical Simulations were synthesized on the shape of solidified droplets produced on surface of substrates that is affected by fluid dynamics and heat transfer process occurring at the collision of liquid droplets with solid surface [12].

A general FDM based 3D Printing defects like misalignment of print platform, disrupted material flow [13]. The manufacturing considerations on metal objects using FDM based 3D printing were analyzed in a more detailed form. Alloy Ink preparation for the manufacturing of metal parts using 3D printer and also estimation of the size and velocity of the droplets during fall, surface tension, viscosity and temperature of the printing ink for the manufacturing of 3D metal part printing [14]. The manufacturing techniques of composite materials using FDM based 3D Printing Technology for 3D

Printer that has been evolved and paved way for the creation of recent composite materials utilizing ceramics [15].

The additive manufacturing technologies SLM and SL for manufacture of multi material arm orthotics, Direct Selective Laser Sintering of Metals for the integration of biomaterials were widely used in Orthopedics applications [16]. SLS possess the capability of producing structurally sound parts directly from metals and ceramics, [17]. 3D products were produced by causing variation in height of the layers and performed various tests for the various mechanical properties [18].

An optimization on the MIG - Lap Joint Fillet Weld of 1.6mm Al alloy primarily by wire feed rate for the fabrication of light weight component is an eye opener for the 3D Printing Technology [19]. The welding of Al-Mg alloy by using the chemical composition of base metal and filler metal and the Microstructure of Al-Mg Dissimilar Weld made by Cold Metal Transfer MIG Welding paves the way for the manufacture, through 3D printing, especially on the process parameter determination in printing composite material using 3D printing [20].

2.Materials and Methods

The prototype model of the 3D printer is designed using SOLIDWORKS.

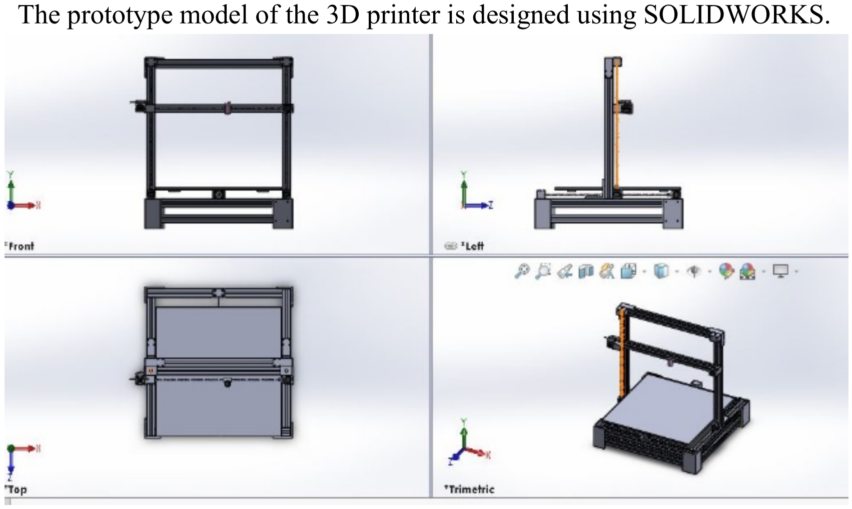

Figure 1: Conceptual Images

A 3D printer setup consists of Arduino board, Ramps 1.4 board, SMPS, Aluminium filament, frame, stepper motor, threaded rods, print bed, hot end, etc. The hot end is made up of mild steel tube wounded over by a k type heating coil which heats up to 1000°C. The frame material is Aluminum. T slot Aluminum is used as the frame. The hot end is connected to the channel section. The channel section is connected to the frame as per the design. NEMA 17 stepper motor is used on the X-axis. The hot end moves in the X-axis direction. NEMA 23 stepper motor which can pull up to 10 kg is used on the Y-axis. The print bed moves in the Y-axis direction. NEMA 17 stepper motor two motors are used in the Z-axis. The frame moves in the Z-axis direction. The stepper motors move over a threaded rod of diameter 8mm.

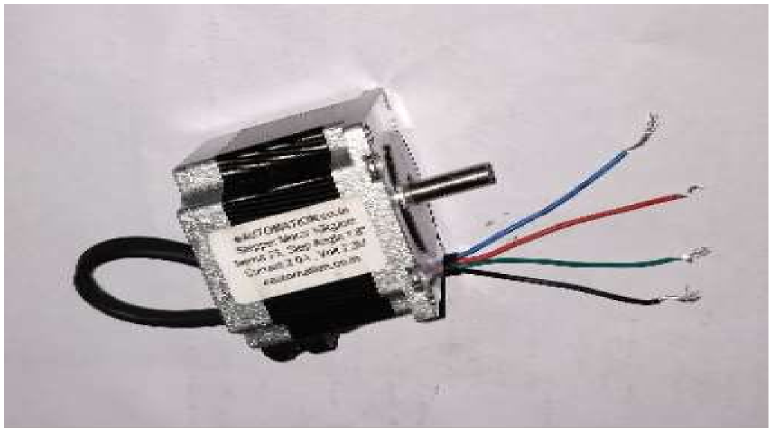

Figure 2: Stepper Motor

The acrylic sheet is used as a bed. The acrylic sheet is selected because of its low weight. The top surface of the acrylic sheet is covered by mild steel sheet metal. The filament feeder is used to feed the Aluminium filament to the hot end setup.

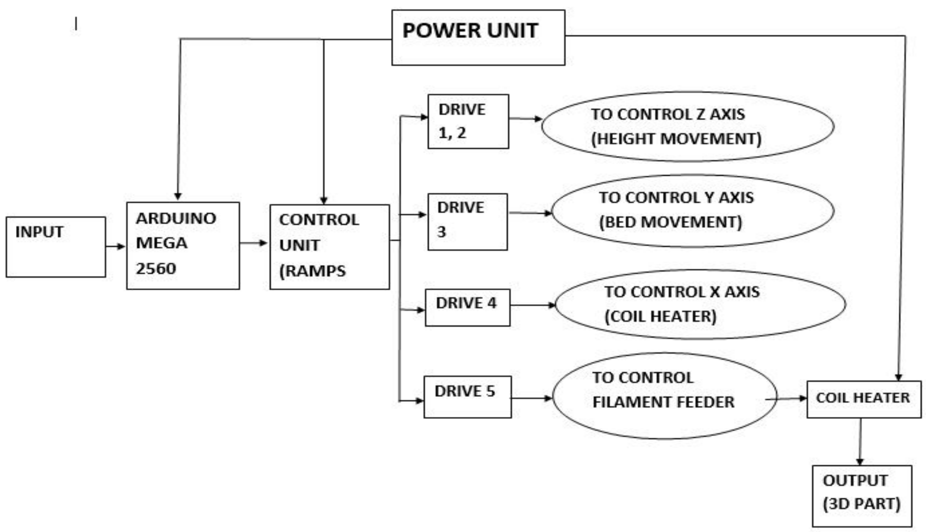

Figure 3: Functional Structure Diagram

The 3D model of a product is designed by using SOLIDWORKS. The designed model is stored in a “stl” file format, then the file is imported to Slic3r software to slice the model based on requirements, and then the file is imported to Pronterface software as G-code format to provide a print command to a 3D printer. The Aluminium filament is inserted into 3D Printer. The Arduino Mega 2560 which is connected to Ramps 1.4 board provides the required pulses to the stepper motor to move the coil heater, print bed, and frame in the required direction.

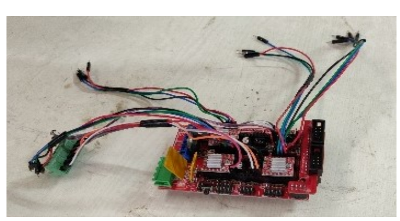

Figure 4(A) : Ramps 1.4

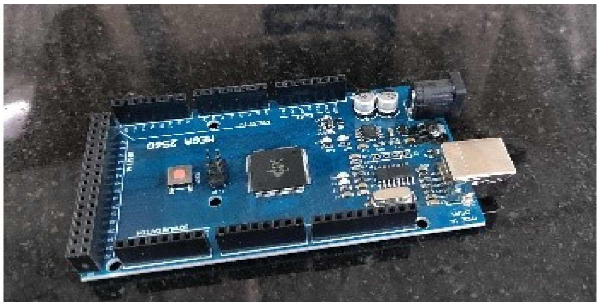

Figure 4(B): Arduino Mega 2560

Figure 5: SMPS

Arduino Mega 2560 and Ramps1.4 board is powered by the SMPS. The Aluminium filament passes through the hot end. The coil heater melts the metal. The melted metal is printed on the print bed as per the imported model (stl file) by the guidance of the X, Y, Z-axis movement.

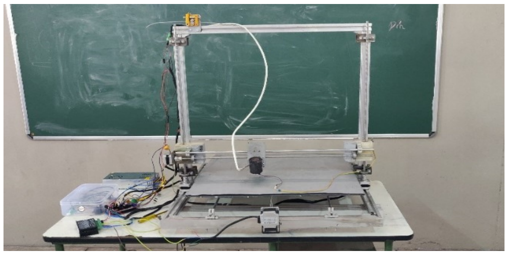

Figure 6: 3D Printer Setup

3.Results and Discussion

The accuracy of printing can be improved by synchronizing the temperature controller with firmware. A Driver board with a higher specification can be used. Various metals with the melting point under 1000 degrees Celsius can be used as printing filament. Intermetallic metals can be printed to improve the strength characteristics as well as the stiffness of the parts. Intermetallic materials with functionally graded requirements can be easily manufactured and can be implemented into service wherever required.

4.Conclusion

The 3D Printer follows the Cartesian coordinate system because more ruggedness and stability are required to produce metal parts. Temperature control systems play a key role in controlling the uniform build quality of parts. The major objective is to improve internal strength and to eliminate voids and internal discontinuities. The process parameters like feed rate, temperature band of the heater, position control, wire diameter, and velocity of slides need to be optimized to increase the build quality.

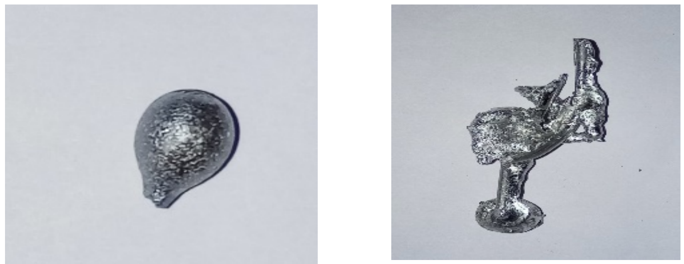

Figure 7 (a): Printed Parts

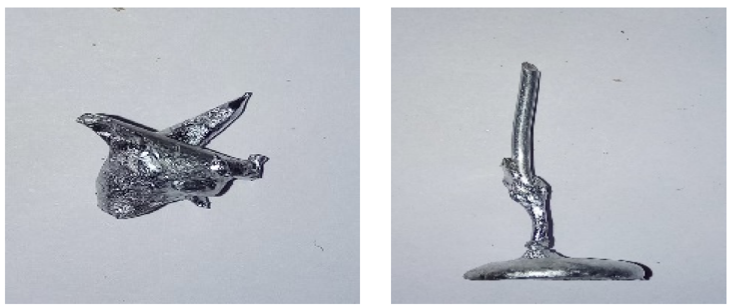

Figure 7 (b): Printed Parts

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