B.TECH. PROJECT REPORT

On

Design, Development and Analysis of Additive Manufacturing of metals

By

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DISCIPLINE OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY INDORE

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Design, Development and Analysis of Additive Manufacturing of metals

A PROJECT REPORT

Submitted in partial fulfilment of the
Requirements for the award of the degrees

Of
BACHELOR OF TECHNOLOGY
in
MECHANICAL ENGINEERING

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INDIAN INSTITUTE OF TECHNOLOGY INDORE
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CANDIDATE'S DECLARATION

We hereby declare that the project entitled **"Design, Development and Analysis of Additive Manufacturing of metals"** submitted in partial fulfilment for the award of the degree of Bachelor of Technology in 'MECHANICAL ENGINEERING' completed under the supervision of **Dr. Yuvraj K Madhukar (Assistant Professor),** IIT Indore is an authentic work.

Further, we declare that we have not submitted this work for the award of any other degree elsewhere.

NIHAR PANCHAL

NISHANT ANAND

CERTIFICATE by BTP Guide

It is certified that the above statement made by the students is correct to the best of my/our knowledge.

Dr. Yuvraj K Madhukar
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Preface

This report on “Design, Development and Analysis of Additive Manufacturing of Metals" is prepared under the guidance of Dr. Yuvraj Kumar Madhukar.

Through this report we have tried to give detailed information on design, development and analysis of the wire arc additive manufacturing setup. The report contains illustrated pictures of manufactured setup and various 3D objects manufactured with the help of the WAAM setup.

We have tried to the best of our abilities and knowledge to explain the content in a lucid manner.

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B.Tech. IV Year

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Abstract

Wire arc based additive manufacturing has received significant attention in recent times due to its high deposition rate and cost effectiveness. The primary objective of this presented work is to develop a WAAM setup in house. It involves procurement of various parts and components followed by a prepared CAD model. The objective was to make a gantry type CNC having a travel length of 1000 x 500 x 300 mm. Many parts and components are fabricated in house to minimise the cost. Further, those parts and components are assembled as per the designed model.

The preliminary set of experiments were conducted to optimise the parameters i.e. deposition voltage, wire feed rate, deposition speed and stand off distance.

Based on this optimised parameters the various 3D shapes are additively manufactured successfully. The fabricated parts do need little post processing i.e. machining in order to achieve the final shape.

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CHAPTER 1 : INTRODUCTION

Metal additive layer manufacturing (ALM) is a technique that manufactures parts or components by adding material layer by layer in the form of powder or wire without the need of tooling. During fabrication, a heat source (welding arc, electronic beam or laser) is moved along a path defined by the computer-aided design file of the component to be produced, melting individual particles of powder or wire to form the component. Wire and Arc Additive Manufacturing (WAAM) techniques have much higher deposition rate and lower cost comparing with laser, electronic beam and powder-based additive layer manufacturing techniques.

Objects can be of almost any shape or geometry and typically are produced using digital model data from a 3D model. Thus, unlike material removed from a stock in the conventional machining process, 3D printing or Additive Manufacturing builds a three-dimensional object from a computer-aided design (CAD) model, usually by successively adding material layer by layer.

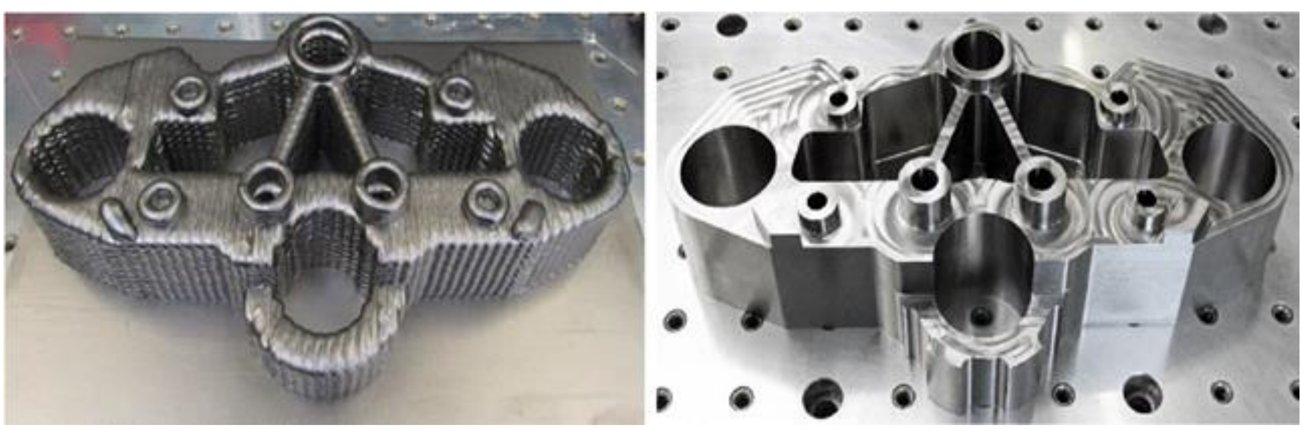


Figure 1 : Additively Manufactured component before and after processing

Components that would not have even been possible just a few years ago can now be made to high standards using a wide range of metal powders. No longer solely a prototyping technology, Additive Manufacturing is now being used for the production of series components for the most demanding applications.

1.1 MOTIVATION

- Additive Manufacturing is becoming increasingly popular as more advancements in research are being done in this field.
- Additive Manufacturing of metals would facilitate manufacturing complex geometric shapes with less material wastage compared to traditional machining processes.
- We aimed at developing a WAAM setup which is easy to operate and cost effective so that it can be used by small industries in manufacturing various metallic objects.

CHAPTER 2 : DESIGN AND DEVELOPMENT OF EXPERIMENTAL SETUP

2.1 An Additive Manufacturing setup

A basic AM system consists of a combination of a motion system, heat source and feedstock. The combination of an electric arc as heat source and wire as feedstock is referred to as WAAM and has been investigated for AM purposes since the 1990s.

WAAM hardware currently uses:

1. Heat Source – 1. MIG

   2. TIG

   3. Plasma Arc Welding

2. Filler Material – Wire or powder

3. XYZ Stage – 1. Robot type

   2. CNC Gantry type

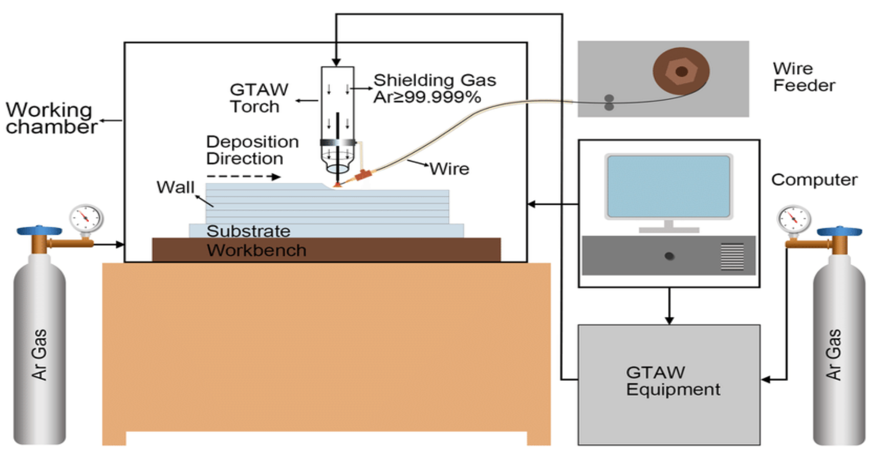


Figure 2 : WAAM setup using TIG welding [1]

Our Wire and Arc Additive Manufacturing (WAAM) setup uses Metal Inert Gas (MIG) welding as our heat source, Wire as our filler material and a CNC Gantry type XYZ stage as the motion system.

2.2 CAD Design of the Setup

Following design considerations were kept in check while developing the 3D CAD model of setup-

1. The controlled motion in XY direction was provided to the deposition plate while the deposition nozzle was given motion in Z direction.
2. The travel lengths in X,Y and Z directions were 1000 mm, 500 mm and 300 mm respectively.
3. The diameter of linear shafts were chosen to be 16 mm in order to minimize the load on lead screw.
4. The supporting structures were designed to minimize the vibration in the entire setup.
5. 3 stepper motors with embedded encoders are used to drive the ball screw which is further converted to linear motion with the help of ball screw nut.
6. The MIG torch is mounted vertically on Z stage for incremental deposition.

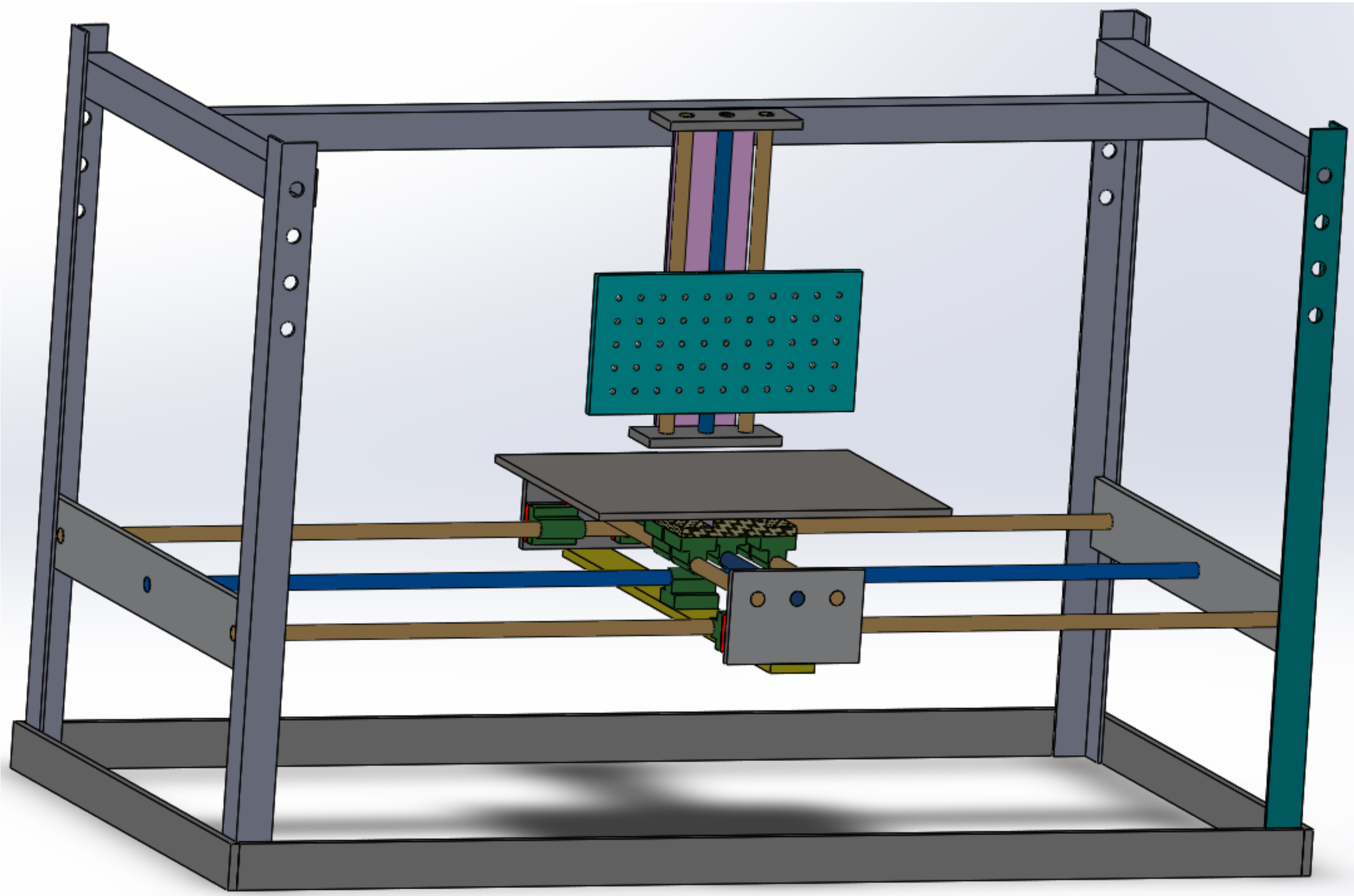
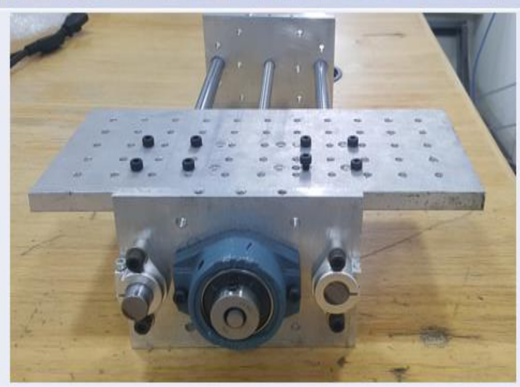


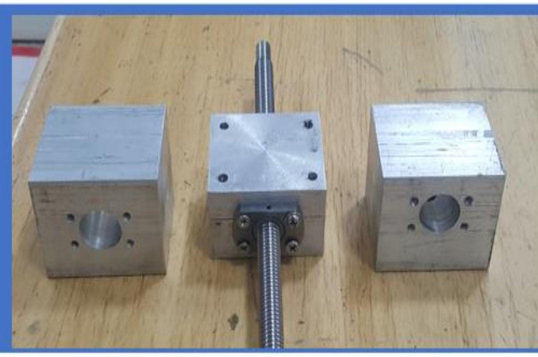
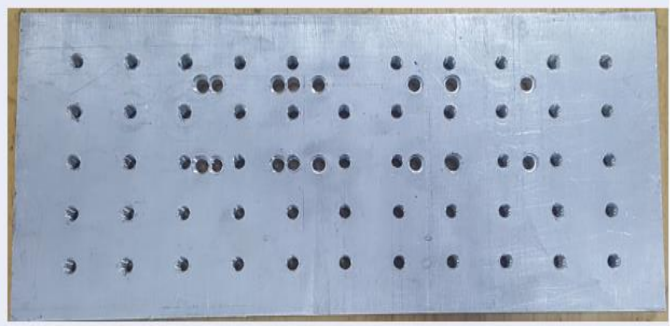
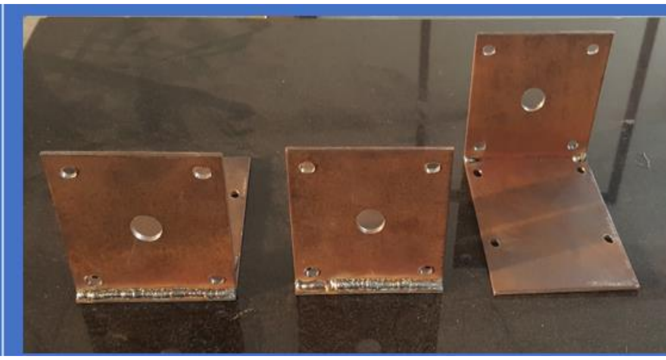
Figure 3 : 3D CAD Design of the WAAM setup

2.3 Fabrication of individual components

Required raw materials and other control system components like stepper motors, micro-controller etc were purchased. The individual components of the assembly post designing were manufactured using the traditional machining processes like Milling, Grinding, Welding etc. Dimensional tolerances were provided to account for errors during machining.

The following table shows the individual components and sub-assemblies :

Part name	Picture of the Part
Mounting Brackets for X, Y and Z axis	
Z axis assembly	

Ball nut mounts for X, Y and Z axis	
Structure Supports	
Bread Board	
Motor mount supports	

2.4 Assembly

Fabricated components were used to get X,Y and Z sub-assemblies and the sub-assemblies were further assembled to get the final setup. The MIG setup available in workshop was used as the heat source. After the assembly, all the three coordinate axes were actuated using stepper motors. Stepper motors were controlled using microcontroller (Arduino Mega) and encoders, which consists the control system.

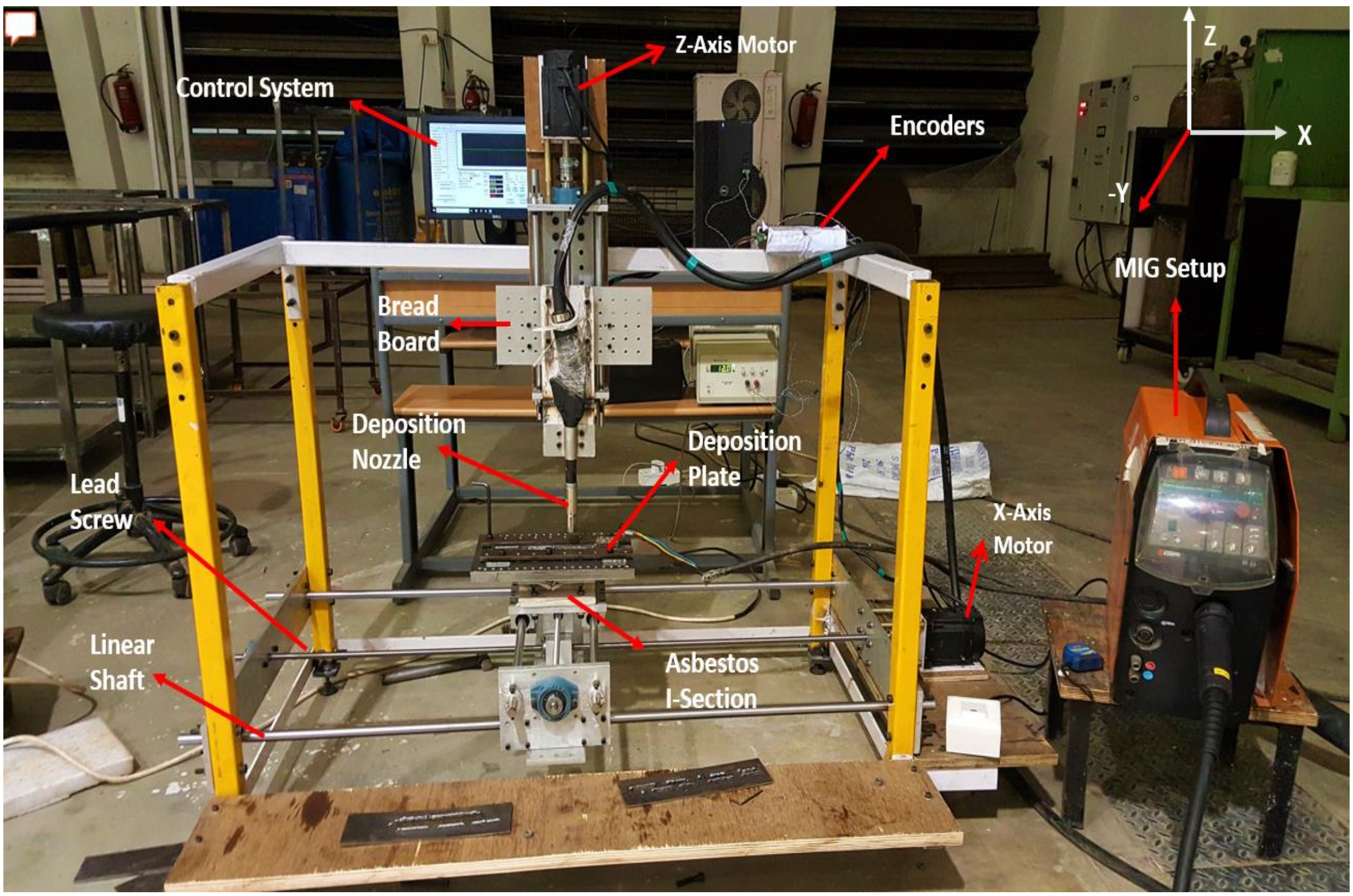


Figure 4 : Manufactured WAAM setup

The setup consists of motion along the three coordinate axes. All the three coordinate axis consists of two linear shafts and one ball screw. The linear shafts carry the load in order to minimize the load on the lead screw. The lead screws are driven by the stepper motors connected to them which gives the motion in the three respective axes. The motors are connected to the encoders which give the current X,Y and Z positions. The encoders are controlled with help of microcontroller (Arduino Mega) which is programmed to control the movement in X,Y and Z directions.

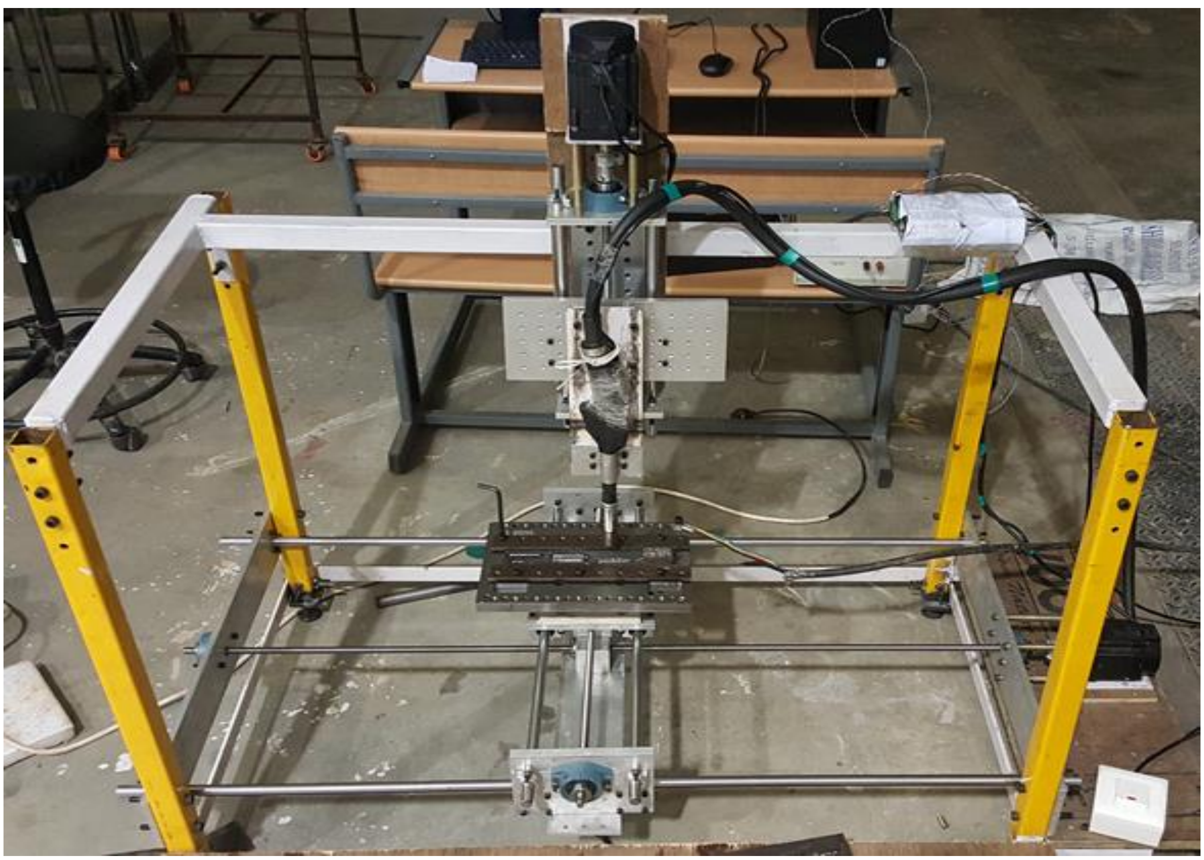


Figure 5 : Front view of the Setup

The deposition nozzle is mounted on the breadboard which is mounted on the Z-axis. The Z-axis motor enables the up and down motion of the Nozzle. The deposition nozzle is connected to the MIG setup from which the filler material i.e wire (Mild steel) is fed. The wire feed rate can be controlled at the MIG control panel. The shielding gas used is CO_2.

The deposition takes place on the deposition plate. A fixture was designed to hold the workpiece stationary and to restrict it against distortion due to generated heat. The deposition plate is mounted on the Asbestos I-section which is a thermal and electrical insulator and thus prevents the current and heat from spreading in the rest of the metallic setup.

Figure 6 : A picture from the working setup

CHAPTER 3 : EXPERIMENTATIONS AND ANALYSIS

3.1 Optimization of parameters

The metallic wire used for deposition was Mild Steel of diameter 0.8 mm.

The parameters that were taken into consideration for weld bead deposition were -

- Wire feed rate (m/min) - The length of the wire coming out of the deposition nozzle per minute is defined as wire feed rate. The wire feed rate determines the volume of the weld bead deposited per minute.
- Deposition speed (m/min) - The distance travelled by deposition plate in X or Y direction per minute is defined as welding speed. The welding speed determines the length of the weld bead deposited per minute.
- Deposition Voltage and Current - The voltage is kept constant for a particular wire feed rate. However the current varies depending on the stand off distance and an average value of current is obtained at the end of deposition.

A preliminary set of experimental runs were performed to optimize the parameters to obtain a high quality, uniform weld bead. Certain runs were performed with varying deposition speed while keeping the wire feed rate constant. The higher deposition speed resulted in a bead of smaller cross section area.

Thereafter, certain runs were performed keeping the deposition speed constant and varying wire feed rate.

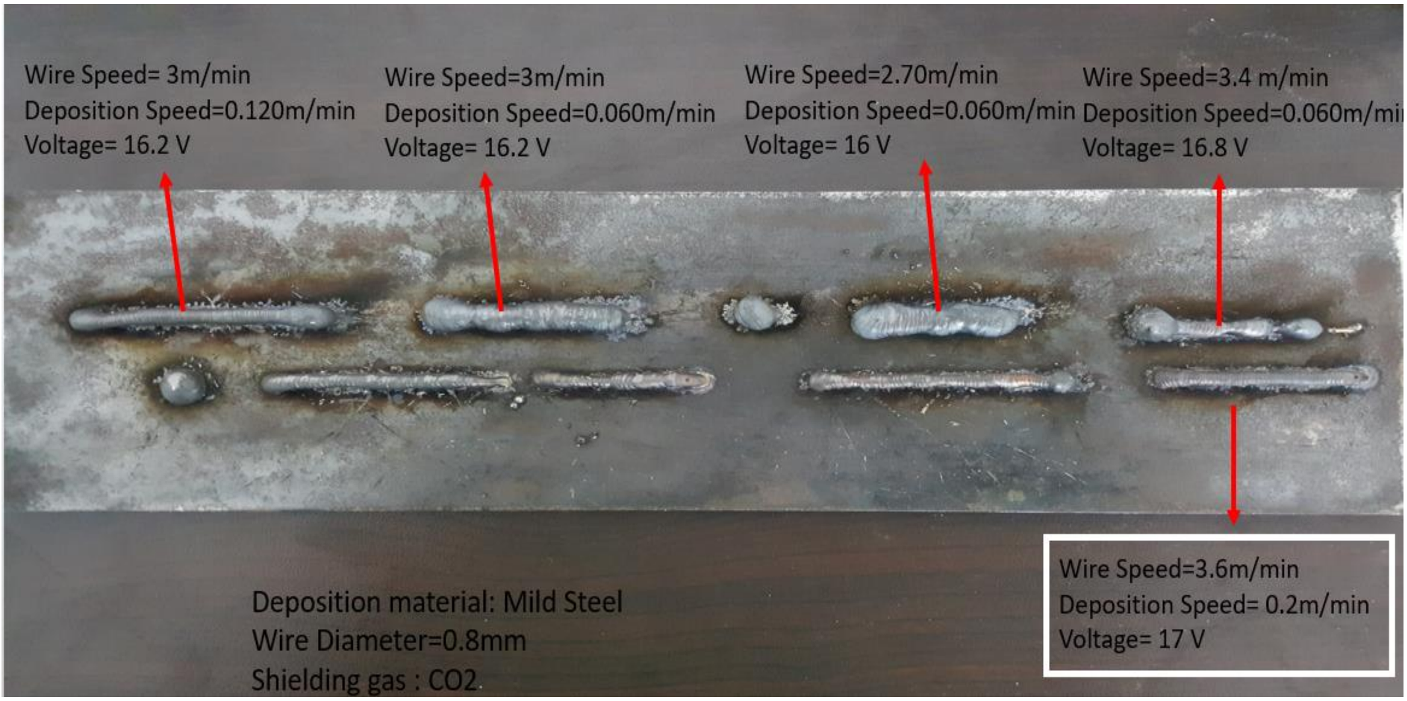


Figure 7 : Weld beads obtained with different parameters

As shown in the figure, the weld bead corresponding to the highlighted parameters has a throughout uniform cross section and hence is the optimized deposition.

Thus, the parameters selected for Additive Manufacturing the objects in the present work are -

Wire feed rate = 3.6 m/min

Deposition Speed = 0.2 m/min

Deposition Voltage = 17 V

CHAPTER 4 : WORKING AND APPLICABILITY

4.1 Additively Manufactured 3D Shapes

1. **3D Wall**

   A wall of one layer width and four layers height was deposited. The following figures show the wall before and after processing i.e Machining.

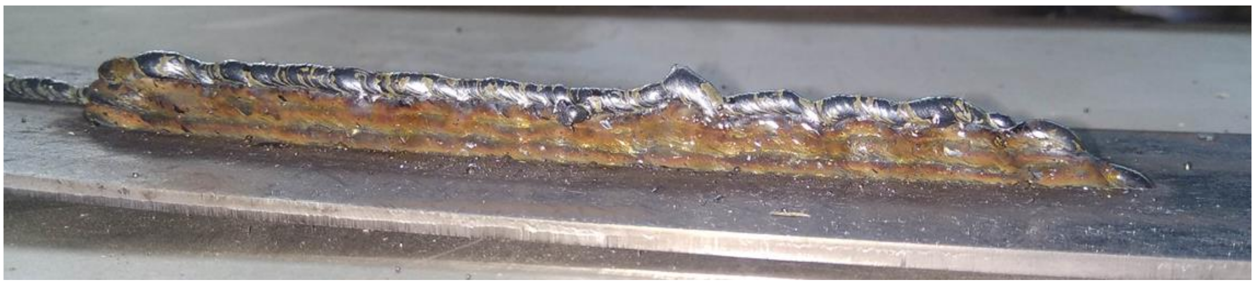


Figure 8 : Wall before Machining

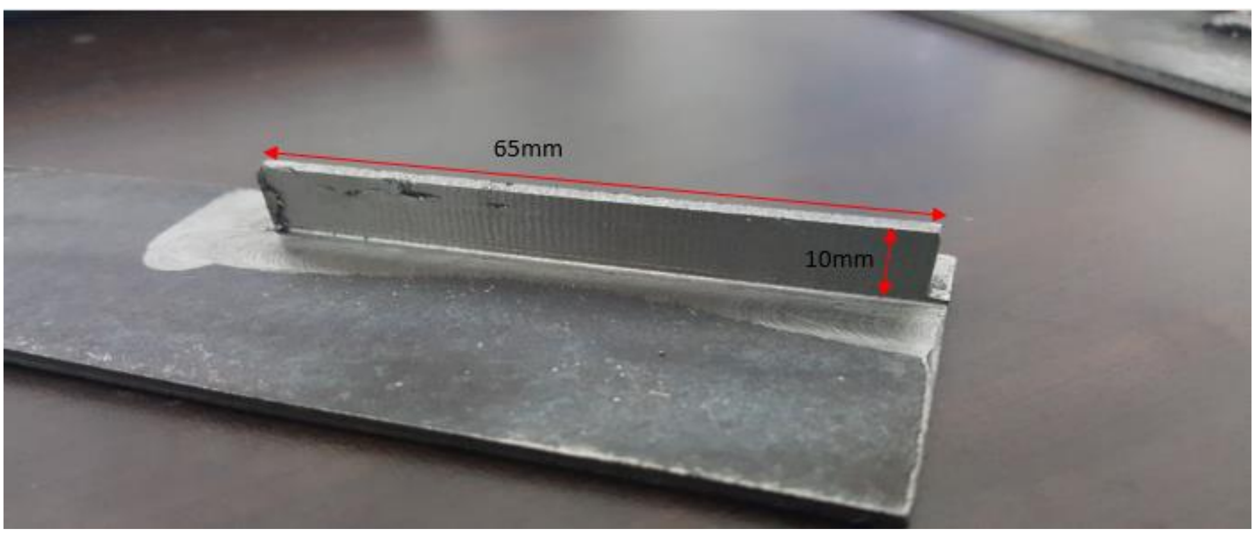


Figure 9 : Wall after Machining

2. 3D Cuboid

A Cuboid of six layers width and six layers height was deposited. The following figures show the wall before and after processing i.e Machining.

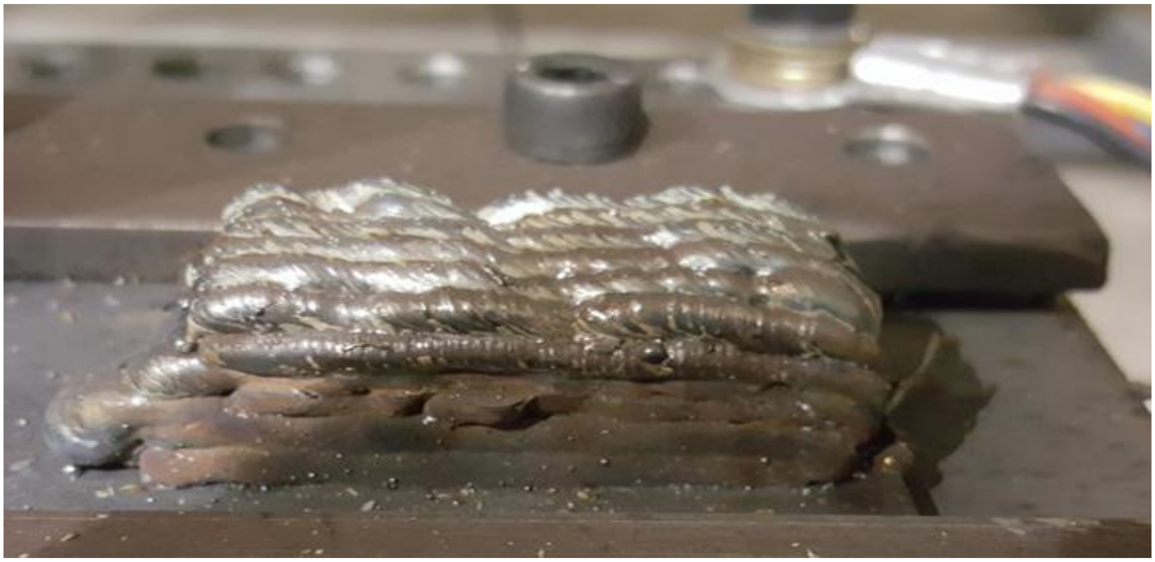


Figure 10 : Cuboid before Machining

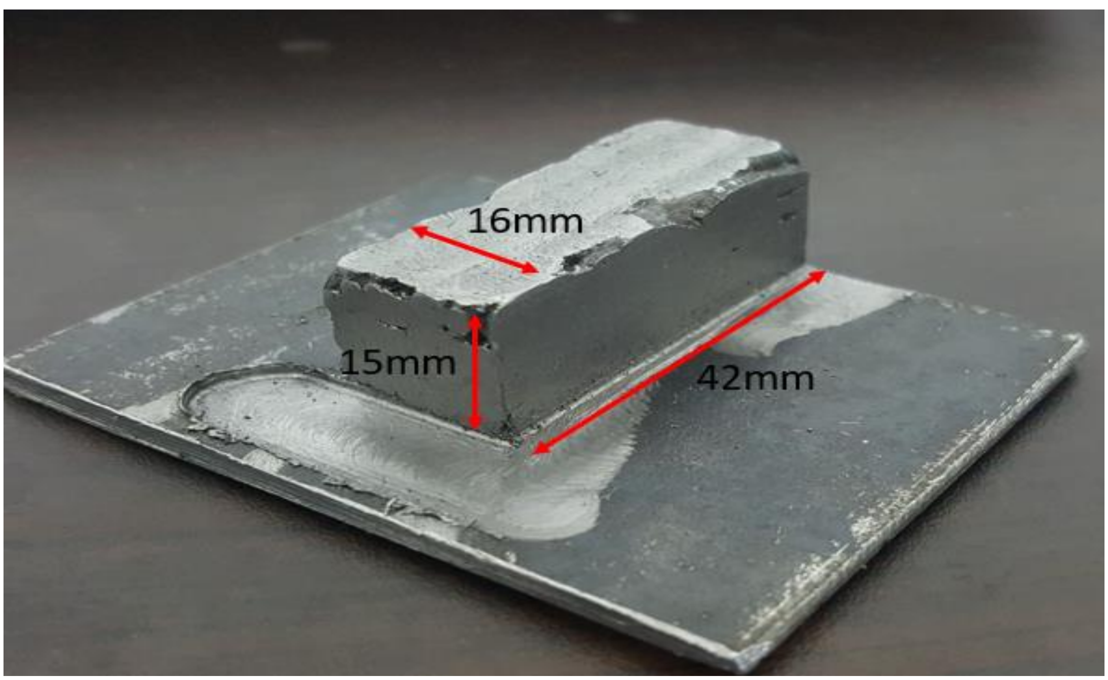


Figure 11 : Cuboid after Machining

3. 3D Pyramid

A pyramid with decreasing width from five layers to one layer and height of six layers was deposited. The following figures show the wall before and after processing i.e Machining.

Figure 12 : Pyramid before Machining

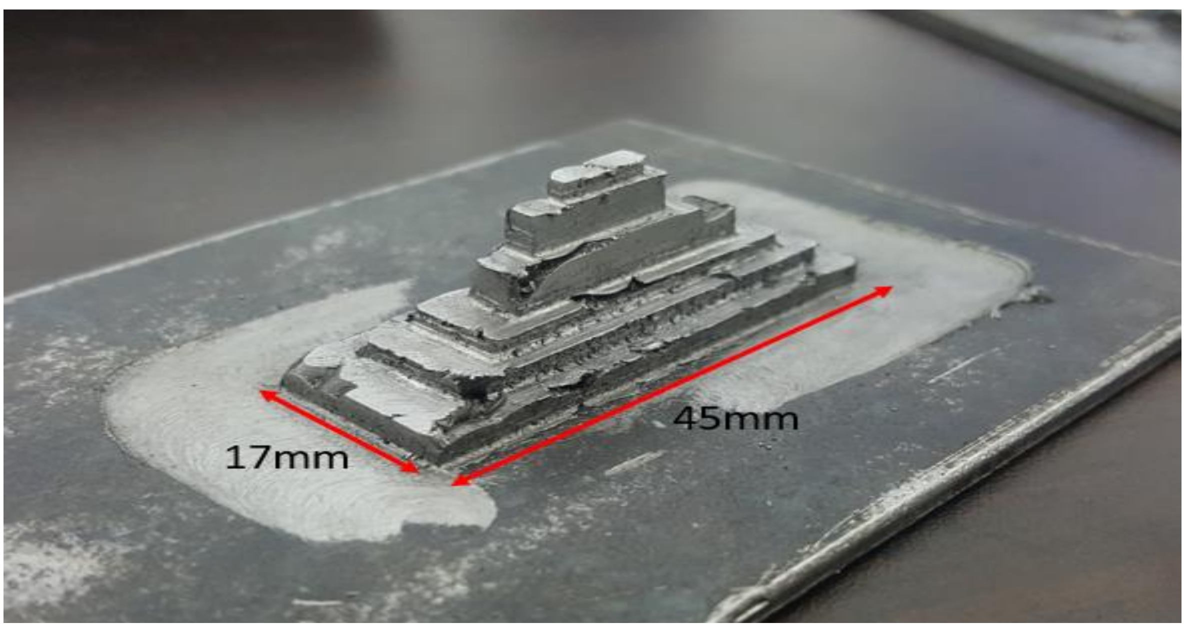


Figure 13 : Pyramid after Machining

4.2 Applicability - Automated Welding

The setup can be also used for various types of Welding. Since the Welding is automated, it will give a throughout uniform and high quality weld bead.

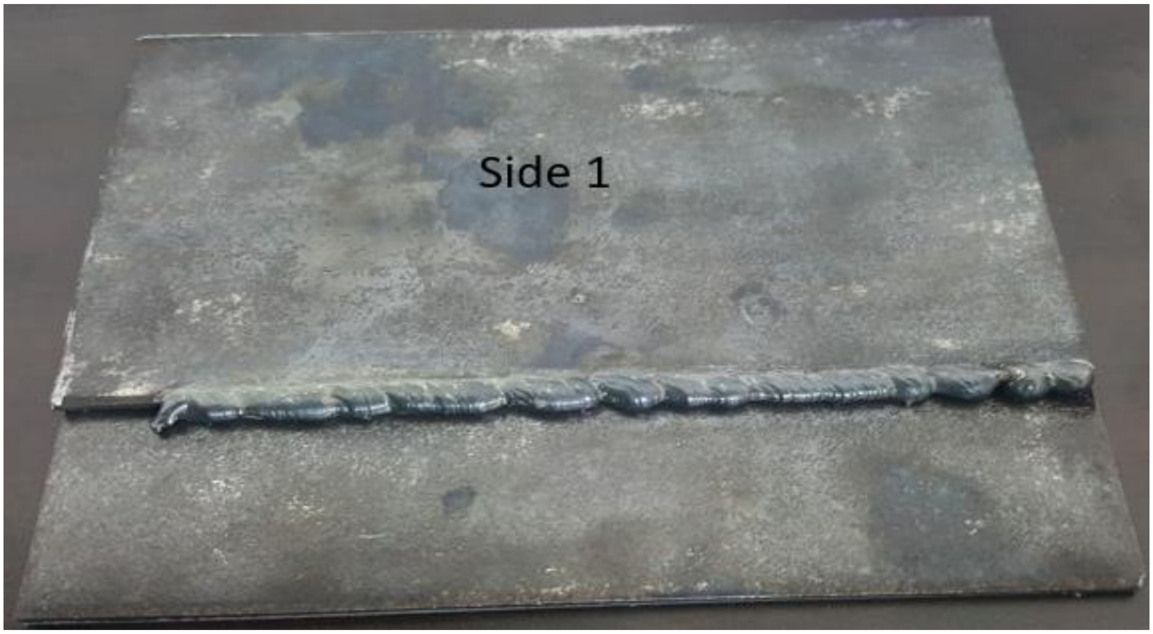


Figure 14 : Lap Joint at 90 degrees between nozzle and plate

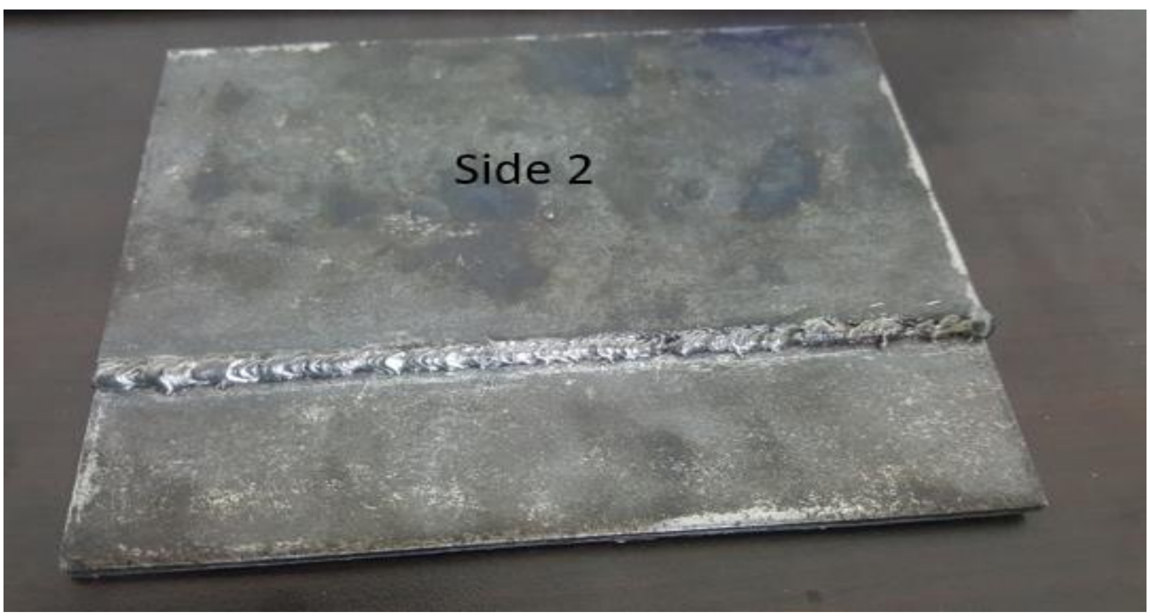


Figure 15 : Lap Joint at 80 degrees between nozzle and plate

CHAPTER 5 : CONCLUSION AND FURTHER SCOPE OF THE WORK

5.1 Conclusion

- WAAM setup has been fabricated in house which serves the purpose efficiently
- The setup is Computer Numerically Controlled.
- We are successfully able to Additive Manufacture 3D shapes after optimizing deposition parameters.
- The deposited geometries do need minimal post processing i.e Machining,
- It has been observed approximately 10% of the material is being removed to achieve the final shape which is significantly smaller as compared to conventional process.
- We have found that the deposited samples are defects free such as blow holes and distortion.

5.2 Further scope of work

- This work can be further extended to fabricate components of real life application such as machine parts, propellers etc.
- Due to time constraint the mechanical properties of the fabricated parts have not been studied which can be considered for future scope.
- The studied analysis suggests the monitoring and control of deposition temperature could add great advantage to the process.

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