

## CHAPTER 4

# DESIGN DEVELOPMENT AND FABRICATION OF CONTINUOUS EXTRUSION MACHINE SET UP


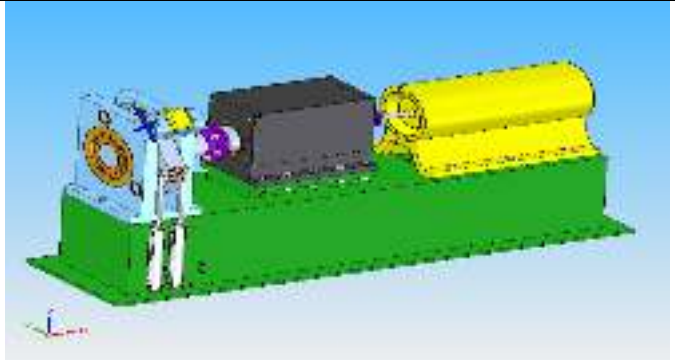
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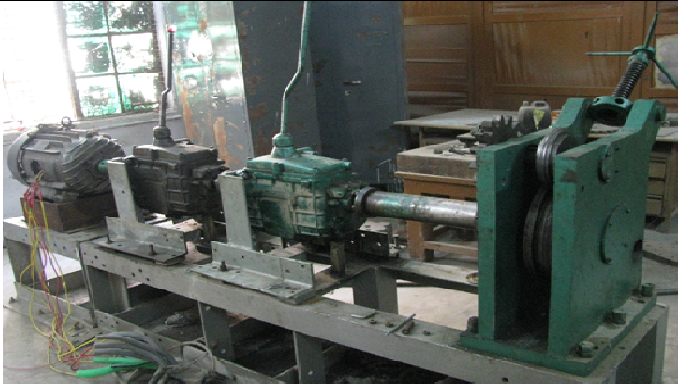
### 4.1 INTRODUCTION


Design Development and Fabrication of Continuous Extrusion setup using the results of simulation is presented in this chapter. A chronological development of the Continuous Extrusion machine took place at IIT (BHU) since 2002-03, which is discussed in brief in Table 4.1. An attempt has been made to modify the existing Continuous Extrusion setup but due to several limitations associated with the existing setup, output product material was not coming out of the extrusion die successfully. Therefore decisions were made to carry out simulations by making several design changes in the geometry of Continuous Extrusion tooling's like Extrusion wheel, Coining wheel, Extrusion shoe and some additional components were also incorporated. After the successful running of simulations and by making several design changes, it was thought to refabricate the Continuous Extrusion setup for 9.5 mm feedstock material. Finally, a Continuous Extrusion setup for 9.5 mm feedstock material has been designed developed and fabricated for producing defect free rods of infinite length of several diameters depending on the size of extrusion die. In this setup of Continuous Extrusion process has been investigated in detail for nonferrous metals and alloys like Aluminum (Al 1100) and Copper (C 101) feedstock materials.

In this chapter, details of each component of the machine setup have also been discussed. Also fabrication and assembly procedure of the machine setup has been presented.

Table 4.1: Chronological Development of Continuous Extrusion Setup at IIT (BHU)

Year	Title of Work	Figure of Developed Setup
2003	<p>Virtual Design, Fabrication and Analysis of the Continuous Extrusion process was done as a M. Tech thesis. The CAD modeling of each element of continuous extrusion setup was carried out using Auto cad 2002. Iterations were applied rigorously to obtain the final virtual designed developed and fabricated setup as shown in Figure 4.1.</p>	 <p>Figure 4.1 : Virtual designed developed and fabricated Continuous Extrusion setup [Sinha et al., (2003)]</p>
2007	<p>CAE Simulation of the Continuous Extrusion process was done as a M. Tech thesis. Each and every element of continuous extrusion was modeled using Solid Edge V 19 as shown in Figure 4.2. CAE simulations were performed using</p>	 <p>Figure 4.2 : CAE model of Continuous Extrusion setup designed developed [Shukla et al., (2007)]</p>

	simulation tool DEFORM 3D.	
2008	Continuous Extrusion setup was fabricated (Figure 4.3) under a DST project for extrusion of thin rods, wires, sheets and strips for 8 mm Aluminum feedstock material using the results of CAE simulation. The details of this setup have been added in section 4.2.	 <p data-bbox="808 730 1479 821">Figure 4.3: Continuous Extrusion setup for 8 mm Aluminum feedstock material [Kumar et al., (2008)]</p>
2012	Modification of Continuous Extrusion setup (Figure 4.4) which was fabricated under a DST project for extrusion of thin rods, wires, sheets and strips for 8 mm Aluminum feedstock material was carried out to bring the setup into functional form. Details have been added in section 4.2.	 <p data-bbox="781 1524 1516 1667">Figure 4.4: Modified Continuous Extrusion setup for 8 mm Aluminum feedstock material after several stages of modification</p>

2015	<p>Design Development and Fabrication of Continuous Extrusion setup (Figure 4.5) for 9.5 mm Aluminum feedstock material has been carried out after modification of previous setup in number of stages. The details of final setup have been added in section 4.3.</p>	 <p>Figure 4.5: Final Designed Developed and Fabricated Continuous Extrusion setup for 9.5 mm Aluminum feedstock material.</p>

## 4.2 DETAILS OF THE PREVIOUS CONTINUOUS EXTRUSION SETUP

A continuous extrusion set up was designed and fabricated (Figure 4.3) for 8 mm feedstock material under a DST project by at IIT-BHU, Varanasi for exploring the continuous extrusion process for various non-ferrous alloys such as Aluminum alloy, Copper alloy, Brass etc. The set up was designed and fabricated for the following purposes mentioned below:

- a. Design for lower power requirement
- b. Design for continuous work load
- c. Design for higher tooling life
- d. Design for higher factor of safety for equipment as well as for operator.
- e. Design for fully automatic process.
- f. Design for lower cost.
- g. Design for minimum wastage of material.



Figure 4.6 : Extrusion Wheel with circular groove for 8 mm feedstock material



Figure 4.7 : Coining Wheel for 8 mm feedstock material



Figure 4.8: Grooved Extrusion shoe for 8 mm feedstock material



Figure 4.9: Extrusion die block for 8 mm feedstock Continuous Extrusion setup



Figure 4.10: Abutment before modification for 8 mm feedstock Continuous Extrusion setup

After fabrication and development of the designed set up for 8 mm feedstock material, it was put for the free test runs. Further, the set up was tested for the commercial Aluminum feedstock Al 1100. It was found that set up encountered so many problems as follows:

- i. The output speed at the shaft of the Continuous Extrusion wheel (Figure 4.6) was very high i.e. 100 rpm which was not suitable for the extrusion of any feedstock and the rotational speed should lie in the range of 4 to 20 rpm.
- ii. The feedstock when fed into the grooved passage of Extrusion wheel and coining wheel (Figure 4.7), the feedstock was affected by slippage and was not able to move further into the grooved passage of extrusion wheel and extrusion shoe (Figure 4.8) and come out through die block as shown in Figure 4.9.

As per the problems encountered by the set up mentioned above, it was necessary to modify and refabricate some existing or additional parts for the successful running of the set up to explore the continuous extrusion process for non-ferrous alloys such as Aluminum and copper.

So, the following modifications were done:

- i. An additional gear box (Figure 4.11) has been installed of the same dimension and configuration as that of previous one in series with the earlier gear box to obtain the desired output speed at the shaft of the extrusion wheel.
- ii. A pair of mating spur gears (Figure 4.12) has been designed and fabricated and incorporated on the shaft of extrusion wheel and coining wheel for the desired motion of the coining wheel in order to avoid the slippage of feedstock in the passage of grooved extrusion and coining wheel.
- iii. The abutment was redesigned and fabricated as shown in Figure 4.13 to provide a desired path for the movement of feedstock at the interface of extrusion shoe and abutment. Figure 4.10 shows the abutment before modification for continuous Extrusion setup of 8 mm feedstock
- iv. A die (Figure 4.14) has been designed and fabricated for the extrusion of feedstock and to facilitate the flow of flash if any formed during the flow of feedstock through the die. The die is housed in the die block as shown in Figure 4.9.



Figure 4.11: Additional gearbox incorporated for modification of 8 mm feedstock  
Continuous Extrusion setup



Figure 4.12: A pair of spur gear for modification of 8mm feedstock Continuous Extrusion  
setup



Figure 4.13: Modified abutment for 8 mm feedstock Continuous Extrusion setup



Figure 4.14: Modified for 8 mm feedstock Continuous Extrusion setup

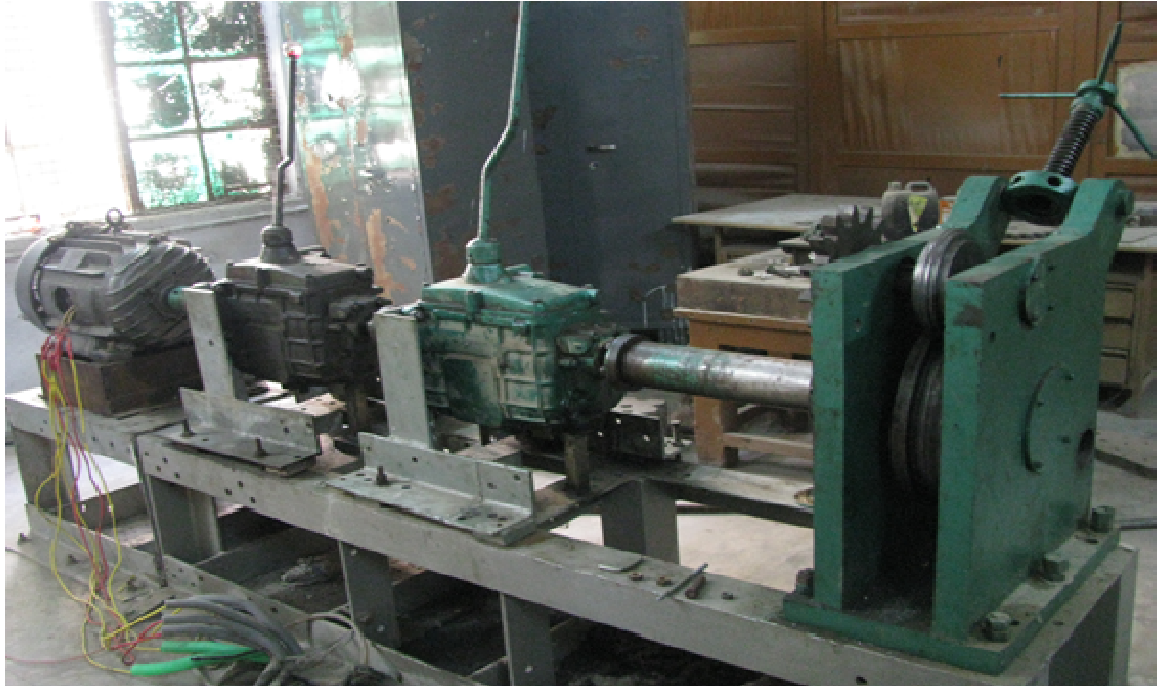


Figure 4.15: Modified Continuous Extrusion setup for 8 mm feedstock material



Figure 4.16: Material coming out of the abutment hole

So after several stages of modification, the continuous extrusion machine setup was modified as shown in Figure 4.15 and it was found that material was coming out of the abutment but was not able to come out of the extrusion die as shown in Figure 4.16.

So decisions were made to carry out simulations by making some design changes in the geometry of Continuous Extrusion tooling's. After successful running of simulations the Continuous Extrusion setup has been completely refabricated.

### **4.3 REDESIGN DEVELOPMENT AND FABRICATION OF THE CONTINUOUS EXTRUSION MACHINE SET UP FOR 9.5 MM FEEDSTOCK MATERIAL**

The previous continuous extrusion set up has been redesigned developed and fabricated for study of continuous extrusion process for nonferrous alloys especially for 9.5 mm Aluminum feedstock. In this section, details of each component of the setup are explained.

#### **4.3.1 Design and Functionality of each part of the Continuous Extrusion setup.**

The developed setup should have special function analysis. The main aim of the setup has been to provide enough torque and power required for the flow of material through extrusion die, it should provide continuous work load, higher tooling life, higher factor of safety for equipment as well as for operator, for lower cost, minimum wastage of material. The setup should work smoothly without vibration and with good rigidity. The redesigned developed and fabricated setup has the following parts and their functionality is explained as below:

##### **1. Extrusion Wheel**

In the designed developed and fabricated continuous extrusion set up for 9.5 mm feedstock material, a 300 mm grooved wheel as shown in Figure 4.17 has been mounted on a shaft. The extrusion wheel is machined out of AISI H13 Steel and heat-treated and tempered to a hardness of RC 48 to 50. The extrusion wheel acts as a carrier of the metal and ensures positive flow of the metal to the die chamber. Tolerance on the groove is given as  $\pm 0.5$  mm.

## **2. Coining Wheel**

In the designed developed and fabricated continuous extrusion set up for 9.5 mm feedstock material, a 150 mm coining wheel as shown in Figure 4.18 has been mounted to assist the movement of feedstock in the grooved passage of extrusion and coining wheel. The coining wheel is machined out of AISI H13 Steel and heat-treated and tempered to a hardness of RC 48 to 50. Tolerance on the flat surface of coining wheel is given as  $\pm 0.5$  mm.

## **3. Extrusion Shoe**

The extrusion Shoe as shown in Figure 4.19 is an L shaped device made of AISI H 13 Steel and heat –treated and tempered to a hardness of RC 48 to 50. The shoe is mounted on a mechanically movable bed plate. The L shaped shoe is machined in such a way that when the shoe is brought close to the wheel , it embraces the moving wheel leaving a constricted gap for the feed rod to pass between the wheel and the plates arranged one over the other. These are called entry plate, friction plate and the feeder plate. These plates are fixed up on the extrusion shoe in such a way that the entry gap between the wheel and the entry plate is 0.9 mm and at the exit is 1.2 mm maximum. Tolerance on the surface of shoe is given as  $\pm 0.1$  mm.

## **4. Abutment**

The extrusion shoe is also provided with an abutment bridge as shown in Figure 4.20, where abutment is fixed. This abutment sits just above the die chamber in the grooved wheel and stops the feed rod to rotate along the wheel beyond this point. This abutment is also made of AISI H13 Steel and heat-treated and tempered to a hardness of RC 48 to 50. Tolerance on the surface of abutment is given as  $\pm 0.1$  mm.

## **5. Die set**

Just below the abutment bridge, there is a die chamber (Figure 4.20) in the shoe. The die along with its support tooling is housed in this chamber. The die housed in die set is made of AISI H13 Steel and heat-treated and tempered to a hardness of RC 48 to 50.

Tolerance in the surface of die is given as  $\pm 0.1$  mm. The corrected and final die is shown in Figure 4.21 as compared to the previous developed die which has been shown in Figure 4.14. The final corrected die profile has been better than previous developed die.

## **6. Hydraulic Intensifiers**

It is meant for exerting locking pressure on the shoe to hold the shoe firmly in position and in turn the die assembly to withstand the extrusion force caused by the constant input of metal by the positive rotation of the wheel pushing the metal. It is made of mild steel.

## **7. Feedstock**

The feedstock to the continuous extrusion machine is 9.5 mm properzi rod of Aluminum Al 1100.

## **8. Electric motor**

It provides the required power to the extrusion wheel and further to the feedstock for its extrusion through the die.

## **9. Gear Box**

Worm gear box is connected in series to transmit the required rotational speed at the shaft of the extrusion wheel.

## **10. Wheel Shaft**

The extrusion wheel is mounted on the shaft which is called wheel shaft. It is made of mild steel. The length and diameter of the wheel shaft are 500 mm and 95 mm respectively. Tolerance on the surface of shaft is given as  $\pm 0.1$  mm.

## **11. Base Plates**

The base plates are welded together to form a structure meant for supporting the continuous extrusion machine set up and its elements. These are made of grey iron.

## **12. Flange Coupling**

Three flange couplings has been designed and fabricated to transfer power from one shaft to another. These are made of cast irons.

### **13. Motor base**

It supports the electric motor which has been installed on the set up. It is made of mild steel.

### **14. Motor Bed**

Motor including motor base rests on the motor bed which has been fabricated by welding of several G.I. angles.

### **15. Bearings**

Two tapered roller bearings has been designed and fabricated to support the shafts on which extrusion shoe and coining wheel are mounted.

### **16. Nut and Bolts**

These are fastening members.

### **17. Foundation bolt**

They are meant for fixing of fabricated set up bed and motor bed to the ground.

### **Specification of the motor**

60 HP, 990 RPM, AC 3 phase electric motor.

### **Specification of gear box used in the set up**

Centre Height distance=12.5 inches worm gearbox

## **4.4 Development and Fabrication of Continuous Extrusion setup for 9.5 mm feedstock material**

After the design of structure and detail design of Continuous Extrusion machine tooling, fabrication has been done. Figures 4.17 - 4.24 shows some developed parts of the Continuous Extrusion setup. Off all Continuous Extrusion machine toolings, Extrusion

wheel has been fabricated first. Extrusion wheel has been fabricated by forging of circular shaft. The deep circular groove has been cut on the peripheral surface of extrusion wheel by machining at very slow speed. After machining of wheel and groove, heat treatment operation has been carried out in order to provide necessary and sufficient strength to the extrusion wheel. After fabrication of Extrusion wheel, fabrication of Coining Wheel has been done by machining method. The flat projected portion throughout the periphery of coining wheel has been fabricated by machining process as shown in Fig 4.18. This flat projected portion over the peripheral surface of coining wheel is meant for providing proper push and gripping to the feedstock material while its entry into the grooved portion of extrusion wheel. Heat treatment after machining process of the coining wheel has also been carried out to provide sufficient and necessary strength to the coining wheel. The holding and motion control unit of the coining wheel has been fabricated and developed as shown in figure to control the motion of coining wheel in vertical direction so as to firmly press and push the feedstock material from the grooved portion of the extrusion wheel to further in forward direction . Scraper and Scraper unit has been developed and fabricated and is mounted on the walls of the frame by welding process. The Scraper as shown in Figure 4.22 removes the excess feedstock material in long and thin chips form. So, Scraper has to be of accurate dimension, shape and size. Scraper is mounted on the scraper unit and scraper is mounted on the main frame by welding process. The abutment die chamber which is one of the most important elements of Continuous Extrusion system has been fabricated and developed as shown in figure. The abutment die chamber has been designed and developed in such a way that feedstock material after striking the abutment finds its way easily through the contoured profile for its easy entry into the extrusion die housed in die chamber to get extruded. Three different sets of extrusion die has been designed, fabricated and developed one of which has been shown in Figure 4.21. The mechanical intensifier has been designed developed and fabricated to provide optimum pressure and passage clearance between feedstock rod and extrusion shoe.

The developed and fabricated tooling's for Continuous Extrusion setup along with assembled Continuous Extrusion setup has been shown below from Figures 4.17 to 4.24.



Figure 4.17: Extrusion Wheel for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.18: Coining Wheel for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.19: Extrusion Shoe for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.20: Abutment Die Chamber for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.21: Extrusion Die for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.22: Scraper for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.23: Variable Frequency Drive for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.24: Die Chamber heating arrangement device for 9.5 mm feedstock Continuous Extrusion setup



Figure 4.25: Design Developed and Fabricated Continuous Extrusion setup for 9.5 mm feedstock material



Figure 4.26: Close view of Design Developed and Fabricated Continuous Extrusion setup for 9.5 mm feedstock material



Figure 4.27: View of Gearbox coupled with Continuous Extrusion setup for 9.5 mm feedstock material



Figure 4.28: Close view of Extrusion Wheel, Coining Wheel and Scraper of Continuous Extrusion setup for 9.5 mm feedstock material



Figure 4.29: View of Extruded material from Design Developed and Fabricated Continuous Extrusion setup for 9.5 mm feedstock material

### **Selection of Electric motor**

It has been investigated that for extrusion of 9.5 mm diameter Aluminum 1100 feedstock material through 9 mm die, 70 A load current is required. So to carry out the extrusion process successfully and to provide initial overload extra torque required, an electric drive motor of 60 HP, 990 RPM AC phase with line voltage of 440 volts has been selected. The motor selected is called drive motor which is useful even for running at very low speed of 2 to 10 RPM. At this very low speed, the motor temperature rises to a tremendous amount so the heat generated is thrown away by means of fan installed in the motor.

### **Selection of Gearbox**

The shaft of Continuous Extrusion machine is connected with the output shaft of gearbox and motor shaft is connected with the input shaft of gearbox. The gearbox selected is worm gearbox of 12.5 inch centre height distance between the gears which has been found compatible to the selected motor of 60 HP capacity.

### **Selection of Variable Frequency Drive**

The main function of the variable frequency drive (Figure 4.23) is to rotate the motor shaft and hence the extrusion wheel at the desired speed so as to carry out the extrusion of feedstock material. Apart from rotating the motor shaft at desired RPM, the variable frequency drive also provides extra torque required at initial stage of entry of feedstock material through the grooved portion of the extrusion wheel further through the abutment die chamber. So, to extrude 9.5 mm feedstock rod to 9 mm output rod it has been found that 70 Ampere load current is required. Therefore variable frequency drive of 50 HP capacity has been chosen for the selected motor of 60 HP capacity.

### **Selections of heating arrangement for abutment die chamber**

In Continuous Extrusion process, the initial heating of the abutment die chamber is done so as to generate sufficient extrusion pressure. Once the process is stabilized, the process itself generates sufficient heat by means of friction and also extrusion pressure required for the extrusion of feedstock material through the die. So, for heating of abutment die chamber to near about 450 °C temperature, a LPG gas cylinder with regulator and heating torch has been selected (Figure 4.24). This heating kit is suitable for heating the abutment die chamber to the required temperature if the heating process is carried out for half an hour.

The sequence of operations which must be followed to start the Continuous Extrusion machine and carry out the extrusion of feedstock material has been listed below:

- ❖ Open the extrusion shoe.
- ❖ Heat the die chamber for 20 minutes so that temperature around 450 °C is attained.
- ❖ While heating is going on, start the VFD and feed the program in the VFD and then start the motor.
- ❖ When heating has been completed while the motor starts, gently close the shoe.
- ❖ Rotate the motor in vector control mode.
- ❖ Now feed the raw material in grooved portion of wheel and vary the torque gently with regulator.
- ❖ Press the shoe with the help of intensifier.
- ❖ Extrusion of material takes place.

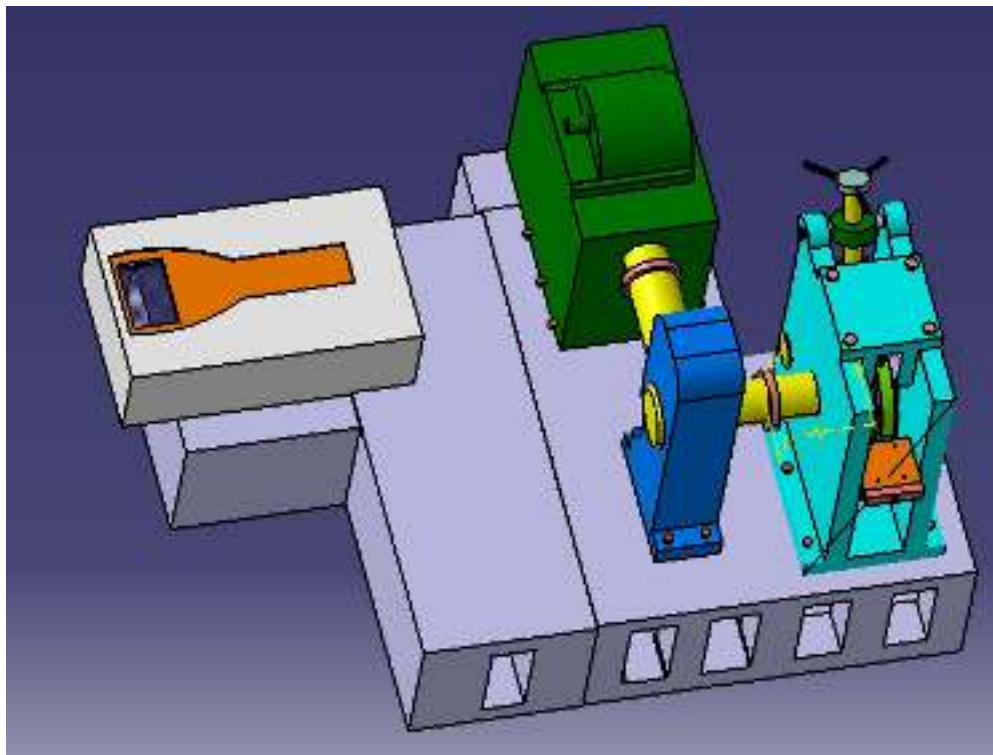


Figure 4.30: Schematic Diagram of Design Developed and Fabricated Continuous Extrusion Setup for 9.5 mm Aluminum feedstock material

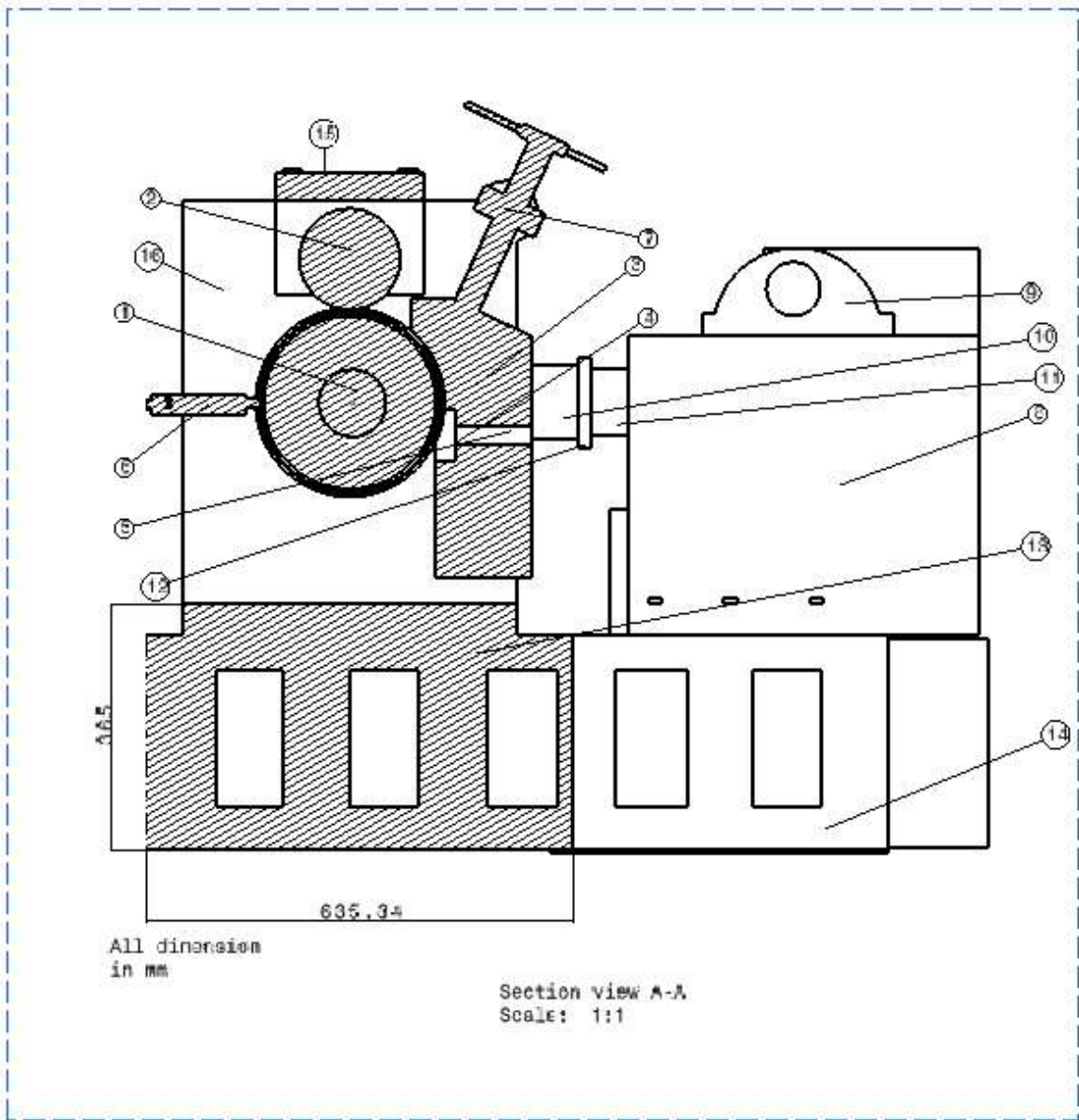


Figure 4.31 Sectional View of design developed and fabricated setup for 9.5 mm Aluminum feedstock

S. No.	Part
1	Extrusion Wheel
2	Coining Wheel
3	Extrusion Shoe
4	Abutment Die Chamber
5	Die
6	Scraper
7	Mechanical Intensifier
8	Electric Motor
9	Motor Fan
10	Gearbox Shaft
11	Motor Shaft
12	Coupling of Motor-Gearbox Shaft
13	Machine base
14	Motor base
15	Coining Wheel adjusting unit
16	Machine frame

Figure 4.32: Table of parts of 2D model (schematic) of Continuous Extrusion setup

The Chronological design development and fabrication of Continuous Extrusion setup that took place at IIT (BHU) has been discussed in brief in this chapter. Several attempts have been made to modify an existing continuous extrusion machine set up to bring it into functional form to carry out extrusion of non-ferrous metals and alloys especially for Aluminum feedstock. But due to several limitations, feedstock was not coming out of extrusion die though it was coming out of the abutment hole successfully. The decisions were made to carry out the simulations again by several design changes in the geometry of tooling's of Continuous Extrusion machine. After successful running of simulations, design development and fabrication of Continuous Extrusion setup (Figure 4.25) has been done for 9.5 mm Aluminum feedstock material and other non-ferrous

materials. Figure 4.26-4.29 shows the different views of design developed and fabricated setup for 9.5 mm aluminum feedstock material. Figure 4.30 shows the schematic diagram of Design Developed and Fabricated Continuous Extrusion Setup for 9.5 mm Aluminum feedstock material. Figure 4.31 shows the sectional view of schematic diagram of design developed and fabricated setup for 9.5 mm Aluminum feedstock .Figure 4.32 shows the parts of 2D model (schematic) of Continuous Extrusion setup in tabular form. Figure 4.33 shows the all view schematic of design developed and fabricated setup for 9.5 mm Aluminum feedstock.

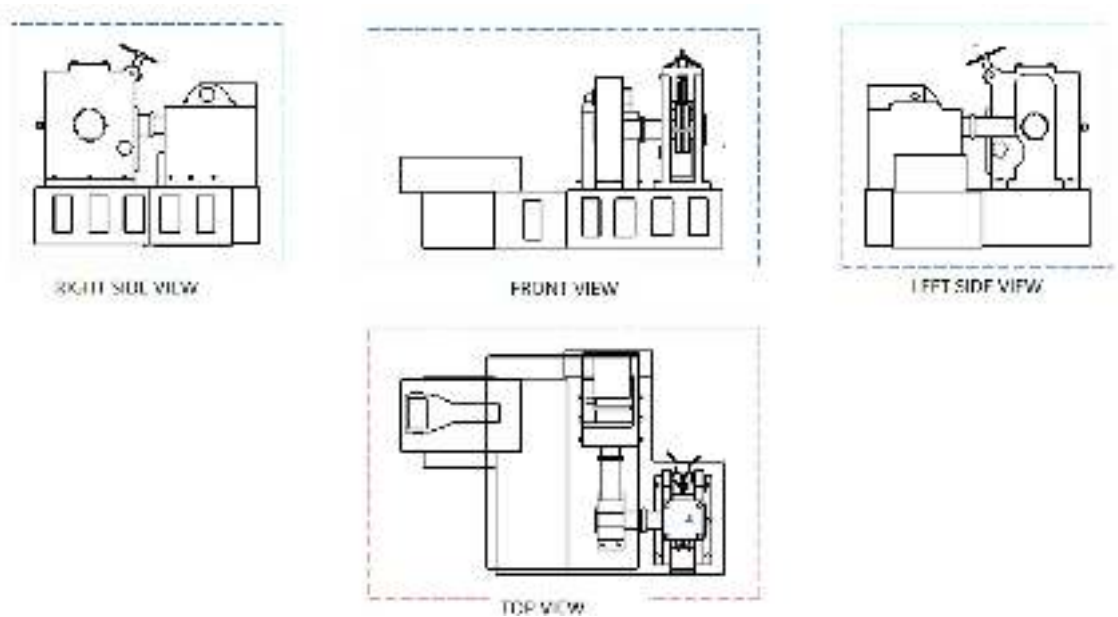


Figure 4.33: All View of design developed and fabricated setup for 9.5 mm Aluminum feedstock

In the next chapter, experimental studies on design developed and fabricated setup and commercial setup has been carried out. The material characterization like microstructural studies, tensile test and hardness test for estimation of material properties of the product samples before and after extrusion has also been carried in the next chapter.