Preface

The Continuous Extrusion forming process uses the frictional force between a circular driving wheel and material. The Continuous Extrusion process can produce sufficiently long continuous products of a variety of sectional shapes which are hard in classical forming processes owing to their methodological limitations. Because of its superiority and impact on the current forming technology, demand from industry has been growing rapidly. The Continuous Extrusion process is better than the conventional extrusion process in many ways such as: (i) The input material can be used in varied forms such as coiled rod, molten metal and powder material. (ii) Tooling's preheating and homogenizing are not needed. (iii) Manpower requirement is low. (iv) Tooling cost and their maintenance cost is also low. (v) Products can be obtained in cut length and in continuous coil form. (vi) Products such as refrigeration tubes and very thin tubes are well produced. (vii) Scrap rate is reduced. The analysis and performance of the Continuous Extrusion process depends on various factors such as peripheral speed of extrusion wheel, extrusion ratio and size of flash gap etc.

A better way to study the behavior of Continuous Extrusion process for non-ferrous materials such as Aluminum, Copper and Brass is by means of Finite Element Method and Computer Aided Engineering based procedure. The technology of product manufacturing by Continuous Extrusion process is developing very fast to shape complex profiles of products.

Most of the works in literatures include review of the development work about the Continuous extrusion machine, Numerical(FEM based analysis) for different size of die such as 6 mm, 7 mm, 8 mm, 9 mm, 9.5 mm and for different nonferrous materials such as Aluminum and Copper feedstock materials. Experimental study Experimental study for Aluminum feedstock material has also been carried out for several extrusion ratio and extrusion wheel speed. But there are not many investigations has been carried out about the extrusion of nonferrous metals at different extrusion wheel speed and extrusion ratio. Also no work in the area of Continuous Extrusion process has been carried out related to optimization of process parameters like wheel speed, extrusion ratio, feedstock temperature, die temperature and friction condition for their effect on total load, torque required, effective stresses and damage value using DOE, ANN and GA.

As a summary the Continuous Extrusion process has been carried out to enlighten the following issues:

a) Literature review of Continuous Extrusion process, FEM simulation and Optimization.
b) Modeling, CAE simulation, parametric study and analysis of Continuous Extrusion process for Aluminum and Copper feedstock materials for different sizes of die and frictional conditions.
c) Design modification and Optimization of Continuous Extrusion process.
d) Design, Development and Fabrication of Continuous Extrusion machine setup for 9.5 mm feedstock material along with measuring facilities.
e) Experiments and testing of the machine setup especially for Aluminum feedstock material of 9.5 mm under different combinations of extrusion wheel speed and extrusion ratio and some parametric study.
f) Validation by comparison between simulation and experimental result of Continuous Extrusion process for Aluminum and Copper feedstock materials.
g) Investigation on microstructural analysis of extruded products before and after extrusion using Light Optical Microscopy (LOM).
h) Investigation on strength of Extruded products by conducting tensile and hardness test of feedstock material before and after extrusion.
i) The optimization of Continuous Extrusion process parameters such as total load, torque, effective stresses and damage value etc. during continuous extrusion of feedstock material for several values of extrusion wheel velocities, product diameters, frictional conditions, feedstock temperatures, die temperatures using statistical software Minitab version 15.1.0.0, USA, Artificial neural network and Genetic algorithms.

The present work has been organized in seven chapters. A brief description of each chapter is presented in the following sections:

An introduction to Continuous Extrusion process has been presented in **chapter 1**. Applications of Continuous Extrusion process in various industries have been introduced. Also **chapter 1** gives a bird's eye view of the work carried out.

Chapter 2 has been devoted to literature survey in the area of Continuous Extrusion process and different research areas related to it. Different areas of research have been identified and the

literature survey has been categorically supplied under various subheadings. The main aim of this chapter is about introducing the various research works that have been carried out related to Continuous Extrusion process and infirmity of them and introducing the areas that still need to be carried out.

In **chapter 3** the analysis, modeling and simulation of the continuous extrusion process is proposed. Upper bound analysis of total extrusion power for Aluminum and Copper feedstock material has been done in third chapter. This chapter is concerned with the analysis of the continuous extrusion process for Aluminum and copper feedstock's of different diameter at different extrusion wheel speed and for different die arrangement in abutment die chamber using upper bound method. Modeling and simulation of continuous extrusion process for different metals and alloys such as pure Aluminum and pure Copper has also been carried out. Modeling and simulation of continuous extrusion process for non-ferrous metals and alloys is presented including connecting CAE processes and FEM. A simulation package (DEFORM 3D) is used to analyze the forming of Pure Aluminum feedstock (AA 1100) and Pure Copper(C 101) feedstock for continuous extrusion process. Simulation results are used to suggest design modifications in the geometry and tooling required to get the optimum result.

In **chapter 4**, Design Development and Fabrication of Continuous Extrusion machine setup using the results of simulation is presented. How the chronological development of Continuous Extrusion machine took place at IIT (BHU) has also been discussed in brief. A Continuous Extrusion machine 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 chapter Continuous Extrusion process has been investigated in detail for nonferrous metals and alloys.

In **chapter 5** experimental studies have been performed on different metals and alloys like Aluminum and Copper. The fabricated and commercial setup has been used for the extrusion of circular rod and results (products) has been found satisfactory. A validation has been performed for Aluminum and Copper rod and result have been compared with simulation. Therefore, the good agreement has been achieved between simulation and experimental study and prediction process is possible. The effect of different parameters on total extrusion power has been presented. Characterization of continuous extrusion process like microstructure analysis and

parametric study including comparison between simulation and experimental results are also performed in this chapter. Microstructure analysis of the extruded products of Aluminum and copper before and after deformation has been carried out. Material properties of Aluminum and copper have been found using tensile and hardness test. A brief parametric study of continuous extrusion process by comparing simulation and experimental results has also been carried out.

Chapter 6 is about Optimization of continuous extrusion process parameters using soft computing methods such as Response Surface Methodology, Artificial Neural Network and Genetic Algorithms has been carried out in seventh chapter. The optimization of continuous extrusion process parameters such as total load, torque, effective stresses and damage value etc. during continuous extrusion of feedstock material for several values of extrusion wheel velocities, product diameters, frictional conditions, feedstock temperatures, die temperatures has been done in this chapter using statistical software Minitab version 15.1.0.0, USA, Artificial neural network and Genetic algorithms.

Conclusion and Scope for future work has been presented in **chapter 7**.