CHAPTER 7

CONCLUSIONS AND SCOPE FOR FUTURE WORK

In the present work, study on Continuous Extrusion process for non- ferrous alloys has been carried out for Aluminum and Copper feedstock materials. Starting with the basics of CE process, review of the previous work done, analysis of extrusion power in CE process, Computer Aided Engineering (CAE) simulation of CE process is presented in the thesis work. Design Development and Fabrication of a continuous extrusion machine setup for 9.5 mm Aluminum feedstock material has been carried out. Experimental study on the fabricated setup and on a similar commercial setup available at Eastern Copper Manufacturing Ltd Kolkata is also carried out to validate results obtained by simulation and the fabricated setup. Characterization of the product samples has been done to study the material properties after deformation. Optimization of the CE process parameters for Aluminum and Copper feedstock materials is carried out using Response Surface Methodology (RSM), Artificial Neural Network (ANN) and Genetic Algorithm (GA) methodologies to find the best process parameters of CE controls(extrusion wheel velocity, product diameter, die temperature, friction conditions, feedstock temperatures).

On the basis of analysis and results presented in this thesis, the main conclusions are summarized as given below:

In the presented work, analysis has been done for the estimation of total power required for extrusion of non- ferrous feedstock materials (Aluminum and Copper) based on upper bound technologyfor several extrusion ratio, wheel velocity, shoe length and die arrangement. The total extrusion power clearly depends on extrusion ratio, different die arrangement and extrusion shoe groove length. The power consumption is high if the extrusion ratio and extrusion shoe groove length is high with square die arrangement. The power consumption is slightly reduced with the streamlined die arrangement for the same value of extrusion ratio and extrusion shoe groove length. It has been observed that as the extrusion wheel velocity increases, the total load required for the extrusion of feedstock material decreases.

It has been observed that for square die arrangement, the total extrusion powers has been found as 14.8 kW (extrusion ratio 2.5), 14.47 kW (extrusion ratio 1.84) and 13.66 kW (extrusion ratio 1.41) at extrusion wheel velocity of 4 RPM whereas simulation powers are 16kW (extrusion ratio 2.5), 15.5 kW (extrusion ratio 1.84) and 14.3 kW (extrusion ratio 1.41) extrusion wheel velocity of 4 RPM. Thus, it is concluded that power required by the simulation process is greater than analytical process.

Since the main aim of the thesis has been to develop a Continuous Extrusion machine setup through CAE simulation, studies has been planned so as to pin point the optimal design of the setup. The CAE simulation of the CE process has been carried out using simulation tool DEFORM-3Dto assess load requirements in CE process, effective stresses, effective strains, temperature field, and quality of product (damage value) obtained during the extrusion of feedstock material in CE process. The results based on upper bound analysis has been found fairly correct and close to the results obtained through CAE simulation and experimental study.

It has been observed that by CAE simulation, for extrusion of 8 mm Aluminum feedstock material to 6 mm, the total load have been observed as 145 kN, 139 kN and 137 kN at wheel velocities of 4 RPM, 6 RPM and 8 RPM respectively. For extrusion of 9.5 mm Aluminum feedstock material to 6 mm, the total load have been observed as 222.22 kN, 180 kN, 119.8 kN and 119 kN at wheel velocities of 4 RPM, 6 RPM, 8 RPM and 10 RPM respectively. For extrusion of 12.5 mm Copper feedstock material to 6 mm, the total load have been observed as 794.44 kN, 525.92 kN, 397.91 kN and 322.22 kN at wheel velocities of 4 RPM, 6 RPM, 8 RPM and 10 RPM respectively. This ensures that the industry based on CE process should carry out the production process corresponding to lower RPM of the extrusion wheel in order to reduce the load consumption. The lower RPM of extrusion wheel also ensures the slip less CE process.

Based on the analytical and CAE simulation results, design development and fabrication of a Continuous Extrusion setup has been carried out for carrying out experiments on non-ferrous alloys for Aluminum and Copper feedstock material at several wheel velocity and extrusion ratio. Design Developed and Fabricated CE setup has been found successful for the extrusion of Aluminum feedstock for extrusion ratio of 2.5, 1.8, 1.41.The fabricated setup has been found successful for producing defect free products of infinite length. The experimental results obtained has been found correct and close to the theoretical and FE results.

The characterization of the product samples such as microstructure examination, tensile and hardness test has been carried out estimate the material properties of Aluminum and Copper feedstock. It has been observed that there is enhancement in the material properties of the product samples.

The microstructure images of all the samples show no considerable changes of grain size during before deformation (extrusion) but the shape of grains is changed as they are elongated after deformation (extrusion). The feedstock before continuous extrusion has uniform grains. The average size of the extruded alloy under extrusion wheel velocity ranging from 6 to 8 RPM, ranges from 80µ to 200 µ. It is seen that under extrusion wheel velocities of 6 and 8 RPM, the grain structures are larger and inhomogeneous. Under the extrusion wheel velocity of 10 RPM, the structure containing fine and uniform grains are obtained. A further increase in wheel velocity to 18 RPM slightly increases the grain size. There is enhancement in the material properties of extruded product samples after extrusion. The UTS and hardness of the product samples has been found more than the raw feedstock samples.

To help the metal forming industries in the area of continuous extrusion in order to maximize the production rate, minimize the power consumption and to produce the defect free products with better surface quality and strength, the optimal value of best CE process parameters has been predicted.

Optimization of the CE process parameters has been carried out using RSM, ANN and GA methodology for Aluminum and Copper feedstock material under the given work. The value of wheel velocity and extrusion ratio (product diameter) has been estimated to minimize the load consumption and to obtain the better quality of product and improved material properties. There exist a particular value of extrusion wheel velocity and product diameter (extrusion ratio) at which the CE process should be carried out in order to minimize the power consumption and to obtain the better mechanical and metallurgical properties of products obtained through CE process.

Table 7.1 gives an idea about the optimum CE process parameters at which the best value of CE responses has been predicted.

Table 7.1: RSM results for Aluminum and Copper feedstock

Material	Optimization technique used	Optimum Parametric Combination		Optimum Result
		Wheel Velocity (RPM)	Product Diameter (mm)	
Aluminum	RSM	6.57	6.33	UTS(Max) = 106.45 MPa
		6.57	6.33	Hardness(Max) = 34.6
		6.06	6.18	YS(Max) = 70.94 MPa
		6.06	6.18	% Elongation(Max) = 46.45
Copper	RSM	10	5.72	UTS(Max) = 250.5 MPa
		10	5	Hardness(Max) = 95.9 HV
		6.36	6.87	YS(Max) = 59 MPa
		6.28	6.84	% Elongation(Max) = 59.46

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The optimum value of input process parameters for optimum value of load obtained in numerical modeling and optimization process of Continuous Extrusion for Aluminum feedstock has been found as 13 rpm as wheel velocity, 5 mm as product diameter, 1.95 as friction condition, 671°C as feedstock temperature and 548 °C as die temperature using ANN-GA technique and optimum value of load achieved is 136.4 kN.

The result reported in this thesis is to help metal forming researchers in the area of Continuous Extrusion of non-ferrous alloys especially for Aluminum and copper feedstock materials.

Scope for future Work

- ❖ The Designed developed and Fabricated Continuous Extrusion setup can be used further for exploring the continuous extrusion of other non-ferrous alloys such as brass and titanium by increasing the source power and motor and gearbox ratings.
- ❖ Pre Extrusion and Post Extrusion lines can be fabricated and installed.

- Hydraulic arrangement can be made for the opening and closing of extrusion shoe which will facilitate the production rate.
- Arrangement for the extrusion of tubes and multi void tubes can be made.
- Optimization techniques used can be applied for other non-ferrous alloys.