CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

Continuous extrusion process is an important manufacturing process for producing complicated endless profiles which cannot be produced by conventional extrusion process. Lots of innovative developments have taken place to keep pace with time since last three decades. There is a vast literature available on continuous extrusion process.

Based upon the type of work, reported in literatures having important issues, this chapter is organized to following sections.

1. Investigation in the optimal design for conform process.
2. Investigation in the flash formation analysis.
3. Investigation in the modeling and analysis of the process.
4. Investigation in the wheel tool gap sensing.
5. Investigation in the surface defect and curling phenomenon.
6. Miscellaneous (Combined)
7. Simulation and Modeling of metal forming

Literatures falling under above mentioned sections are given below:

2.2 Optimal design for conform process.

Cho et al. (2000) proposed to calculate the powers required in steady state CONFORM process. A simplified equivalent side extrusion process is made for calculating the powers required in the CONFORM process, and the upper bound method applied to the die and groove regions. The present similarity and theoretical results were illustrated and verified through model problems and DEFORM simulations. According to the numerical results, calculation of the powers required in the complicated CONFORM process is possible with the simplified equivalent side extrusion to an acceptable accuracy. In addition, comparison with respect to the extrusion ratio was made, from which it was observed that the powers decrease as the extrusion ratio increases. Aluminum (Al -1100) of yield stress 60 MPa was used as the raw material.

Tonogi et al. (2002) describes the technology of conform extrusion developed for irregular section copper and examples of products to which it can be applied. Die strength, metal flow and internal defects of copper irregular sectional extrusion was examined. Consequently, they were able to extrude irregular sections and significantly reduce the number of process steps by using a near net shape. They also found the ways of replacing cutting process with extrusion process.

2.3 Analysis of flash formation

Manninen et al. (2006) explain the mechanics of flash formation during steady state continuous extrusion. They developed an analytical model for estimating the flash shape and the amount of scrap produced. The model shows a functional relationship between the flash formation and the extrusion pressure friction, flash gap size and geometrical factors. The derived functional relationship establishes a ground for rational selections of flash gap size. A reasonable correspondence was found between predicted values with numerical and experimental results.

Katajarinne et al. (2006) carried out realistic 3D finite element simulations to study the formation of flash in continuous extrusion of copper under different frictional condition.

2.4 Modeling and Analysis of the process

Kim et al. (1998) investigated the effects of several significant process parameters on the process characteristics in the CONFORM process, such as material flow, defect occurrence, temperature and effective strain distributions using DEFORM commercial FEM Code. Since there are many parameters governing the process, it is not easy to obtain an optimal combination of process parameters. Therefore, here, according to the parametric investigation of general forming methods, they carried out numerous numerical simulations and suggested a qualitative guide for the optimal CONFORM process.

Lu et al. (1998) developed a mathematical model for the continuous extrusion process. The model enables the prediction of the temperature, stress, strain and strain – rate fields in the work piece into machine and machine components. It provides useful insight into machine design optimization and proper selection of material for tools, dies and other moving machine parts. The numerical results obtained from the model have been extremely useful in providing guidelines for process control and optimization. In many instances, the model gives insight into the extrusion of new alloys, improvement in feed preparation (cleaning, pre heating homogenizing etc.) and the quality control techniques for commercial production. The generalized mathematical formulations developed allow the incorporation of phenomena that may occur due to variations to the standard process, eg. Inert gas shrouding, in-line heat treatment and quenching, in-line die-drawing of extrudate and cladding amongst others.

Manninen et al. (2010) investigated the FEM modeling of conform extrusion. The material model was visco plastic and thermally coupled. The abacus/explicit and DEFORM-3D codes were used for the simulation. The modeling results depicts that considerable internal shearing occurs within the extrusion chamber. Changes in the tool geometry can affect the material flow and process conditions. Streamlined tool designs may facilitate the use of conventional tool steels in the extrusions of copper. Savings in tool material costs can be significant in the long run.

2.5 Wheel tool gap sensing

Khawaja et al. (2001) investigated an active gap sensing and control system for improving conform extrusion product quality. The gap is measured using an air gauge system and controlled using a hydraulic actuation system. A feedstock controller is employed to attain the required gap specified by the user. By providing active gap control, less flash is produced at the start of extrusion process when the conditions change form cold to steady hot working temperatures. Alternative gap sensing and measurement technologies have been investigated, ultrasonic – based gap measurement technique in particular.

Khawaja et al. (2004) investigated and designed a high temperature capacitive gap sensing system and implemented on a copper extrusion machine in a production plant. It was shown that machine set-up time was reduced from 35-40 minutes to 5 minutes with active gap sensing. It was also shown that there is a linear reduction of waste levels from 20% to 2% when gap size is reduced from 1mm to 0.15mm.

Clode et al. (2005) investigated and implemented high temperature capacitive gap sensing system on a copper conform extrusion machine in a production plant. They proved that the sensors can be used for on-line direct gap measurement and control and for the first time, provide a detailed view of extrusion zone gap behavior during a full production cycle. Form the experimental results, three different stages of a conform extrusion cycle, start, slugs feed, and steady state extrusion can be clearly identified. The gap sensor is used to evaluate the relationship between gap size, and waste levels. It is shown that there is a linear reduction of waste levels from 20% to 2% when the gap size is reduced from 1 to 0.15.mm.

2.6 Surface defect and curling phenomenon

Cho et al. (2000) addressed a parametric investigation on the occurrence of the surface defect in this process. Here, the wheel velocity, the extrusion ratio, the abutment height, the friction coefficient and the flash gap size are taken as parameters and numerous parametric numerical experiments are carried out in order to analyze their effects on the surface defect occurrence. They used DEFORM-3D for the simulation.

Cho et al. (2001) addresses the three dimensional finite element analysis of the process aimed at the parametric investigation of the curling phenomenon and the understanding of the process characteristics closer to the real process .For this goal, they first made the flow dynamic analysis on the phenomenon as well as three dimensional finite element analysis of CONFORM process.

Cho et al. (2003) numerically examined the effects of wheel diameter on the surface preparation and curling phenomenon as well as after significant process characteristics, through the two-dimensional finite element analysis of CONFORM process for solid section aluminum products.

2.7 Miscellaneous (Combined)

Sinha et al. (2003) carried out virtual design and fabrication of Continuous Extrusion machine setup with process analysis.

Zhu et al. (2004) investigated a new severe plastic deformation (SPD) technique which combines equal channel angular pressing (ECAP) with conform to process ultrafine grained (UFG) materials in a continuous extrusion manner. In this invention principle used to generate frictional force to push a work piece through an ECAP die is similar to conform process, while a modified ECAP die design is used so that the work piece can be repetitively processed to produce UFG structures.

Shukla et al. (2007) carried out CAE Modeling and Simulation of Continuous Extrusion machine. A detailed application of CAE process for the design and development of Continuous Extrusion (continuous rotary extrusion) machine modeling of different components has been done on the solid edge (V19). The model has been validated and redesigned by the simulation on Deform-3D.

Peng-yue et al. (2007) carried out study on CONFORM process for producing concave bus bar under different extrusion wheel angular velocities by three-dimensional finite element technology based on software DEFORM-3D. The distributions of velocity field, stress field, strain field, temperature field and damage field were investigated under different extrusion wheel angular velocities.

Kumar et al. (2008) designed developed and fabricated a Continuous Extrusion machine setup for 8 mm feedstock material for extrusion of material to wires, strips and rod form. The machine setup has been developed to explore the continuous extrusion process in detail for nonferrous alloys such as Aluminum, Copper and Brass.

Wei et al. (2009) analyzed the deformation behavior of the pure copper rod in the continuous ECAP process using DEFORM-2D.The effect of die angle φ and the friction between the die channels and the specimen on the stress strain distributions, strain homogeneity, the feature of shear deformation and the torque was investigated. In the continuous ECAP, shear deformation exists in the die angle ranged from 900 to 1200, however the pattern and extent of shear deformation are different to that in Conform and ECAP. The effective strain is uniform in most parts of the work piece. As ϕ increases, the corner gap becomes smaller and the strain distributions are less homogeneous. The extent of shear deformation, homogeneity of stress strain can be improved by the friction on the interface of the die and work piece but the maximum torque value increases. The assumed shear deformation was further divided into three stages, which was well explained by torque-time curves and the effective stress fields. The results indicate that the continuous ECAP process is a promising approach for producing ultra-fine sheet, bar, rod and wire.

Langdon et al. (2010) made investigation to critically evaluate the ECAP-Conform process with a special emphasis on the two areas where no information is at present available. First, detailed hardness measurements were undertaken to evaluate the extent of homogeneity within the microstructure after processing by ECAP-Conform with separate measurements taken to determine both the homogeneity within the cross-sectional planes of processed rods and the variations in the micro structural homogeneity along the lengths of the processed rods. Secondly, mechanical testing was undertaken to determine the extent of any plastic anisotropy that may be present within the rods after processing by ECAP – Conform. The experiments were conducted using a commercial Al-6061 alloy.

Zhang et al. (2008) successfully carried out the continuous extrusion forming of AZ31 magnesium alloy on the modified commercial conform extrusion machine and demonstrated the possibility of the efficient continuous forming of magnesium alloys. The author compared the conventional direct extrusion process and conform extrusion process and concluded that conform process can refine the grain structure, improve the degree of the structure homogeneity and change the orientation of basal plane , and hence enhances the ductility but slightly decrease tensile strength. The fracture mechanism of the alloy prepared by conventional direct extrusion process and conform process change from the mixture of ductile and brittle to the full dimpled rupture.

Zhao et al. (2013) carried out the experiments and numerical simulations to analyze the continuous extrusion of AA6063 aluminum alloy under extrusion wheel velocities of 0.52, 0.78, 1.04 and 1.3 rad/simulation results indicate that variations in extrusion wheel velocity directly affect the material deformation and significantly influence the maximum extrusion temperature. The work also revealed that deformation and temperature have apposing effects on the microstructure of the resulting product. Greater wheel velocity causes a higher strain rate and extrusion temperature. Increasing the wheel velocity, at an initially low speed, causes a large increase in strain rate. This results in a decrease in grain size. In contrast, at high wheel velocities, further increase to wheel velocities have much less impact on the strain rate, leading to an increase in grain size as the increased extrusion temperature dominates the mechanics of grain growth.

2.8 Simulation and Modeling of Metal forming

Hodek et al. (2012) described a DEFORM-3D FEM modeling of high strength materials (titanium) using finite element software DEFORM-3D. The model traces temperature and strain fields which are then compared to experimental data obtained from continuous extrusion of titanium feedstock. The temperature of the wheel, the temperature of the input titanium feedstock and the circumferential speed of the wheel have substantial impact on the entire forming process. The goal is to find adequate boundary conditions to make the mathematical model fit the real world process as much as possible and to allow its optimization.

Hodek et al. (2013) described a DEFORM-3D FEM model and experimental continuous processing of titanium rods. The model traces temperature and strain fields which are then compared to experimental data obtained from continuous extrusion of titanium. The temperatures of the wheel, the temperature of the input titanium feedstock and the circumferential speed of the wheel have substantial impact on the entire forming process.

Zemko et al. (2013) carried out fem modelling of continuous extrusion of high-strength metals using commercial conform™ machine. This work describes 3D modelling of continuous extrusion of high-strength materials (titanium) using the finite element method software DEFORM-3D. The model traces temperature and strain fields which are then compared to experimental data obtained from continuous extrusion of titanium stock. The temperature of the wheel, the temperature of the input titanium feedstock and the circumferential speed of the wheel have substantial impact on the entire forming process. The goal is to find adequate boundary conditions to make the mathematical model fit the real-world process as much as possible and allow its optimization.

Song et al. (2013) carried out microstructural evolution in cu-mg alloy processed by conform process. The objective of this study has been to investigate the possibility of continuous extrusion forming (Conform process) and microstructural evolution the of Cu-Mg alloy. The results indicate that Conform process can break as-cast grains and refine the structure, meanwhile. This process can improve the degree of the structure homogeneity. The TEM and EBSD techniques were used to investigate the morphology, grain size and disorientation of the samples at cavity entrance and cavity export. Refined structures after shear deformation include broken grains and sub grains formed by dislocation reconstruction. Due to the relatively high deformation temperature, dynamic recrystallization occurred during deformation. The sub grain rotation nucleation took place, and grain boundary migration resulted in grain growth. However, the coarse grains were refined by anneal twins.

Sinha et al. (2014) carried out studies on effect of feedstock temperature in continuous extrusion. The temperature of the feedstock in continuous extrusion process plays a vital role in the deformation of feedstock. Temperature of the feedstock has considerable effects on the process characteristics of continuous extrusion process such as total load and torque required to extrude the feedstock through the die orifice. In this paper, a numerical investigation is made to study the effect of temperature of the feedstock on the process characteristics such as load distribution, torque distribution, effective stress distribution, effective strain distribution, temperature distribution, damage distribution and velocity distribution using FEM simulation tools. The investigation result suggest that if the temperature of feedstock lies in the warm range, then total load and torque required to deform the feedstock is considerably reduced in continuous extrusion process. A number of case studies have been taken to establish the process for Aluminum alloy.