ABSTRACT

Aluminum alloys are widely found in various products regularly used in our daily lives, from aluminum foil for food packaging and easy open aluminum cans for beverages to the structural members of the aircraft. The wide use of aluminum alloys is possible because of their desirable combination of high specific strength, low density, good corrosion resistance, machinability and cost and also the ease with which they may be produced in a great variety of forms and shapes with wide variety of surface finishes.

The challenge posed to process designer in metal forming is to produce net-shape or near-net shapes economically with desired mechanical properties and quality. This necessitates the designer to have an understanding the behavior of metals and alloys at hot deformation conditions. The finite element methods and deformation processing maps are the important techniques available to characterize the material behavior under different processing conditions in metal various forming operations. To use these techniques effectively an accurate constitutive model is needed for better process control and parameter optimization in the hot working operation.

Since the constitutive relation among flow stress, strain, strain rate and temperature is complex and nonlinear the results obtained from the parametric approach to constitutive modeling are not accurate. Because of inherent properties of artificial neural network (ANN) an alternative to the parametric modeling is found to be ANN. Flow stress data for hot working of as cast aluminum alloys are very much limited. Hence flow stress data of cast
4043 (Al-5Si), 5182 (Al-4.5 Mg) and RR58 aluminum alloys were generated by conducting compression tests in the range of temperatures from 500 K to 800 K and strain rates from 0.02 s\(^{-1}\) to 8 s\(^{-1}\). The present study has tried to investigate the feasibility of utilizing the neural network to extract the complex relationship involved in hot deformation process modeling. This work attempts to develop a back propagation neural network model to predict flow stress data of cast aluminum alloys for any given processing conditions. The flow stress data obtained from the experiments were used in conjunction with back propagation neural network for the purpose of training network. This could in turn be used to predict the flow stress value for any given processing conditions. It has been found that the flow stress values predicted by the network agree closely with actual experimental values, thus indicating the possibility of using the neural network approach to tackle hot deformation problem.

The aim of the present investigation is also to study the deformation processing of aluminum alloys with a view to establishing an interrelation between the process parameters (temperature and strain rate), the microstructure and the product properties. The optical micrographs were obtained on the section of the product. The generated flow stress data were used to develop processing maps to delineate the process domains for safe metal working. The power dissipation efficiency maps and the instability maps were generated for the alloys to reveal instability regime. The safe processing zones of the investigated alloys were reported. The mechanical properties namely yield strength, hardness and reductions in area of the upset forged specimens were determined at 300 K as a function of upsetting temperature and strain rate. Based on the micrographs and mechanical
properties of the product the safe processing windows for the cast aluminum alloys have been identified. The following conclusions are obtained:

The hot deformation behavior of cast Al-5Si, Al-4.5Mg and RR58 alloys was investigated by hot compression tests conducted at the temperature range of 500 to 800K and strain rates at the range of 0.02 to 8s\(^{-1}\). Flow stress values of all three materials increase with increase in strain rate and decrease in working temperature.

Artificial Neural Network (ANN) modeling has been carried out for the first time on hot working of cast aluminum alloys giving excellent prediction of flow stress at various combinations of strain, strain rate and temperature.

By using the flow stress data predicted by ANN models, the power dissipation efficiency and instability parameters were calculated and processing maps were constructed for strain of 0.4. The optimum domains and instability zones have been obtained from the maps.

The power dissipation efficiency maps have revealed a maximum efficiency of 45% for Al-5Si alloy, 33% for Al-4.5Mg alloy and 39% for RR58 alloys.

The safe regime for hot working of Al-5Si has been observed at low strain rate range of 0.02 to 0.2 s\(^{-1}\) and a temperature range of 625-675 K. The safe hot working regime for RR58 alloy has been observed at low strain rate of 0.02 to 0.2 s\(^{-1}\) and a high temperature range of 625-675K.
The safe working range for Al-4.5%Mg alloy has been observed at strain rate of 0.02 to 0.2 s\(^{-1}\) and a temperature range of 700-750K. In all the three alloys the flow softening occurred at high temperature and low strain rate due to recovery and recrystallization processes. This has been confirmed by the recrystallized structure and high ductility at this temperature range and strain rate.

The flow stress values of the cast alloys are lower than that of forged alloys over the ranges of temperatures and strain rates. The maximum power dissipation efficiency in the DRX domain of cast alloys are lower than that in forged alloys.