INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student	:	SAIBAL KANCHAN BARIK
Roll Number	:	146103015
Programme of Study	:	Ph.D.

Thesis Title: Formability and Failure Response of AA5052-H32 Sheets Deformed using a Shock Tube

Name of Thesis Supervisor(s)	:	Prof. Niranjan Sahoo and Prof. R. Ganesh Narayanan
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SHORT ABSTRACT

The emerging interest to minimize fuel consumption and carbon emission, lightweight component design has become one of the important goals in the automotive industries. Among the lightweight materials, aluminium alloys are used significantly in automotive body construction because of their acceptable strength to weight ratio, toughness, ductility, and corrosion resistance. However, the limitations include the moderate formability in the conventional sheet forming processes at room temperature and significant springback during stamping of complex geometries. Thus, improving the formability of aluminium alloys receives much attention in the stamping industries. Generally, warm forming and high-velocity forming are preferred to improve the formability of aluminium alloys. However, heating metals during deformation imposes an additional cost to the forming operation. Thus, various high-velocity forming processes are in demand because the inertial effect developed during these processes that delays necking by developing additional tensile stress outside the neck resulting in enhanced formability. In the recent past, various high-energy rate forming (HERF) processes such as electro-magnetic forming (EMF), electro-hydraulic forming (EHF) and explosive forming (EF) have been preferred to fabricate net-shaped products without any defects. Despite several advantages of HERF processes, the major limitations are the higher capital cost, difficulties in machine handling, and requirement of skilled persons.

Recently, the shock tube facility is also introduced in many studies as a dynamic loading device. The shock tube generates a shock wave during the bursting of a diaphragm, which separates the high-pressure driver section and the low-pressure driven section. The high-velocity shock wave creates a dynamic loading environment at the end of the shock tube that helps to deform the material at different strain rates. In the present study, the shock tube has

been utilized as a dynamic bulging device to study the forming behavior of sheets at different strain rates. In addition to this, the high pressure induced gas developed inside the shock tube can be utilized to propel a rigid body at a high velocity, which can deform a material at even higher strain rates. This facilitates the shock tube to serve as a dynamic Erichsen sheet testing device, which allows to study the rate-dependent forming behavior, as well as the failure mechanism of the sheets.

During such dynamic deformation, to understand the forming behavior of aluminium alloys, several empirical, semi-empirical, and physical-based flow stress models considering the effect of strain rate and temperature have been proposed in the past. Various ductile fracture criteria have also been proposed, which can be utilized in conjunction with the finite element (FE) model to predict sheet failure and forming limit. Thus, the influence of different stress-strain relationships and failure models have also been studied in the current work to predict the dynamic forming and failure of sheets deformed using a shock tube.

Generally, in sheet metal forming, the blank is made of one piece. Thus, understanding the forming behavior of the welded sheet becomes important in many industries. To join aluminium sheets in lap configuration, friction stir spot welding (FSSW) is mostly preferred because of its better mechanical strength and weld quality. Many research activities focus on various joint performance tests such as lap shear test, cross-tension test, peel test and uniaxial tensile test. Scarce attempts are made to understand the effect of welding parameters during dynamic forming of the FSSW sheet. Thus, the shock tube based impact forming can be utilized to understand the dynamic formability and failure response of aluminium sheets with FS spot welds.

The main objectives of the thesis are to analyze the effect of various material processing parameters on the deformation of AA5052-H32 sheets of two different thicknesses 1 mm and 1.5 mm during the shock tube based forming and to predict the dynamic forming behavior for efficient process design. Thus, the shock tube is first used as a dynamic bulging device to study the effect of pre-strain on the material forming parameters of the sheets. The rate-dependent forming behavior of the sheets are predicted by a FE code DEFORM-3D. Further, a hemispherical end nylon striker is used in the shock tube to deform sheets both in the safe limit and beyond the safe limit. Deforming beyond the safe limit allowed us to understand the failure response of the sheets. In addition to this, study on the effect of the choice of flow stress models and failure models also gives a thorough understanding about the failure strain, necking location and fracture pattern during the prediction of dynamic forming of sheets. During the study of dynamic forming of the sheets with FS spot welds, the effect of tool rotational speed, plunge speed and plunge depth on the FS spot welding outputs and forming outputs are understood. Furthermore, DEFORM-3D FE code is used to perform FE simulation of both the FS spot welding and forming of the welded sheets interactively. The predicted material flow phenomenon gives an insight about the joint formation during FSSW. Various forming outputs predicted by FE simulation have a fair agreement with the experimental data.