Experimental Report

07/05/2014

Proposal: **1-02-117** **Council:** 4/2012

Title: Residual stresses in cold formed automotive grade aluminium alloys

This proposal is a new proposal

Researh Area: Engineering

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Samples: Aluminium alloy

Instrument	Req. Days	All. Days	From	To
SALSA	4	4	21/03/2013	25/03/2013

Abstract:

Sheet metal forming is a widely used manufacturing process that converts thin, flat sheet into a desired part using a set of tooling. The plastic deformation that occurs during the process is commonly assumed to take place under plane stress conditions, where out-of-plane stresses are absent. However, it is common for tools to have features (eg. the die radius) with a radius to sheet thickness ratio of less than 20, so that the plane stress assumption becomes less valid. While this has been known for some time, recent work highlighted that out-of-plane contact stresses can exceed yield stress when the flat sheet first comes into contact with the tool radius, leading to defects in the part and high tool wear. The aim of this experiment will be to measure the stresses in the walls of two channel sections and to relate it to the critical conditions that exist during the forming process.

Experimental report for 'Residual stresses in cold formed automotive grade aluminium alloys' – experiment number 1-02-117

Introduction

The aim of this experiment was to measure the in-plane longitudinal and out-of-plane residual stresses in two channel sections (Fig.1). The data that was obtained will be compared to the through-thickness stress distribution predicted by Pereira et. al [6] for a channel section and will allow us to identify the critical conditions that exist during the forming process. The channel sections are made from automotive grade aluminiums (AA5754-O and AA6111-T4).

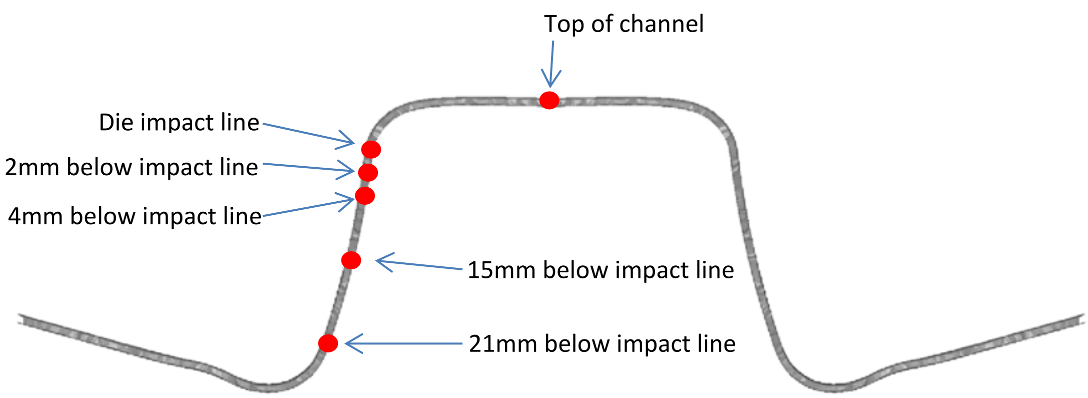


Fig.1 Location at which measurements were taken

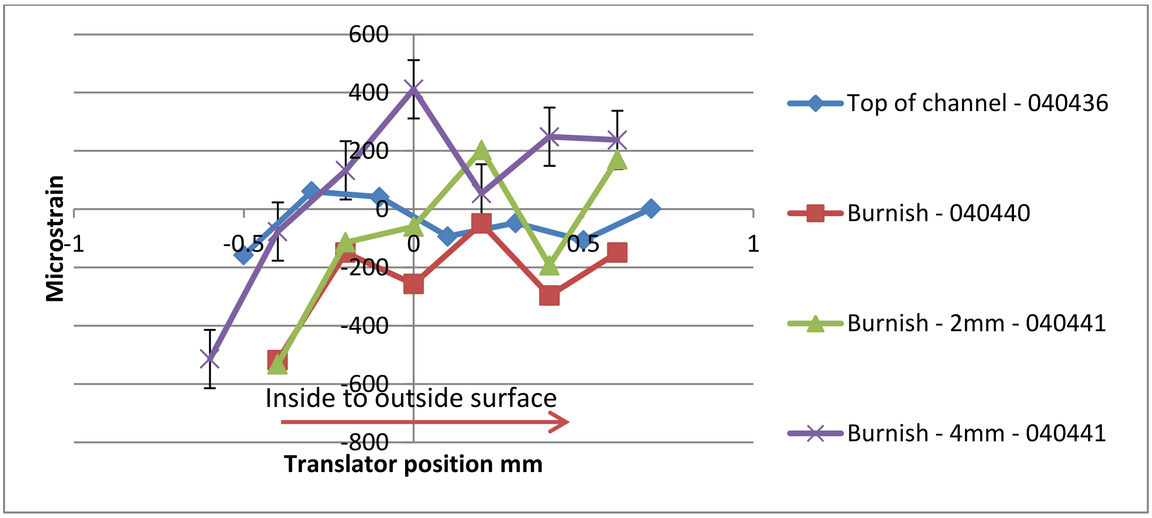
Method

The experiment was carried out on the SALSA beamline equipped with a six-axis robotic Stewart platform and a full description of the beamline was described by Hughes *et. al*. The detector used was the Bidim 26 area detector that detects up to 24° in 2θ. The objective was to measure residual stresses at the locations marked in Fig.1. At each point, measurements were made at 0.1mm intervals along the thickness of the samples and two stress components were measured: along the in-plane direction (σ_1) and in the out-of-plane direction (σ_3). The measurements were carried out for two grades of material: AA6111-T4 and AA5754-O. A jig was built on the hexapod to hold the samples in place during the experiments. During the course of the experiments, the hexapod was rotated about its ω-axis orientation to align the measured residual stress component to the q-vector. Each point (Fig.1) took about 20 minutes to measure and a complete measurement of a single stress component took about 20 hours to complete. Because of the length of time, the motion of the hexapod was automated with a purpose-written computer script. Prior to each experiment, the script was tested by carrying out a dummy run. To locate the centre of the gauge volume, a 0.3mm pin was mounted in the sample holder and the position of the hexapod was adjusted until a signal was detected. The precession of the ω axis of the hexapod was ensured by rotating it through 160° while ensuring that the pinhead remained in the beam.

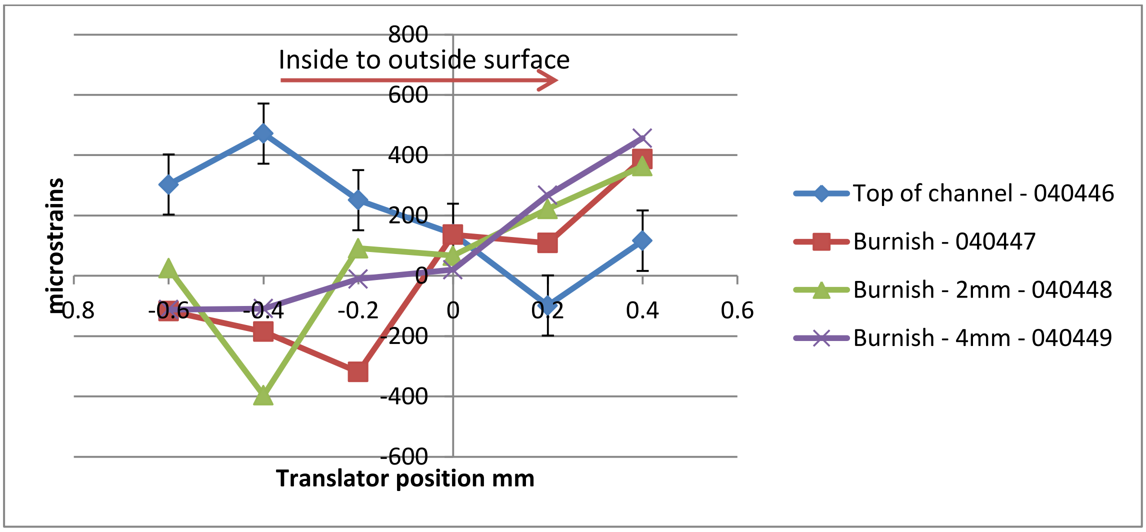
The raw data from the detector was analysed using the ILL's LAMP software for peak shifts. Using the 'Top of channel' measurement as the strain free reference, the strains at the other points were calculated. The intensity of the reflected beam varied along the thickness and was found to peak in the middle of the sheet. The intensity variation was used to centre the strain profile along the thickness of the sheet.

Results

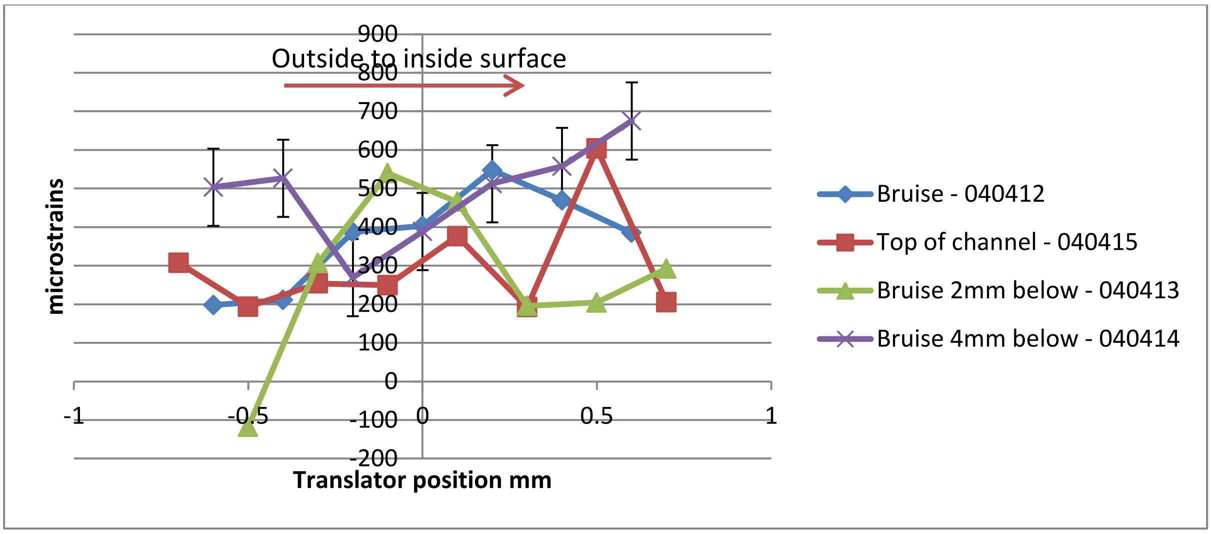
Out-of-plane residual strain distribution for 6111-T4, corrected for position, scan direction and including measurement uncertainty.



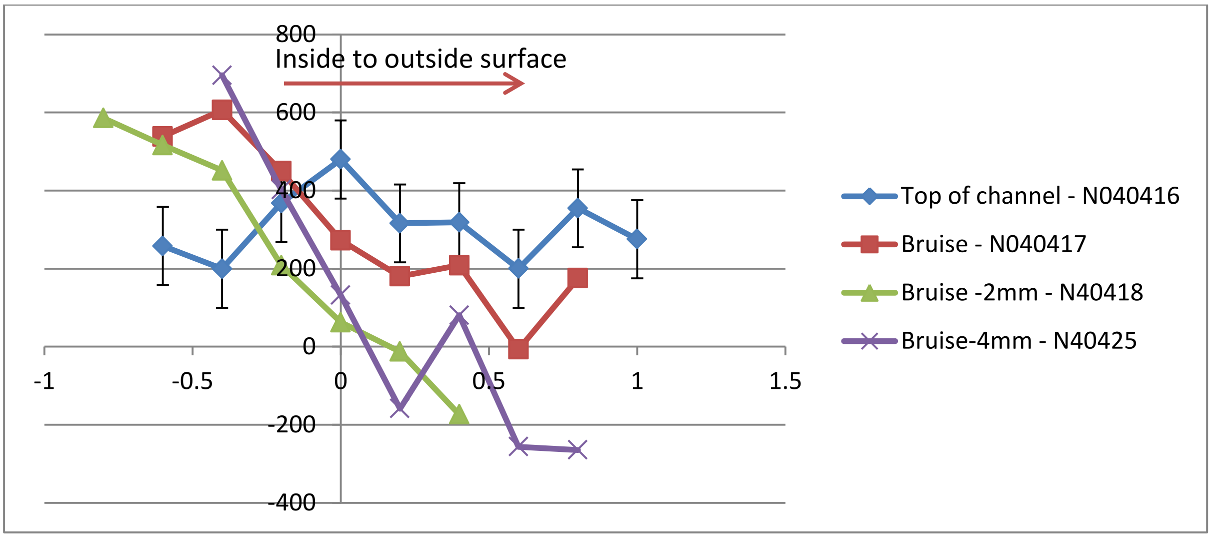
In-plane *residual* strain distribution for 6111-T4, corrected for position, scan direction and including measurement uncertainty.



Out-of-plane *residual* strain distribution for 5754-O, corrected for position, scan direction and including measurement uncertainty.



In-plane *residual* strain distribution for 5754-O, corrected for position, scan direction and including measurement uncertainty.



Discussion and conclusions

Two observations can be made from the results. First, both materials display out-of-plane strains in the walls that are significantly higher than at the top of the channel. However, the magnitude is greater for the AA6111-T4 sample compared to the AA5754-O sample. Second, both materials display significant in-plane strains compared to the top of the channel. However, the through-thickness distribution of these strains is in opposite directions for the two grades, even though they were produced using the same process.