Experimental report

12/04/2016

Proposal: **1-02-153** **Council:** 4/2014

Title: Tube drawing with tilted die - Study of residual stresses and texture

Research area: Engineering

This proposal is a new proposal

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Samples: Cu

Instrument	Requested days	Allocated days	From	To
SALSA	9	3	05/11/2014	08/11/2014

Abstract:

In order to be able to predict the complex deformation processes, finite element studies are good possibilities to model the process and evaluate the initial parameters as well as to deliver the optimum parameters for quality. On the other hand, to be able to build a model close to the real process, reliable experimental data are needed for both, initial and final conditions of the material to be simulated. It is also well established that the die geometry affects the mechanical properties of drawn tubes, such as residual stresses and the crystallographic texture. To be able to analyze the initial and final state in the material – bulk and surfaces - it is necessary to use non-destructive methods for residual stress and texture measurement. The optimum is given with the instrument SALSA at ILL.

Tube drawing with tilted die

Proposal Number: 1-02-153

Within our project in collaboration between TU-Causthal, IPCM-Strasbourg and the ILL, we investigate the influence of tilt and shift of a die on eccentricity, residual stresses (RS), and texture development on precision drawn Cu-tubes. Cold-forming generates RS arising from the elastic response to inhomogeneous distribution of plastic deformation. Depending on how RS interact with external loads, they can influence the mechanical behavior and lifetime of components in a positive or negative way. The goal is to develop a Finite Element model that describes as well uncertainties during fabrication.

Experimental

In order to distinguish between stresses, introduced by the drawing process and those, already present in the pre-tube, a drawing process was interrupted, such that the both parts are in one sample. This allows to trace the evolution of the stress-field from the pre tube through the deformation zone to the final tube.

Tubes, designated 1 and 3, were drawn, using an inner plug and the tool geometry as shown in table 1. Tube 3 was drawn with a die tilted to 5°. Tri-axial stress tensor determination, measuring in the principal axis directions, was performed at 10 locations between the pre-tube part and the exit of the tool by performing through thickness-scans with 17 measuring points each at the side of maximum and minimum wall thickness. The measuring locations are shown in figure 1

Table 1 the used tube and the tool which were used for drawing process

Tube (n°)	Plug Ø (mm)	Deform. $\varphi_d+\varphi_t$	Die (n°)	Outer Ø (mm) d_{A0} d_{A1}		Av. thickness tave0 tave1(mm)		Δ thickness Δt (mm)		Ovality O (%)	Eccentricity E (%)	
				Before	After	Before	After	Before	After		Before	After
I	54.8		60	64	60	3.1	2.6	0.2	0.14	< 0.05	2.5	2.0

Performance of the experiment

The Copper {311}-reflection was used for stress determination, which appears at 2θ ~97.9° at a wavelength of 1.644 Å. In order to guarantee small pseudo peak shifts, radial collimators were used for beam definition. We selected a gauge volume cross section of 0.6 x 0.6 mm^2. The vertical beam dimension was set to 2 mm, using the third radial focusing collimator in the primary beam. This ensured good lateral resolution in all

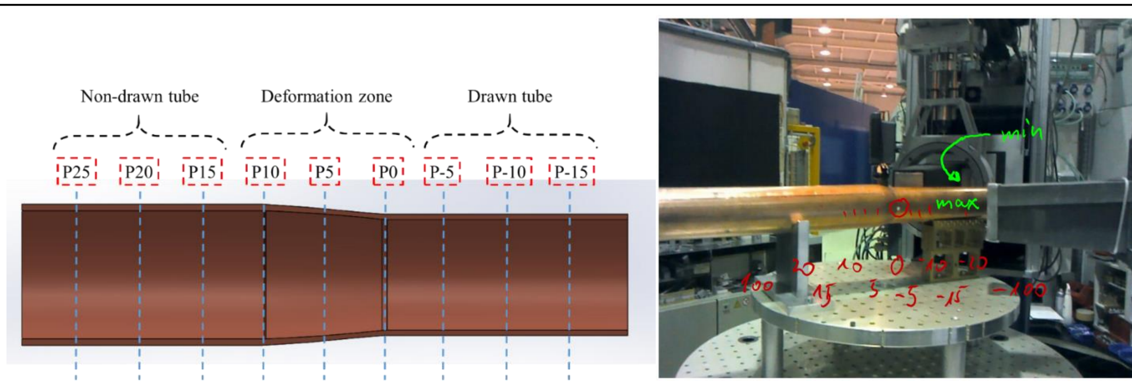

Figure 1, left: The different zones in the sample and measuring locations. Right: sample mount on SALSA for longitudinal measurements.

orientations of the sample. Radial and tangential measurements were performed with the tube mounted vertically and longitudinal measurements in a horizontal mount (Figure 1).

Since through thickness scans were performed with the gauge volume not fully emerged by the sample material, pseudo strain correction has to be applied. We used the analytical model developed at the ILL. The parameters, describing geometric effects and wavelength dependent influences on peak position, were obtained by scans of a 0.3 mm thick steel sheet across the gauge volume in reflection and transmission geometry. Figure 2 shows the evolution of the pseudo peak shift for the scattering geometry of this experiment and exemplarily the correction of one of the data sets.

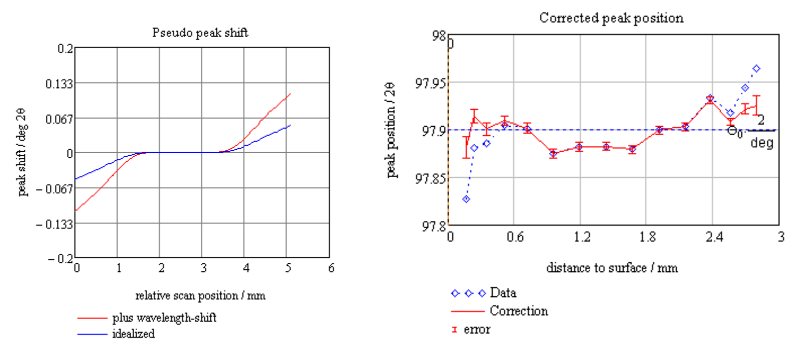

Figure 2, **left**: pseudo peak shift. The blue curve shows the geometrical correction and the red curve includes wavelength dependent peak-shift. **right**: Correction of one data-set. Blue: data as measured; red: after correction

The average count time was 8 minutes due to the small gauge volume and since measurements close to the surfaces were performed. As a result we could only finalize tube 3 and the longitudinal scans of tube 1. For finalization of these measurements we were asking for additional beam time.

Selected Results and short discussion

Figure 3 shows some stress profiles, obtained from tube 3 with 5° tilted die. As can be seen for the measured point P10 (3-a), the tube is in a compression RS state in hoop direction, with a higher level at the outer surface than at the inner one. The radial RS starts from a zero state and shifts slightly to tensile RS at the inner tube surface. Axial RS keep its level more or less constant over the wall thickness. By entering the deformation zone - P-5 – the RS are in compression state in all directions on the surface of the tube, caused by the reduction in diameter and circumference. Because of the high shear deformation in tube drawing, the hoop RS has a higher value than the other two ones. However, after leaving the die (P 0) all three components of RS on the surface change to the tensile state with the same trend over the thickness. The results for P-10, positioned in the stationary area of the tube, are given in 0-d. As it can be seen, the RS trends for axial and hoop direction are towards a tensile state on the outer surface turning to compression at the inner side of the tube.

The results have been submitted for publication (Residual stresses evolution in Cu tubes, cold drawn with tilted dies – Neutron diffraction measurements and finite element simulation, F. Foadian1, A. Carradó, T. Pirling, H. Palkowski)

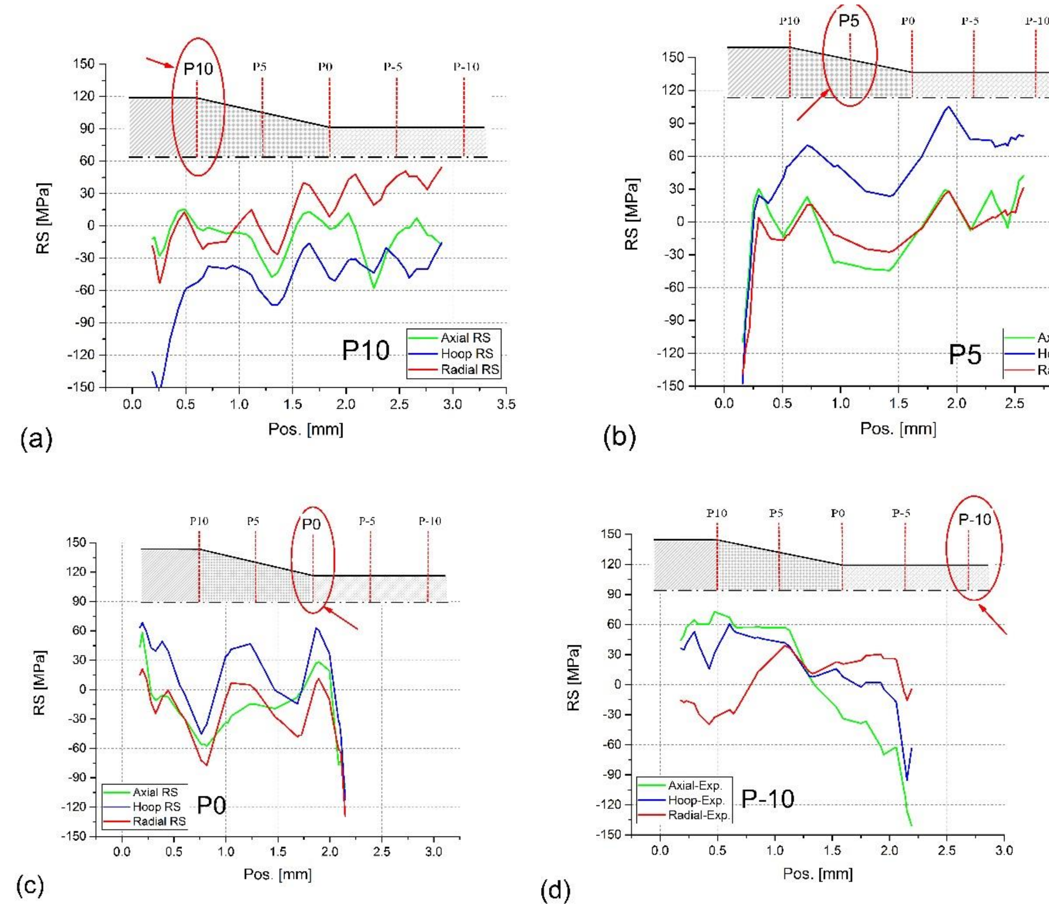

Figure 3, Measured RS in axial, hoop, and radial direction for positions (a) P10, (b) P5, (c) P0, and (d) P-10.