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DETERMINATION OF RESIDUAL STRESSES DISTRIBUTION WITHIN THE FORMED PART

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Abstract: The aim of this paper is to determine the residual stresses distribution through the sheet thickness in the case of cylindrical deep-drawn part. The metal sheets were made in FePO 5MBH steel. The analysis was performed both, experimentally and by simulation, respectively. The experimental tests were performed by using the hole drilling method and for simulation the ABAQUS software was used. A reasonable agreement concerning the stresses profiles obtained from the two analysis techniques resulted.

1. INTRODUCTION

The lifetime of a structural component is usually determined by the iteration between the defects within the component and the stresses to which it is exposed. These stresses are a combination of those applied in service and those which develop during manufacturing and processing, namely the *residual stresses.*

Residual stresses vary within the body of the component and may be sufficiently large to cause the local yielding and plastic deformation, both on microscopic and macroscopic level. The magnitude and the distribution of the residual stresses can be critical to the component performance and should be considered as a compulsory stage in the design of structural elements and in the estimation of their reliability under real service conditions.

In the case of parts obtained by deep-drawing of thin metal sheets, residual stresses are the main cause of springback. The complex loading of material during the deep-drawing process leads to an alternative compressive-tensile state on the upper zone of sheet and opposite on the lower one (fig. 1). Particles inside the material follow different flow paths in adjacent zones, generating thus residual stresses. These stresses correspond to particular boundary conditions; once these conditions are modified (for instance, when tools are removed) a redistribution of stresses according to the fundamental principle of equilibrium occurs, producing the springback phenomenon. Therefore, it is important to be able to measure and monitor the development of residual stresses into the parts at various stages of manufacturing, in order to understand the occurrence mechanism and the evolution of the springback phenomenon.

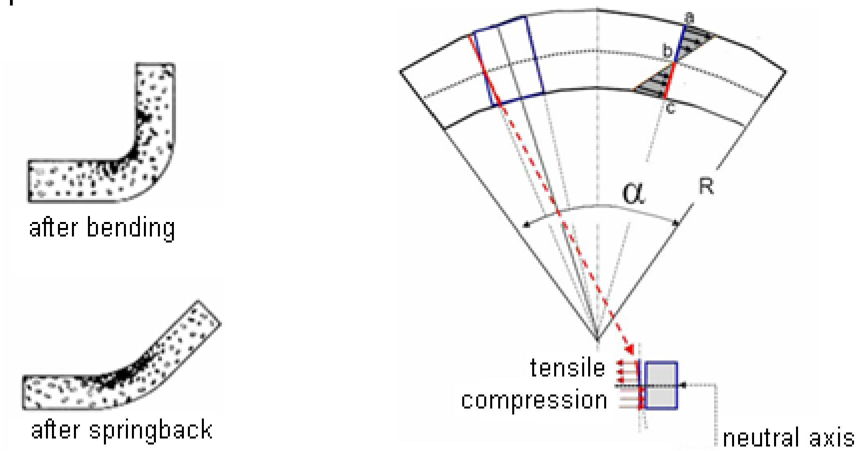


Fig. 1 Complex loading of material

The aim of this paper is to determine the residual stresses distribution through the sheet thickness in the case of cylindrical deep-drawn part. The analysis was performed both, experimentally and by simulation, respectively.

2. EXPERIMENTAL ANALYSIS OF THE RESIDUAL STRESSES DISTRIBUTION

2.1 Methodology and testing conditions

The experimental study was performed in order to determine the distribution of the residual stresses through the sheet thickness of the part. As measurement technique, the hole drilling method was used. This method is generally considered semi-destructive, because the small hole drilled into the component can often be tolerated or repaired in large structures. The basic hole drilling procedure consists in a specially configured electrical resistance strain gauge rosette that is bonded to the surface of the test part containing residual stresses and a small shallow hole is drilled through the center of the rosette (fig. 2). The local changes in strain due to introduction of the hole are measured and the relaxed residual stresses are computed from these measurements. The accuracy of this method is directly related to the strain gauge installation, drill alignment, accurate zero depth detection and temperature compensation. Skill of the operator to perform the measurement set-up is also a factor to be considered. Because the measured strains are small, any kind of disturbance of the output strain gauge signal could seriously affect the residual stresses computing.

The tests were carried out by using the equipment presented in figure 3. The acquisition of the strain gauges signal was achieved by using the Spider 8-30 device. The software used for data acquisition and calculus of the residual stresses was Catman v4.0, which provides a wealth of mathematical and graphical functions for analyzing and evaluating the measured data.

The parts were made in FEPO 5MBH steel with the following properties: Young's modulus 200000 MPa, Poison's ratio 0.3, density 7800 kg/m^3. The blank dimensions were: 200 mm diameter and 0.8 mm in thickness. The parameters used to drawing the parts were as follows: drawing depth - 30mm; drawing speed - 18 mm/min; blank-holding force - 30kN, without lubrication.

Fig. 2 Drilling a small hole in the center of the bounded strain gauge

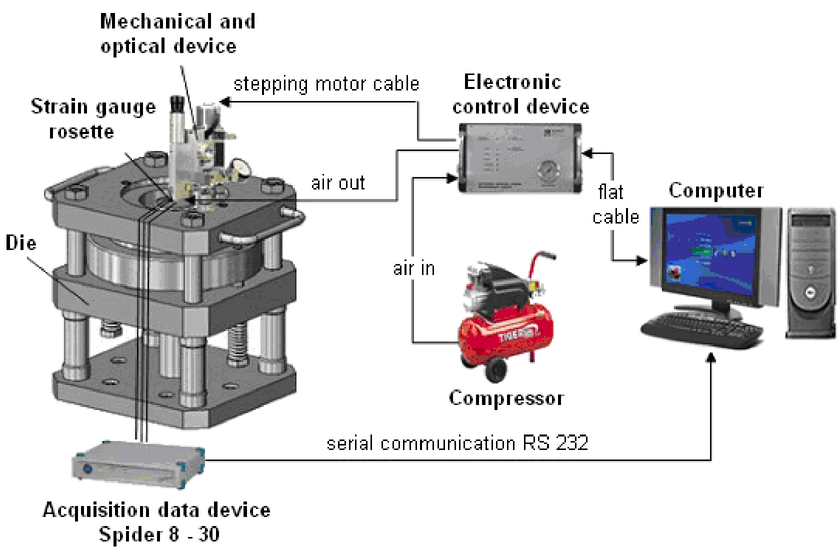


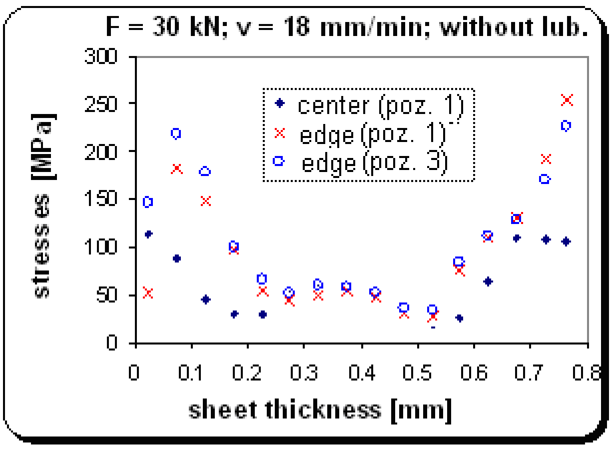
Fig. 3 Equipment used to perform the experimental tests

2.2 Experimental results

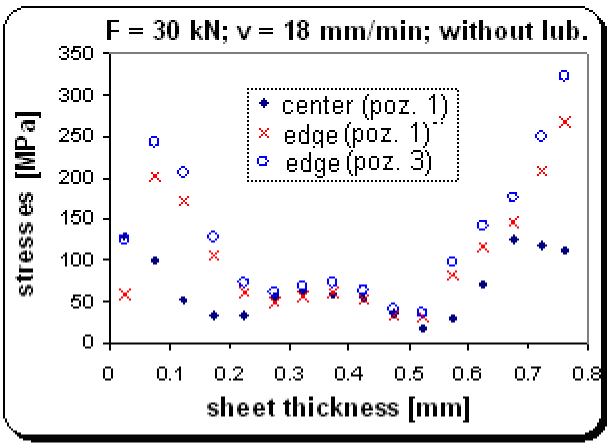
The residual stresses distribution was obtained by applying the *Integral method*, due to its affordance to evaluate the stresses distribution in the hole depth, even if they are variable through the thickness.
In order to run the program, 16 calculus steps were chosen, distributed on the sheet thickness so that a minimum effect of the measurement error to be obtained.
The sheet thickness was considered zero toward the part outside and 0.8 mm toward the part inside.
By processing the resulted data (table 1), distribution of the residual stresses in the analysed zones of the part (see figure 2) was obtained (fig. 4).

Table 1

Residual stresses distribution on the sheet thickness						
Depth [mm]	von Mises stresses, [MPa]			Tresca stresses, [MPa]		
	1	2	3	1	2	3
0.025	114.917	52.193	146.139	129.783	60.186	126.390
0.075	88.347	181.131	217.357	100.709	202.212	242.654
0.125	46.964	148.101	177.721	53.458	170.803	204.964
0.175	29.126	97.080	99.992	33.626	106.912	128.294
0.225	30.459	54.961	65.953	35.098	60.766	72.919
0.275	49.490	43.958	52.749	56.793	50.723	60.868
0.325	55.314	50.456	60.547	61.815	57.776	69.331
0.375	55.414	53.161	58.477	60.279	60.963	73.156
0.425	49.866	48.258	52.119	54.513	52.783	63.339
0.475	31.786	30.689	36.827	35.605	34.922	41.907
0.525	18.228	27.659	33.191	19.151	31.089	37.307
0.575	25.067	75.937	83.530	28.938	81.603	97.924
0.625	63.567	109.630	111.823	71.591	117.424	140.908
0.675	109.877	129.778	128.480	125.627	146.990	176.388
0.725	108.091	191.944	170.830	118.898	207.791	249.349
0.775	106.306	254.109	226.157	112.168	268.592	322.310



a. Von Misses stresses



b. Tresca stresses

Fig. 4 Distribution of the residual stresses

3. ANALYSIS BY SIMULATION OF THE RESIDUAL STRESSES DISTRIBUTION

3.1 Conditions of simulation

Finite element method was used for the analysis of the residual stresses distribution. The cylindrical deep-drawing process was simulated using input data similar to the experimental process. Two points of the part mesh were chosen whose position (nodes 1 and 43 respectively, fig. 5) is similar to the position of the strain gauges on the part in the experimental case. Only one location was chosen at the edge of the part bottom because only half of assembly was modelled (fig. 6) in order to reduce the computational time in simulation. For the same reason only five points of integration through the sheet thickness were used.

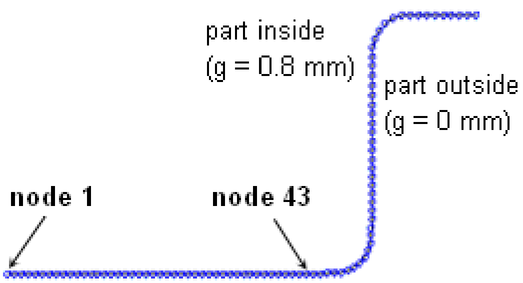


Fig. 5 Position of the mesh nodes

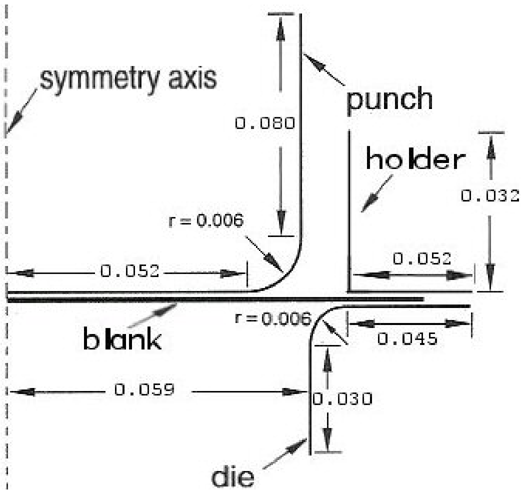
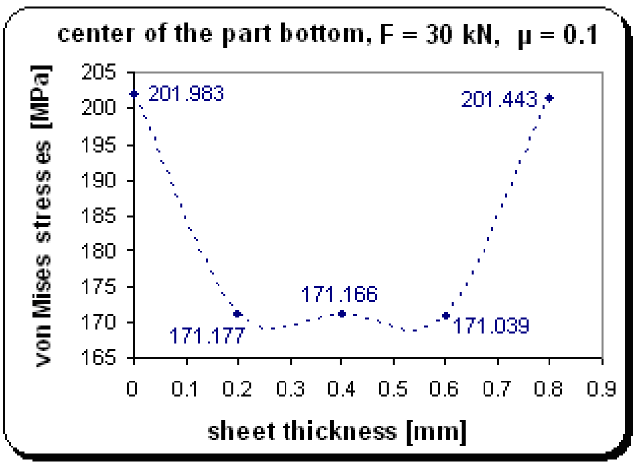


Fig. 6 Model used in simulation

3.2 Simulation results

The residual stresses distribution through the sheet thickness, for the two predefined zones, is shown in figure 7.



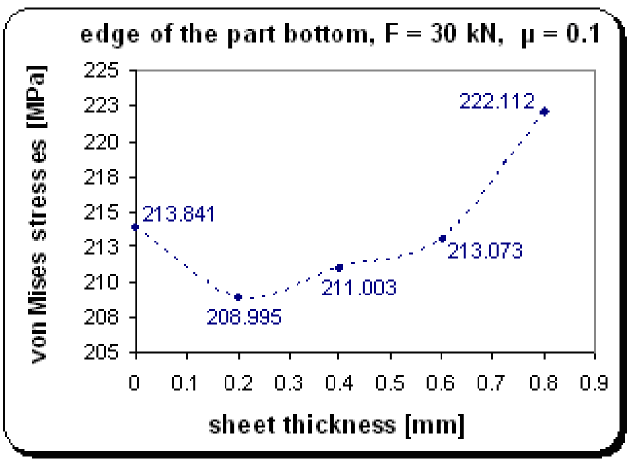


Fig. 7 Distribution of the residual stresses resulted from simulation

4. CONCLUSIONS

By comparing the results of the two investigation techniques (fig. 8) the following conclusions were stated:

- the residual stresses distribution is the same in the two cases, experimental and simulation: stresses are maximum on the outer sheet surfaces and decrease through the sheet thickness, both in the centre and at the edge of the part bottom, respectively;
- in the centre of the part bottom, stresses determined by simulation are higher compared to those experimentally determined. This difference may appear due to the different number of calculation steps through the sheet thickness: 16 in the case of experimental analysis and 5 in the case of simulation; the way in which the material parameters were implemented into the analysis programme could be also a cause.
- at the edge of the part bottom, differences between the amplitude of the stresses from the two sheet surfaces are more accentuated in the case of simulation compared to the experimental case.

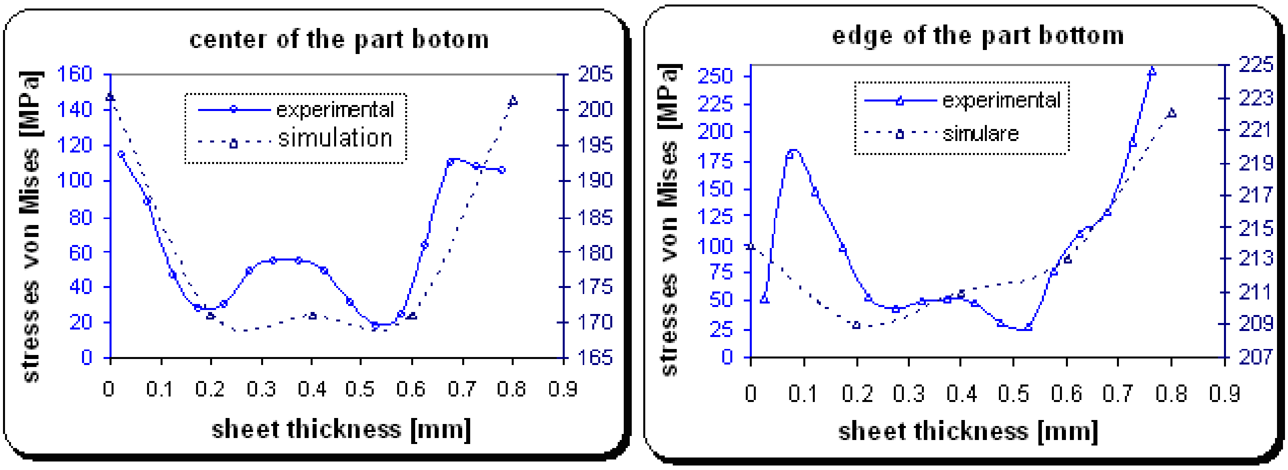


Fig. 8 Comparative analysis of results

Because the part bottom is less stressed during the forming process, the influence exerted by the state of stresses from this region on the springback parameters is quite small. From this reason, a study of the residual stresses distribution along the entire part and through the sheet thickness and its effect on the dimensional part accuracy should be performed.

5. REFERENCES

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