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VERIFICATION OF SHEET THICKNESS REDUCTION USING STEREO-PHOTOGRAMMETRY

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Abstract: Deep drawing process is a complex process of significant planar deformation. Deformation in the thickness direction is a critical phenomenon in most cases regarding possible crack creation. Therefore, it is necessary to pay a special attention to its measuring. Direct measurement of the sheet metal thickness of parts is limited by complexity of their geometry. So it is necessary to evaluate it indirectly, e.g. by optical measuring of true strain using deformation networks. The digital photography method has been proven as effective but limited to only planar strain. Multiple images stereo-photogrammetry enables digitalizing the part surface into the three-dimensional model including real texture of deformation network. Strain measurements of individual network elements are accomplished only on the virtual model with no geometry restrictions. This contribution presents the way of verifying simulation results by photogrammetric measurement of thickness changes of B-pillar drawn by KUKA ENCO WERKZEUGBAU s.r.o.

Keywords: measuring, digital photography method, stereo-photogrammetry, deep drawing process

INTRODUCTION

Deep drawing is one of the main technologies used in automotive industry. In the material there is a combined stress state, which result in planar strain, but also undesirable strain in the thickness direction, which has to be monitored due to the risk of cracking. Considering the complexity of the drawing process of complex parts, manufacturing of the parts has to be preceded by its thorough analysis in the FEM (Finite Element Method) software.

CONCEPT OF DRAWING TECHNOLOGY OF B-PILLAR

Concept of drawing technology of B-pillar and all parameters option has been carried out in the simulation software DYNAFORM. Using this simulation software first the blank geometry has been considered – material removals on the both sides of the blank have been designed. Another part of the simulations has been focused on optioning the appropriate distribution of the supporting forces ($F_p=800\text{kN}$) and the optimal location and geometry of the draw beads. These simulated

parameters ensure a uniform material flow into the die and therefore the drawn part without critical thickness reduction and waves formation in the boundary areas is performed [1]. The Figure 1 shows distribution of the sheet metal thickness in different locations on the drawn part.

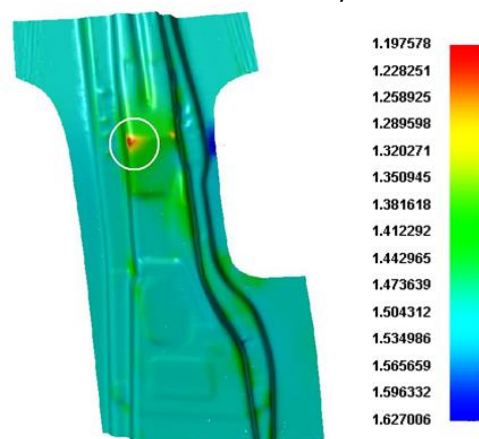


Figure 1. Sheet metal thickness of the drawn part [1]

STEREO-PHOTOGRAMMETRY SCANNING OF DRAWN PART

The 2D digital photography method (compared to the microscopic one) has been proven as effective

but limited to only planar strain. Multiple images stereo-photogrammetry enables digitalizing of the part surface into the three-dimensional model including real texture of deformation network. This enables determination of points' coordinates on general areas [2].

We used the PhotoModeler Scanner software from EOS Systems Inc. to create the model from photogrammetric images. Stereo-couple of images is needed and after their orientation process, the software can create the point cloud and 3D surface of scanned surface. As a prerequisite, the surface has to provide sufficient textural information that enables detection and matching of homologous points [3]. Points' coordinates are calculated by image correlation and collinear conditions. Principle is based on supposition that each pixel of the image has its unique surrounding – pixel matrix by whose comparison the position of the point on the second image is identified. The bigger the dimension of comparing matrix is, the bigger probability of finding homologous couple of points and the longer computation will be [4].

Process of 3D surface model creation

First of all, the camera has to be calibrated in the PhotoModeler Scanner software. Calibration runs automatically by processing minimum eight images of testing calibration grid that contains coded targets (Figure 2) [2].

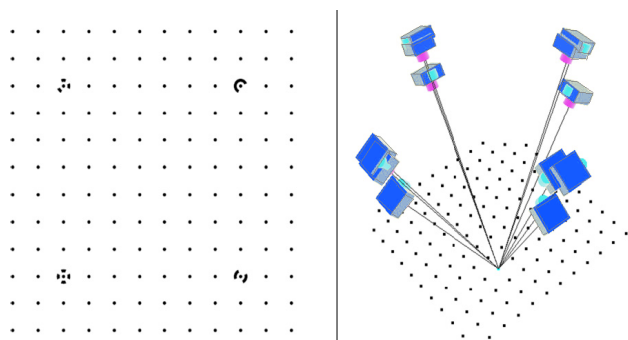


Figure 2. The calibration grid and its image processing during automatic calibration [5]

Image for the photogrammetric scanning process has to be made while keeping specific rules (Figure 3), that results from image correlation principle. Camera axis of the image couple should be slightly convergent (15° - 30°) and the proportion base/distance (b/h) should be of range $0.1 \div 0.5$ what ensures good coverage. Ideal proportion is 0.25. Noise and blur can cause problems to image

correlation or even make it impossible. Therefore the smallest ISO sensitivity and tripod are used. The same lightening in images without flash is important. For mutual referencing it is suitable to use coded targets [2][5].

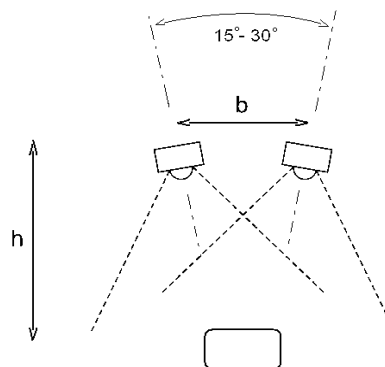


Figure 3. Image-taking conditions [5]

Two couples of images with axes convergence of 15° are used for processing (Figure 4, Figure 5). In the referencing mode we manually match the pairs of homologous points and then we process the project to orient the images and to calculate 3D coordinates of all the points. Mean error of all points' corrections has been 0.101px which corresponds to 0.005mm.

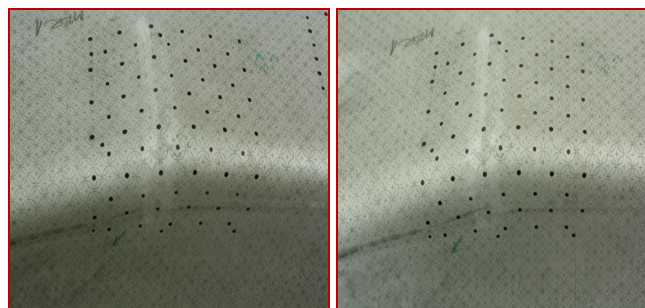


Figure 4. Couple of images used for 3D digitalizing of the top side of surface

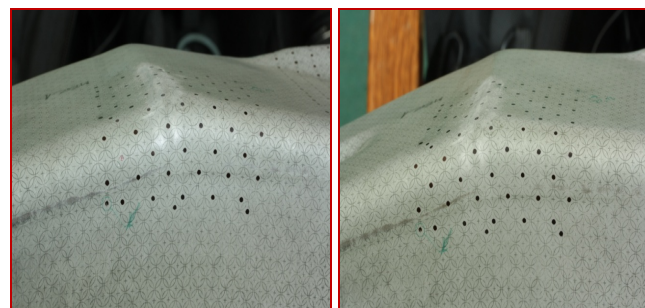


Figure 5. Couple of images used for 3D digitalizing of the side of surface

In the Dense Surface Modeling module a point cloud is generated on the principle of image correlation. Based on the calibration information the influence of image distortion caused by camera

lens has been eliminated and so that the photographs have been idealized before the final processing by means of Idealize Project module. The images have been resampled and the black trimmed regions have been obtained on each photograph [6]. By the function Trim boundary, the region of image correlation modeling could be selected and before calculation we could option these parametres:

- ❑ images couple,
- ❑ sampling rate,
- ❑ depth range,
- ❑ sub-pixel,
- ❑ super-sampling factor,
- ❑ matching region-radius,
- ❑ texture type.

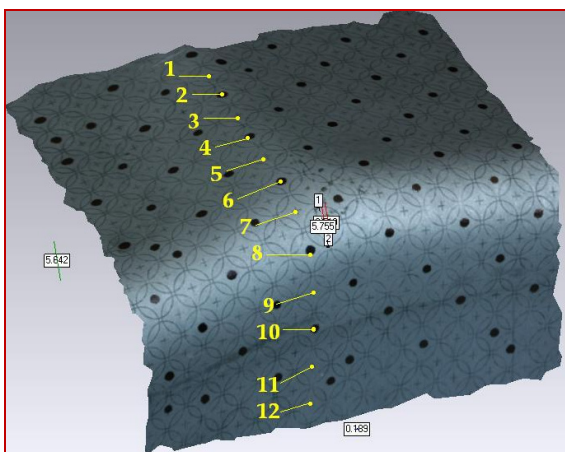


Figure 6. 3D visualization of generated part surface

The Figure 6 shows the final textured part surface. The regions where the software could not find homologous pixels by image correlation because of reflections from glossy metal surface have been trimmed. The surface is exportable into many formats that are widely used by current CAD software. After determination of the scale model, it is possible to measure the deformation network elements [2].

EXPERIMENTAL RESULTS

Direct measurement of the sheet metal thickness of parts is limited by the complexity of their geometry, so the true strain in the thickness direction in different locations can be determined indirectly based on planar strains from the equation [7]:

$$\varphi_2 = -(\varphi_1 + \varphi_3) \tag{1}$$

where: φ_1 – major strain, φ_2 – minor strain, φ_3 – strain in the thickness direction

The value of sheet metal thickness can be determined from the equation:

$$\varphi_2 = \frac{\ln s_1}{s_0} \tag{4.2}$$

where: s_1 – thickness after drawing process; s_0 – initial sheet metal thickness

Table 1. The value of true strains and thicknesses in different locations

Location	PhotoModeler Scanner			
	φ_1 [-]	φ_2 [-]	φ_3 [-]	s [mm]
1	0,102	0,024	-0,126	1,323
2	0,108	0,028	-0,136	1,309
3	0,122	0,032	-0,153	1,287
4	0,132	0,029	-0,161	1,276
5	0,135	0,029	-0,164	1,273
6	0,135	0,047	-0,181	1,251
7	0,129	0,071	-0,200	1,228
8	0,111	0,098	-0,210	1,216
9	0,141	0,069	-0,210	1,216
10	0,065	0,023	-0,088	1,373
11	0,055	-0,002	-0,053	1,423
12	0,105	-0,011	-0,094	1,366

Location	DYNAFORM			
	φ_1 [-]	φ_2 [-]	φ_3 [-]	s [mm]
1	0,071	0,021	-0,092	1,368
2	0,082	0,025	-0,107	1,348
3	0,093	0,029	-0,122	1,328
4	0,109	0,035	-0,144	1,299
5	0,131	0,044	-0,175	1,260
6	0,150	0,057	-0,207	1,220
7	0,147	0,081	-0,228	1,194
8	0,116	0,082	-0,198	1,231
9	0,082	0,046	-0,127	1,321
10	0,059	0,030	-0,089	1,372
11	0,042	0,022	-0,064	1,406
12	0,052	0,021	-0,072	1,395

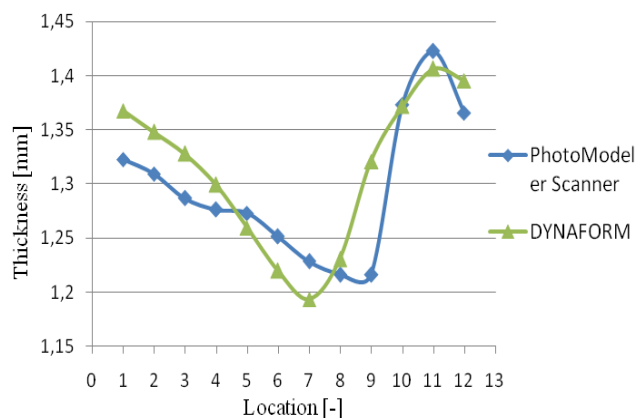


Figure 7. Comparison of dependences of thickness on location in PhotoModeler Scanner and DYNAFORM software

Table 1 contains the values of true strains and thicknesses in different locations evaluated by the PhotoModeler Scanner and DYNAFORM software. These results are depicted and compared in Figure 7 by the dependence of thickness on location [1].

CONCLUSION

While direct thickness measurement of sheet metal parts is limited by the complexity of their geometry, strain in the thickness direction can be evaluated also indirectly using stereo-photogrammetry. It allows us to specify the strain also on general surfaces, which are digitized and so the measurement is made only on the 3D model. The simulation shows the possible location of the critical thickness reduction, and therefore it is necessary to check the dependence of the thickness on location. Stereo-photogrammetric measurement results confirm location of the critical thickness reduction, but without the risk of cracking. The dependence of the simulated thickness is very similar to results of stereo-photogrammetry, and thus confirmed the accuracy of the chosen approach.

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