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DEVELOPMENT AND USE OF SOFTWARE FOR MEASUREMENT OF DEFORMATION IN EXTRUDED PRODUCT.

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Abstract. *Extrusion is the process by which a block of metal is reduced in cross-section by forcing it to flow through a die orifice under high pressure. It is accepted practice to classify extrusion operation according to the direction relationships between the material flow and the punch movement. The basic extrusion operations are called backward-extrusion, forward-extrusion, radial-extrusion. In a back extrusion process, a punch penetrates into the sample, and the material is forced to shear heterogeneously at localized regions connected to the penetration channel. This work presents the development and use of software for measuring deformations in the backward extrusion process. Work pieces were made of steel ABNT 1010 and marked with a circular grid pattern. The deformed grid pattern was measured and compared with its original size, and strains were computed. The strain measurement was performed manually or automatically. The manual measurement used a profile projector. The measurement was made automatically by means of a software image analysis with calibration based on calculation of the transformation matrix between the coordinate system associated to the image plane, acquired by the vision camera, and with the world reference coordinate system. Finally, the results were compared and automatic measurement uncertainty was known.*

Keywords: *Backward extrusion, Strain analysis, Visioplasticity, Computer vision, Image processing.*

1. INTRODUCTION

The metal forming is a process widely used in industries due to the minimal waste, dimensional accuracy and adjusted mechanical properties. It presents economic advantages over machining such as: material savings, productivity and operating cost.

Among some of forming processes there are cold extrusion, drawing and pressing (Zhang et al., 2006). Extrusion is the process by which a block of material is reduced in cross section by forcing it through a hole under high pressure. The cold extrusion process (direct and indirect), it is possible for many materials, relating with the cold forming of wires and bars for production of parts such as shafts, pins, screws and terminals for the automotive industry being an important alternative of commercial process. (DIETER, 1976).

The steels most commonly used in cold forming are low carbon steels such as ABNT 1010, replacing the machined steel (ABNT 12L14 and DIN 9SMn36) and low-alloy heat-treated (ABNT 10B22).

The mechanical conformation changes the mechanical properties of the material. There is often a change of mechanical strength due to cold deformation. The magnitude of this change depends not only on the initial and final dimensions of the product, but also the deformation path at which the product was subjected. After some initial hardening, there is the possibility that more deformations may soften the material. The improvement of cold forming technique involves some difficulties because of the number of parameters that constitute the process. Preferred process parameters include fewer forming steps, less abrasive tools, less lubrication and the stabilization of the process with minimum waste as possible. The cold forming can make use of experimental tests as a method of development, bringing with it high costs.

Computer modeling of each stage of the forming process by finite element method can make the process sequence more quickly and efficiently, decreasing the use of conventional methods of "trial and error" (CHO et al., 2003). The existence of a database obtained experimentally and in combination with a specific simulation "software" enhances the value of the simulation, and, more importantly, the speed of the process development.

Several finite element software packages are commercially available for the conformation analysis. However, each program may provide a different result for the same case. It is very important to relate the results obtained through finite elements with the experimental results. The measurement of the deformation is necessary for comparison.

The main deformation measurement methods are marking mesh, strain gages, mechanical and optical strain gages, and manual measurement. Mesh marking or visioplasticity is one of the most widely used methods of deformation analysis in the process of metal forming because of the relative simplicity All mesh marking methods did not alter the intrinsic properties of the material and are widely used in different experiments (OZTURK et al ., 2009).

Mesh marking is the process of printing patterns of lines in the area of interest of the sample. The knit pattern used must be precise in order to prevent the spread of errors of deformation. Different techniques are used for mesh measurement. These include both manual and automated methods of measurement. The development of automated measuring systems is important, because the manual measurement techniques are slow and need experienced operators to avoid mistakes (CARASUSÁN, 2003)

2. EXPERIMENTAL PROCEDURE

The objective is to automate the measurement system introduced by Silva (2012). To establish the stages of the work we tried to combine the manual measurement and automatic measurement of samples with and without deformation obtained by the indirect extrusion process.

The raw material used is steel ABNT 1010 Cold Drawn in the form of bar diameter of 14 mm. Chemical analysis of steel ABNT1010 was obtained in optical emission spectrometer and Leco. To eliminate the influence of the deformation path, a rod was annealed, that is, austenitized at a temperature of 900 ° C for one hour in a salt bath and cooled to a temperature of 400 ° C, then cooled to room temperature in air. Samples were taken in the transverse direction of the Cold Drawn bar and of the annealed bar for metallographic analysis.

The visioplasticity method was used in order to calculate the deformations in the extruded product. The method was divided into three stages with production and marking of specimens for extrusion, extrusion of these specimens in hydraulic press and measurement and calculation of the mesh deformation.

For manual measurement of markings on specimens we used a profile projector Mitutoyo, model PH-A14 -172 810. Initially, the device was used to check the diameters of the circles on the surface of the undeformed test piece. Being the diameter on axis “x” and the diameter on axis “y”. The coordinate axes have been set using a matrix system, that is represented by axis line “x” in the range of 1 to 19 and column represented by axis “y” in the range 1 to 9. The Figure 1 shows the layout of circles on the surface of the body without deformation test.

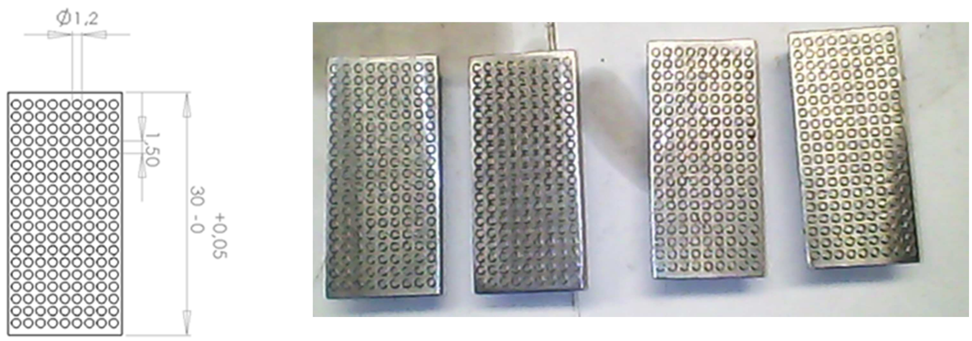


Figure 1. Position of circles on test body without deformation

After measuring the recorded circles in non-deformed specimen was determined the arithmetic mean of 342 measurements made Equation (1).

$$\overline{D} = \left(\sum Di\right)/n^{*} \tag{1}$$

Where $\overline{D}$ is the average of the measurements, Di the value of each measurement and n^{*} is the number of measurements made.

The standard deviation of measurements $S(Di)$ and averaging the measurements $S(\bar{D})$ was determined by the equations (2) and (3).

$$S(Di) = \left[\sum(Di - \bar{D})^2/(n^* - 1)^{1/2}\right] \quad (2)$$

$$S(\bar{D}) = S(Di)/\sqrt{n^*} \quad (3)$$

The expression of measurement uncertainty Type A, determined from n^* measurements to γ degrees of liberty and confidence level (p) = 95% was obtained by equation (4).

$$I(U_A) = I(\bar{D}) = \pm * t_{95\%}(\gamma) * S(\bar{D}) \quad (4)$$

which $I(U_A)$ is the measurement uncertainty, is the value of the coefficient "Student t".

Figure 2 (a) and (b) shows the initial circle with its size and sense used in the X and Y axes for the measurement and some shapes of circles after extrusion

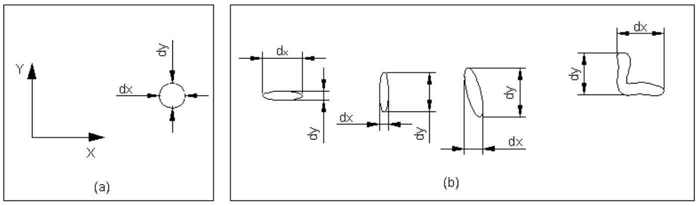


Figure 2. (a) Direction of the axes, shape and dimensions of the original circle before the extrusion, (b) dimensions and format of the circles after extrusion.

After the deformation of the specimens, some markings were lost in the punch penetration regions and in the vicinity of angular contact. The deformations of the circles were studied in three different regions (A, B and C) throughout the test body extension. (Figure 3(b)). For automatic measurement were captured calibration pattern images of the mesh without deformation and mesh with deformation. Image processing algorithms were used to calculate the transformation matrix (system calibration) and measurement of diameters and circles. The image acquisition system used consists of the sensor element for image capture with a CCD camera, AxioCam ERc5s, Carl Zeiss MicroImaging GmbH manufacturing with a resolution equal to 2560 by 1920 pixels COMPUTAR® lenses, MLH-10X model with manual adjustment focal length, iris and focus Fig. 3(a).

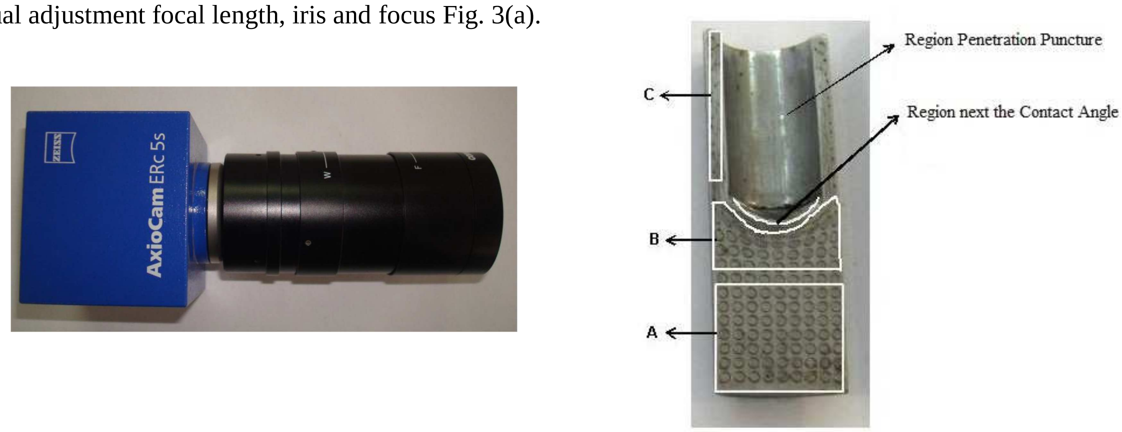


Figure 3. (a) Lens assembly coupled to the camera AxioCam ERc5s, and (b) regions studied (A, B, C)

The camera was attached to a wooden base on which there was a diffuse illumination composed of 6 electronic lamps of 11 W positioned around the camera. On a structure of welded steel tubes was placed a glass sheet and on top of which the object to be captured. All acquisition system is set, as shown in Fig. 4.

It was proposed a calibration procedure for the camera based on the calculation of the transformation matrix between the coordinate reference systems of the image plane, originated from the camera image capture, and the coordinate system of the world reference. For this, digital imaging processing techniques were used. After running the calibration process, points acquired by the vision system are converted to the coordinate system of the world through the calculated transformation. This makes it possible to remove information from images.

The camera calibration was performed by observing the calibration standard, brand Edmund Optics.

Figure 4. Structure for image acquisition (a) Front view (b) Top (c) Calibration standard

3. RESULTS AND DISCUSSION

The comparison between the results obtained in manual and automatic measurements for the samples not deformed is made through the uncertainty type A. Tables 1 and 2 present the analysis of statistical data measurements to the drawn specimen toward X.

Table 1- Statistic Data of Drawn Material toward X (Manual measurement)

Sample size	Average $\bar{D}$	Standard desviation of measures $\overline{(S(D_i))}$	Standard desviation of average $(S(\bar{D}))$	Coefficient Student $t_{99\%}$	Type A Uncertainty evaluation (I(A))
162	0,981mm	0,021mm	$1{,}722\times10^{-3}$ mm	63,66	±0,109 mm

Table 2- Statistic Data of Drawn Material toward X(Automatic measurement)

Sample size	Average $\bar{D}$	Standard desviation of measures $\overline{(S(D_i))}$	Standard desviation of average $(S(\bar{D}))$	Coefficient Student $t_{99\%}$	Type A Uncertainty evaluation (I(A))
161	1,002 mm	0,013 mm	$1{,}087\times10^{-3}$ mm	63,66	±0,069 mm

Uncertainty type A for the manual and automatic measurement of the drawn specimen was equal to ± 0.109 mm ± 0.069 mm, respectively. That is a difference of 57%. The Tables 3 and 4 show the statistical data measurements for the drawn specimen toward Y

Table 3- Statistic Data of Drawn Material toward Y (Manual measurement)

Sample size	Average $\bar{D}$	Standard desviation of measures $\overline{(S(D_i))}$	Standard desviation of average $(S(\bar{D}))$	Coefficient Student $t_{99\%}$	Type A Uncertainty evaluation (I(A))

162	1,000 mm	0,020 mm	1,605x10^{-3} mm	63,66	±0,102 mm

Table 4- Statistic Data of Drawn Material toward Y (Automatic measurement)

Sample size	Average $\bar{D}$	Standard desviation of measures $\left(\overline{S(D\iota)}\right)$	Standard desviation of average $\left(S(\bar{D})\right)$	Coefficient Student $t_{99\%}$	Type A Uncertainty evaluation (I(A))
161	1,027 mm	0,017 mm	1,399x10^{-3} mm	63,66	±0,089 mm

The Figure 5 shows the Region B of the drawn specimen highlighted and identifying markings to show in the chart. The measurements for the two drawn specimens are shown in Fig. 6.

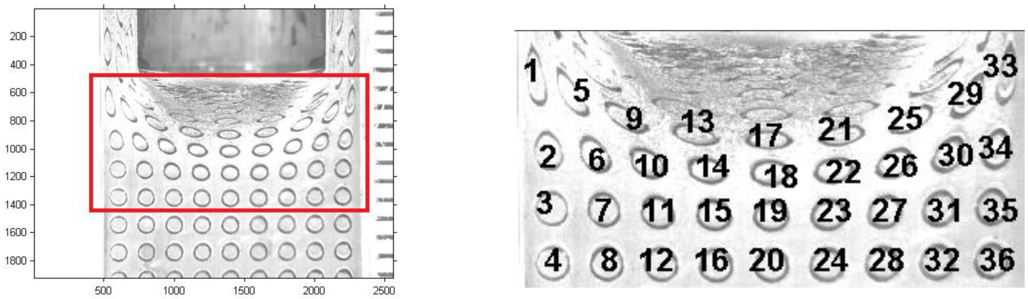
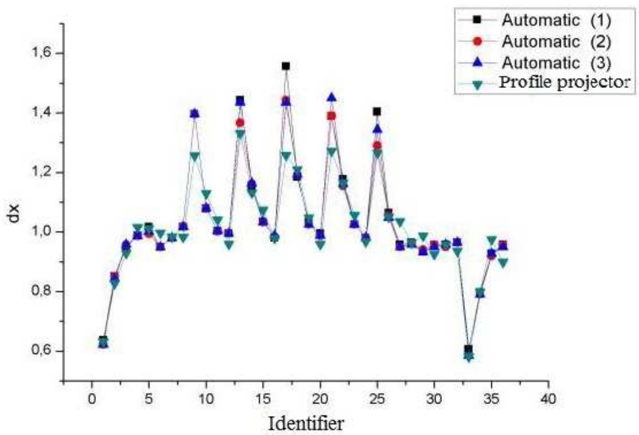
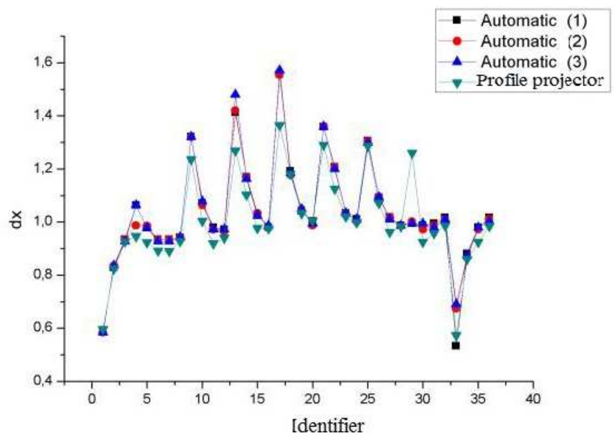


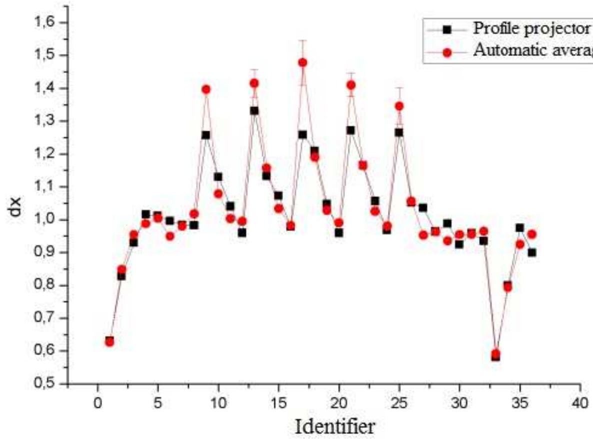
Figure 5. Region B of the drawn specimen

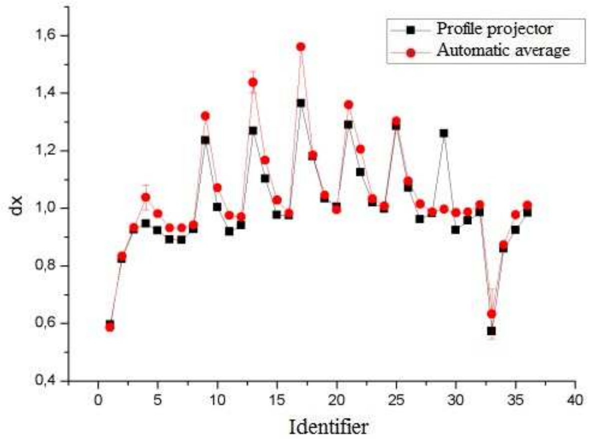


(a)



(b)





(c) (d)

Figure 6. The measurements of the two drawn specimens

In Figure 6 (c) the identifiers 13, 17, 21 and 25 show standard deviations of 0.041, 0.067, 0.034 and 0.056, respectively. These identifiers are part of the region just below the angle of the punch contact, low contrast between markings and the specimen have increased the standard deviations.

The Figures 7 (a) and (b) respectively presents the deformations calculated toward X and toward Y to the drawn specimen 1. The deformations in X for drawn material 1 in the Region A were near 0 in the Region B obtained the maximum value of +0.4 and Region C - 0.8. The markings (row 1, column 1) and (line 19, column 9) were lost during the measurement process.

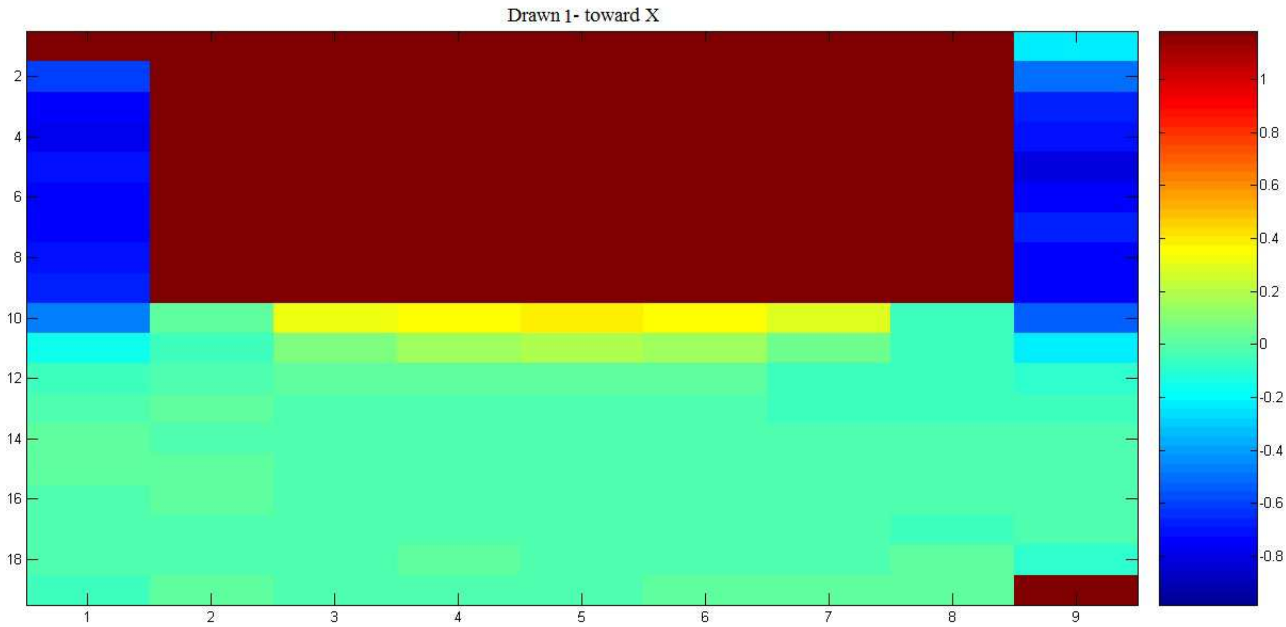


Figure 7 (a). Deformations calculated toward X

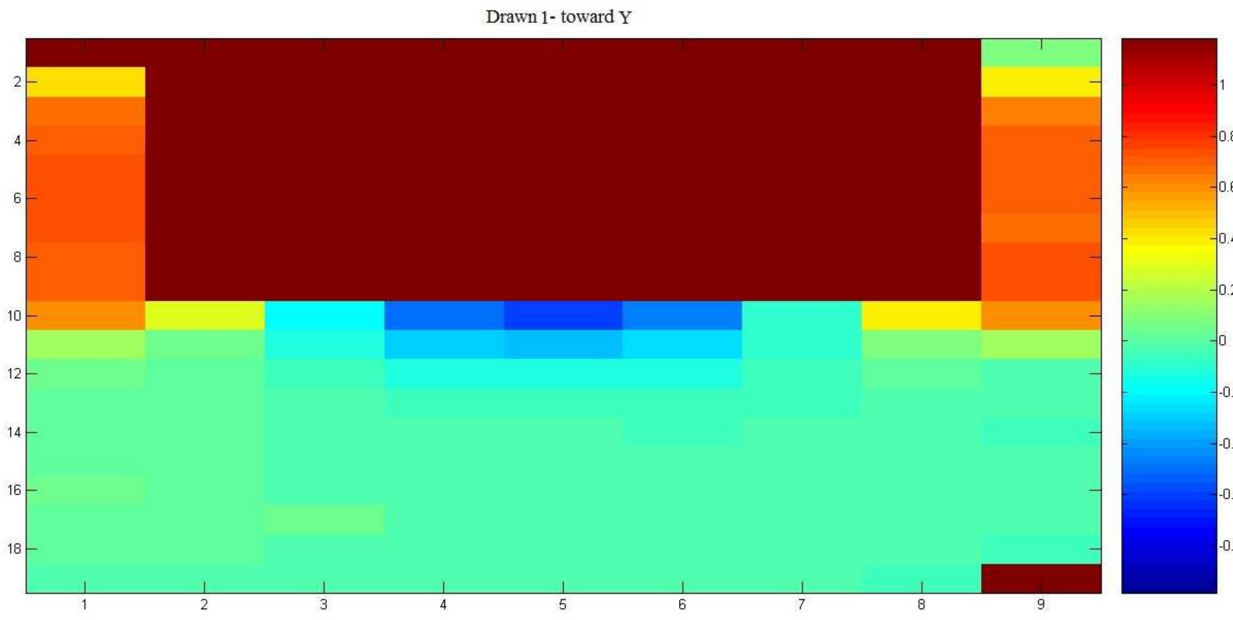


Figure 7 (b). Deformations calculated toward Y

The implemented algorithm is efficient for images where the acquisition phase was efficient. Good results were obtained for all analyzed regions. However, it was sensitive to noises near the edges of the markings and the lack of contrast between markings and the specimen.

The comparison between the manual and automatic method for the test piece without deforming was favorable to the automatic measurement for all the measurements, which is explained by the lack of repeatability of manual measurement when compared to the automatic measurement.

The comparison between manual and automatic method for the specimen with deformation showed that the supervision of the binarization obtained by the algorithm to verify possible errors is required. Measure the mesh more than once does not require a great effort and the standard deviations found between measurements serve to identify possible errors.

4. ACKNOWLEDGEMENTS

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6. RESPONSIBILITY NOTICE

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