Survey of the geometric characteristics of a test specimen before punch sharpenings

Miglena Paneva[1], Peter Panev [1], Nikolay Stoimenov[1*]
Institute of Information and Communication Technologies, Bulgarian Academy of Science, Sofia, Bulgaria[1]
*nikistoimenow@gmail.com

Abstract: *This article analyses the widths and thicknesses of the test specimen after operating the punch before sharpening the guillotine blades. The principle of operation of a 3D computer tomograph with an accuracy of 3µm is considered. The analysis will be performed in two ways: by using a micrometer and a caliper and by using a 3D computed tomography for determining the width and thickness*
Keywords*: PUNCH, 3D TOMOGRAPHY, WIDTH, THICKNESS, TEST SPECIMEN*

1. Introduction

Mechanical tests of materials in different structural states can be performed in the laboratory under strictly defined conditions to obtain specific characteristics of the mechanical properties. The force applied to the test piece causes it to deform, for example in tension. In the tensile test, the test specimens are tested, the shape of which must ensure a homogeneous uniaxial tensile state of tension in the working part during the test. When testing a steel sheet, the test body has a rectangular cross-section. For the preparation of the sample and the correct testing of the mechanical parameters, its linear dimensions (width and thickness) must meet a certain standard. The blades need to be observed often aiming not to wear. With worn blades, there is a loss of uniformity over the entire area. After the prolonged operation of the punch for cutting the test body, a notch is noticed on its edges and crushing on both sides of its working area. These defects are reflected in the further analysis of the tube - tensile strength testing.

Length is a physical quantity that characterizes the linear dimension of an object, usually in the directions of the largest size. The length of an object is the distance between its extreme points, in other words, the linear size along its length, measured from end to end. Width is a linear dimension, which is the distance between the two sides of an object, measured perpendicular to the length. In physics and engineering, length and width are denoted by l or L, and thickness by δ [1].

Length and width are one-dimensional measures, while the area is two-dimensional (product of length by width. The unit of measurement of length is in SI, meter-m, and thickness is mm.

The present work aims to compare the linear values of a test body for testing the tensile strength - width and thickness by measuring with a caliper and micrometer, as well as a 3D industrial computed tomography. The test body was prepared with a press and a punch, which was operated for a long time. The accuracy of the values of these quantities is of great importance, as they participate in the calculation of the tensile strength parameters. A more detailed analysis will be performed by scanning the sample using a 3D computed tomography, due to the greater accuracy of the device - visualization of the defects themselves from different angles, as well as taking precise and accurate data on width and thickness parameters.

2. Used Equipment

The traditional measuring instruments for measuring width and thickness are a micrometer (Figure 1) and a caliper (Figure 2).

The width and thickness of the test body (Fig. 3) were measured using an electronic caliper with a range: 0-150 mm / 0-6 ″ and an accuracy of 0.01 mm, and a mechanical micrometer with a range of 0-25 mm and an accuracy of 0.01 mm.

Fig. 1 *Micrometer.*

Fig. 2 *Electronic caliper INSIZE [2]*

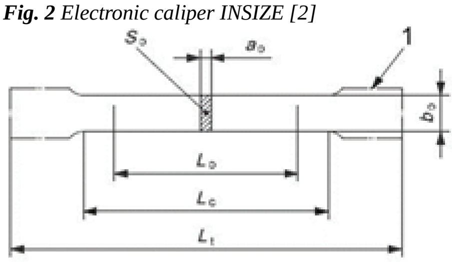


Fig. 3 *Model of punched test body with a rectangular cross-section [3].*

Where:

a_0- thickness of the test body, mm;
b_0- width of the original thickness of a flat test specimen, mm;
S_0- section of the test specimen, mm;
L_c- parallel length, mm;
L_0- original gauge length, mm;
L_t- total length of the test piece, mm.

The dimensions of the test piece are determined according to the standard BDS EN ISO 6892-1 [3] with a width and tolerance of 20 ± 1 mm.

Another method for measuring the linear characteristics is through 3D computed tomography, which allows for non-destructive testing with high accuracy in the study of the internal and external structure of objects. Computed tomography provides additional observations of the density of materials and their microstructure. The application of industrial 3D computed tomography proves to be effective in obtaining information about the internal characteristics of the examined object.

The test specimens must comply with the standard BDS EN ISO 6892-1 [3], for specimen preparation and BDS EN 10025 [4], BDS EN 10111: 2009 [5], BDS EN 10130: 2006 [6], BDS EN 10139: 1997 [7] for technical conditions of delivery of the material and tolerances for shape and dimensions according to standard BDS EN 10051: 2011 [8].

3. Principle of Operation of 3D Computed Tomography

Another The Nikon XT H 225 3D industrial computed tomography (Fig. 4) with an accuracy of 3µm, was used for the analysis of the linear values of width and thickness [9, 10, 11].

Computed tomography (CT) is a non-destructive method that provides high accuracy and can examine the internal and external dimensions of the provided samples (samples, blanks). Besides, it provides an additional view of the internal structure of the microstructure of the object under study.

It works on the following principle: the sample is placed on a rotating table between the X-ray source and the detector; positioning the sample closer to the X-ray increases the accuracy of the data obtained; an X-ray is generated and transmitted through the sample; the digital detector captures an image that consists of multiple shades of gray based on a shadow caused by the absorption of X-rays as they pass through the scanned sample; thicker or denser materials, such as iron, copper, and lead, resulting in darker areas than thin or light materials such as plastics, paper, or air.

The CT is used as an X-ray source with microfocus, large inspection volume, high image resolution (maximum detector capacity is 1900x1500 with an active area of 467 cm2), fast 3D computer reconstruction, the cross-section of the X-Ray beam is below 3 μm, has five-axis positioning system. The maximum allowable weight that can be placed on the turntable is 15 kg, and the maximum dimensions of the object are 15x15x15 cm.

The obtained results are presented in the 3D volume, which consists of a series of consecutive 2D X-ray images, which are captured while the object is rotated 360º (Fig. 5). After scanning, the resulting images are reconstructed by the CT scanner software to generate a 3D image of the scanned object. Also, the reconstructed object contains all the information about the microstructure of the surfaces and the interior. Monitoring by computer tomography software on any surface is possible.

Fig. 4 *3D industrial computed tomography Nikon XT H 225.*

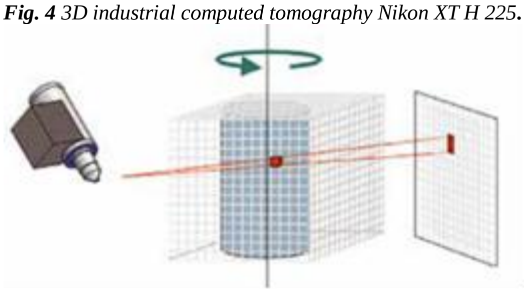


Fig. 5 *Outline of X-ray technology [10]*

4. Methodology for Scanning and Examination of Metal Samples

To perform a 3D CT scan of the provided metal samples, it is necessary to perform the following sequence of actions:

1. Introduction to the need for 3D CT scanning of metal samples.
2. Placing the metal sample in a base suitable for mounting in the computed tomography.
3. Determining the position of the metal sample relative to the X-Ray beam.
4. Set the required beam force.
5. Determining the required number of screenings (from 2000 to 8000)
6. Preparation and selection of necessary parameters for 3D reconstruction.
7. Analysis of the obtained images.
8. Determination of width and thickness.
9. Analysis of the obtained results.

The implementation and determination of the set tasks are personal for each metal sample. The above tasks are the key ones, which follow the expansion of some methods and the creation of new ones.

The metal sample was subjected to 3D X-ray scanning with an industrial computed tomography. The test specimen needs to be fixed. It is currently fixed in a porous material with a lower density. This avoids its occurrence during scanning. The porous material is attached to a specially designed stand for placement in the scanning area. It is envisaged to create a specialized method of fixing the samples to reduce the time for this operation. The objects are placed as close as possible to the X-ray beam to achieve a more detailed picture and increased accuracy. The required beam power and the number of projections are determined. The software of the manufacturer is used to read the values of thickness and width.

5. Experimental Results

An analysis of the linear dimensions of 10 pcs. test body with same parameters was made in two ways: by micrometer and caliper, as well as by 3D computed tomography as the test body was measured in 3 zones, each zone is measured in 3 points: top (at one site near the edges), middle (3 points are made successively from left to the right of the working area), and bottom (the opposite side of the test piece near the edges). The test piece must correspond to a thickness of 1,0 ±0,15 mm and a width of 20,00 ± 1 mm. The experimental results of one of the specimens of the measurements are shown in Tables 1 and 2.

Table 1: *Test specimen values measured with a micrometer and a caliper*

Position of the sample measurement		**Width, mm (b)**	**Thickness, mm (a)**
Top	1	20,00	0,96
	2	20,01	0,96
	3	19,99	0,95
	∆	**20,00**	**0,96**
Middle	1	20,01	0,97
	2	20,02	0,96
	3	20,02	0,96
	∆	**20,02**	**0,96**
Bottom	1	20,01	0,95
	2	20,00	0,95
	3	20,00	0,96
	∆	**20,00**	**0,95**

Table 2: *Test specimen values measured with a 3D computed tomography.*

Position of the sample measurement		Width, mm (δ)	Thickness, mm (t)
Top	1	20,06	1,02
	2	20,06	1,03
	3	20,03	1,02
	∆	**20,05**	**1,02**
Middle	1	20,08	0,91
	2	20,09	1,03
	3	20,09	0,86
	∆	**20,09**	**0,93**
Bottom	1	20,09	1,02
	2	20,09	1,01
	3	20,07	1,01
	∆	**20,08**	**1,01**

When bringing the arithmetic mean of the measured widths and thicknesses of the test body, the following parameters will be obtained:

- Test specimen values measured with a micrometer and a caliper

a= 0.96 mm; b= 20.01 mm

- Test specimen values measured with a 3D computed tomography

a= 0.99 mm; b = 20.07 mm

If we do a simulation of tensile strength testing at force F= 6.5 kN it will be calculated by formula Rm% = x100 and cross-section area S= a.b, we will obtain the following values:

Table 3: *Simulation of tensile strength calculation*

Measured with:	S, mm	Rm, Mpa
micrometer and caliper	19.2096	338
3D CT	19.8693	327

The results show that the values of the samples measured with a micrometer and a caliper differ from those measured with a 3D computed tomography.
Figures 6 and 7 show images from a 3D computed tomography of the scanned test specimens of thickness and width.

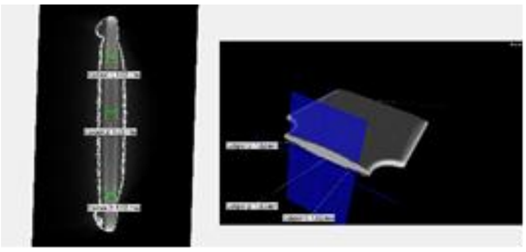


Fig. 6 *Measured thickness with a 3D CT.*

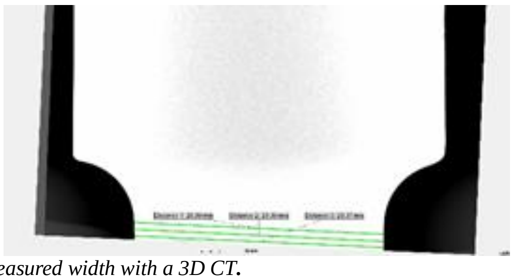


Fig. 7 *Measured width with a 3D CT.*

When cutting the test specimen by punching, during prolonged operation, the blades wear out. This phenomenon is observed in fig. 8. The height of the observed defect (sharp edge on the surface) was measured using a 3D CT. The size of the resulting defect is 0.18 mm. After the analysis by the computed tomography it is seen that on both sides of the test body, the thickness is significantly less than the real one, which is a consequence of the worn blades during punching fig. 9 a) and b).

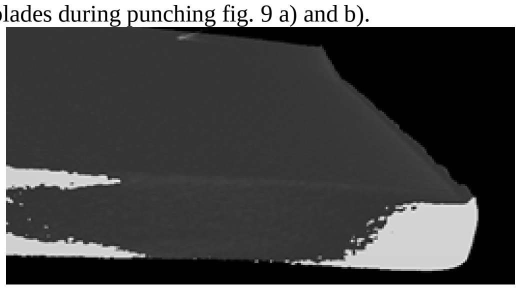
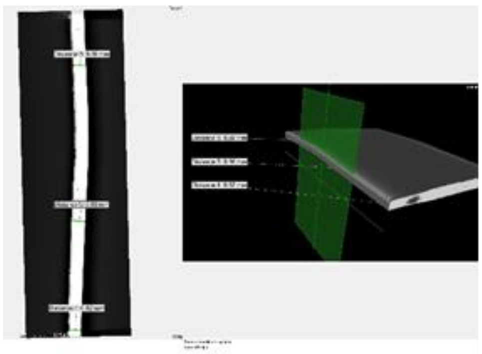


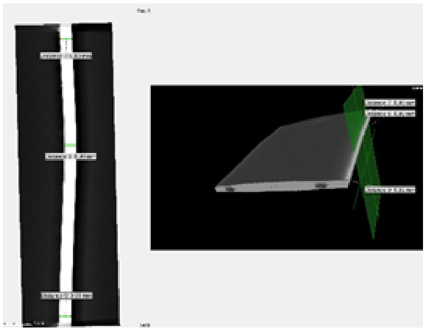
Fig. 8 *3D Scanned test body with a defect after punching.*

6. Conclusion

As a result of the developing world, the analysis equipment is being modernized. Therefore, it was chosen to compare the measurement of linear quantities using standard measuring instruments - caliper and micrometer and the modernized 3D computed tomography, which provides more detailed information about what problems may acquire in the preparation of a test body for tensile strength testing. The analyses show that despite the discrepancy in the measurement by the two methods, the dimensions of the sample meet the ISO standards for width and thickness. However, a simulation to calculate the tensile strength with the values measured with a micrometer and caliper and with a 3D computed tomograph shows that different values are obtained. If you need to calculate accurate results, the error of incorrect measurement would create a problem. But the analysis with the 3D computed tomography shows detailed defects after cutting off the test body after punching. The thickness on both sides of the sample is crushed from 1.02 mm average thickness in the middle to 0.90 mm. The other defect that is visualized is the appearance of an edge also due to the worn blades of the punch.



a)



b)

***Fig. 9** 3D Scanned test body – middle - a) left, b) right.*

Acknowledgment

The paper was supported by the Bulgarian Academy of Sciences, a program for supporting young scientists and doctoral students, and by the Bulgarian Ministry of Education and Science under the National Research Program "Young scientists and postdoctoral students" approved by DCM # 577 /17.08.2018.

References

[1] Wikipedia, last visited June 2020
https://bg.wikipedia.org/wiki/%D0%94%D1%8A%D0%BB%D0%B6%D0%B8%D0%BD%D0%B0

[2] Polymeta-S, last visited June 2020
https://www.polymeta.bg/shop/instrumenti-i-okomplektovka-za-metalorezheshti-mashini/insize-2/shubleri/elektronen-shubler?v=461b1990fe86

[3] Standard BDS_EN_ISO_6892-1

[4] BDS EN 10025

[5] BDS EN 10111: 2009

[6] BDS EN 10130: 2006

[7] BDS EN 10139: 1997

[8] BDS EN 10051: 2011

[9] Kazakova S., Kamenova I., Klochkov L., Stoimenov N., Popov B., Sokolov B., Application of 3D Industrial Tomography In Dental Medicine., International Scientific Conference "Industry 4.0", December 2017, Borovets, Bulgaria, pp. 187-190, ISSN: 2535-0021, Publisher: Scientific Technical Union of Mechanical Engineering Industry – 4.0

[10] Nikon Metrology Brochure –
http://www.nikonmetrology.com/en_EU/Products/X-ray-and-CT-Inspection/Computed-Tomography/XT-H-225-ST-Industrial-CT Scanning/

[11] Ruzic J., Stoimenov N., Advanced copper matrix composites, 2016 "Prof. Marin Drinov" Publishing house of Bulgarian Academy of Sciences, ISBN 978-954-322-859