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APPLICATION OF OPTICAL 3D SCANNING IN THE EVALUATION OF DUCTILITY PARAMETERS OBTAINED FROM TENSILE TESTS

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1. Introduction

Tensile testing is one of the most widely used methods for determining the mechanical properties of engineering materials. Besides strength-related parameters, ductility indicators such as elongation at fracture and reduction of area provide important information regarding deformation and fracture behavior.

Conventionally, these parameters are determined through direct measurements performed after specimen failure. However, such procedures may be challenging for materials exhibiting limited plastic deformation and can be influenced by measurement uncertainties. Recent developments in optical metrology have enabled the application of non-contact measurement techniques for geometric characterization of test specimens. Optical 3D scanning systems provide accurate digital representations of specimen geometry before and after testing, allowing precise evaluation of dimensional changes caused by deformation.

This study aims to evaluate the applicability of optical 3D scanning for determining elongation at fracture and reduction of area in tensile testing specimens and to compare the obtained results with conventional extensometer measurements.

2. Experimental procedure

Two metallic materials with different fracture characteristics were investigated: structural steel S355J2+N and hot-work tool steel X37CrMoV5-1.

Before tensile testing, all specimens were scanned using a GOM ATOS optical measurement system, Fig 1. The acquired scans were converted into STL models and compared with the corresponding CAD geometry to verify dimensional

accuracy and determine the initial specimen dimensions.



Fig. 1. GOM Atos optical measuring system measuring specimen tested for tension

Tensile tests were performed using a SHIMADZU servo-hydraulic testing machine equipped with a Mess & Feinwerktechnik MFA25 extensometer, Fig 2.



Fig. 2. Elongation measurement using extensometer

After the fracture, the specimen halves were carefully reassembled and rescanned using the same optical procedure. The resulting STL models were used to determine the final gauge length and

minimum cross-sectional area, which served as the basis for calculating elongation at fracture and reduction of area.

3. Optical Measurement

The optical measurement methodology is based on comparing specimen geometries acquired before and after tensile testing.

Reduction of area Z was calculated according to:

$$Z = \frac{A_0 - A_f}{A_0} \cdot 100[\%] \quad (1)$$

where (A_0) is the initial cross-sectional area and (A_f) is the minimum cross-sectional area measured after fracture.

For the structural steel specimen (S355J2+N) and hot-work steel specimen (X37CrMoV5-1), the following values Z were obtained by optical analysis and shown in Table 1.

Table 1. Reduction of area Z values

Material	A_0 [mm ²]	A_f [mm ²]	Z [%]
S355JR	50.08	17.50	65.06
X37CrMoV5-1	33.16	26.41	20.36

The structural steel specimen exhibited pronounced necking before fracture, indicating significant plastic deformation and high ductility. This observation was confirmed by the measured reduction of area of 65.06%, which is consistent with the expected behavior of S355J2+N structural steel. In contrast, the X37CrMoV5-1 specimen showed no significant necking before fracture. The measured reduction of area was only 20.36%, indicating substantially lower ductility and a more brittle fracture behavior.

Elongation at fracture was determined by comparing the initial gauge length L_0 and the final gauge length L_f :

$$\delta = \frac{\Delta L}{L_0} \cdot 100[\%] \quad (2)$$

The optical measurements were performed using a gauge length of 75 mm. To enable direct comparison with extensometer measurements obtained over a gauge length of 50 mm, elongation values were converted according to BS EN ISO 2566-1 using the Oliver conversion relationship:

$$\delta_2 = \delta_1 \left(\frac{K_1}{K_2} \right)^{0.4} ; K_i = \frac{L_i}{\sqrt{A_i}} \quad (3)$$

where K_1 and K_2 are the proportional ratios of the tested specimens and L_1 and L_2 are the respective gauge lengths.

The corresponding elongations for a defined gauge length were obtained and shown in Table 2.

Table 2. The elongation at fracture values

Measuring device	The elongation at fracture [%]	
	- over 50 mm gauge length	- over 75 mm gauge length
Mess & Feinwerktechnik MFA25	22.32	18.98
Gom Atos	22.08	18.77

The difference between the converted optical measurement and the extensometer result was approximately 1%, showing excellent agreement between the two measurement techniques.

4. Conclusions

The optical measurement system accurately captured specimen geometry before and after tensile testing, enabling the reliable determination of ductility-related parameters. The measured reduction of area clearly distinguished the ductile behavior of S355J2+N steel from the lower ductility of X37CrMoV5-1 tool steel. Comparison with extensometer measurements showed excellent agreement, with deviations of approximately 1% after conversion to a common gauge length. These results confirm that optical 3D scanning is a reliable method for evaluating elongation at fracture and reduction of area.

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