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EXPERIMENTAL AND 3D VISUALISATION-BASED ANALYSIS OF TENSILE BEHAVIOUR OF DC01 STEEL UNDER VARIABLE TESTING SPEEDS

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Abstract: This study presents a visualization-driven approach for analysing the tensile behaviour of DC01 sheet steel under varying testing speeds. Tensile tests were conducted at crosshead speeds of 2, 5, and 10 mm/min, and the corresponding stress–strain responses were used to determine key mechanical properties, including ultimate tensile strength and elongation. Particular emphasis is placed on the application of three-dimensional (3D) surface visualization, which enables simultaneous analysis of the interaction between testing speed and elongation. The developed surface provides enhanced insight into strain-rate sensitivity and reveals interaction effects that cannot be clearly identified using conventional two-dimensional analysis. The results demonstrate a gradual increase in tensile strength with increasing testing speed, accompanied by a slight reduction in elongation, indicating moderate strain-rate strengthening behaviour. In addition to visualization, a regression-based modelling approach was applied as a complementary tool for quantitative approximation of the observed trends. The findings highlight the importance of multi-parameter visualization for improved interpretation of tensile behaviour and provide a useful framework for material characterization and engineering applications involving variable deformation rates.

Keywords: DC01 steel, tensile behaviour, 3D surface visualization, regression modelling, strain rate effect, response surface analysis

1 Introduction

Tensile testing is one of the most widely used experimental methods for evaluating the mechanical behaviour of engineering materials [3]. It provides essential information about fundamental mechanical properties such as yield strength, ultimate tensile strength, Young's modulus, and ductility, which are critical for understanding material performance under uniaxial loading conditions [3].

Sheet steels are extensively used in various industrial sectors, including automotive, construction, and manufacturing industries, due to their favourable combination of strength, formability, and cost-effectiveness. Among these materials, DC01 low-carbon steel is commonly applied in cold-forming processes and structural components where reliable mechanical behaviour is required [1].

The mechanical response obtained during tensile testing can be influenced by several factors, including material microstructure, specimen geometry, and testing conditions. One of the key parameters affecting the measured properties is the tensile testing speed, which directly influences the strain rate during deformation [5]. Even small variations in testing speed may lead to measurable differences in the stress–strain response and mechanical properties of the material. The influence of deformation rate on the mechanical response of metallic materials has also been investigated through experimental studies involving high-strain-rate testing of aluminium alloys [16].

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Traditionally, mechanical behaviour of materials is influenced by various process and testing parameters, which has been demonstrated in previous studies [11]. Optimization and statistical approaches, such as the Taguchi method, have also been applied in previous studies to analyse the influence of process parameters [12]. Statistical modelling and experimental design approaches have also been applied to investigate the influence of processing parameters on tensile strength in additively manufactured materials [17]. However, such approaches are often limited in their ability to simultaneously represent the interaction between multiple variables. For this reason, advanced visualization techniques have been increasingly applied in engineering analysis to improve the interpretation of experimental data [9].

In this context, 3D surface visualization represents a powerful tool for analysing complex relationships between variables. Similar approaches have been applied in recent studies focusing on visualization and modelling of material behaviour [9,13,14]. By simultaneously considering multiple parameters, such as testing speed and elongation, it enables a more comprehensive understanding of material behaviour and facilitates the identification of trends, transition regions, and interaction effects.

The aim of this study is to investigate the tensile behaviour of DC01 sheet steel at different testing speeds and to apply a 3D surface visualization approach for improved interpretation of the experimental results. Tensile tests were performed at three different crosshead speeds, while the corresponding stress–strain responses were analysed. In addition to conventional analysis, 3D surface and contour plots were developed to illustrate the combined influence of testing parameters on tensile strength.

The presented approach provides additional insight into the mechanical behaviour of low-carbon steels and demonstrates the importance of integrating visualization techniques with experimental analysis for forming and material processing applications [5]. However, limited studies have combined experimental tensile analysis with 3D surface visualization for strain rate interpretation in low-carbon steels, particularly in the context of DC01 steel. To the best of the authors' knowledge, only a limited number of studies have specifically addressed the interaction between strain rate and elongation using three-dimensional visualization in low-carbon steels.

While regression-based modelling approaches have been widely used to describe the relationship between testing parameters and tensile strength, such methods are often limited in their ability to provide intuitive insight into the interaction between multiple variables. In this context, the present study focuses on the application of three-dimensional (3D) surface visualization as a primary tool for analysing tensile behaviour. Unlike conventional approaches, this method enables simultaneous interpretation of the combined influence of testing speed and elongation on material response.

A previously published study by the authors investigated regression-based modelling of tensile strength as a function of testing speed [15]. In contrast, the present work extends this approach by emphasizing multi-parameter visualization and interaction analysis, providing enhanced insight into strain-rate sensitivity and deformation behaviour of DC01 steel.

The novelty of this study lies in the integration of experimental tensile testing with three-dimensional data visualization and interaction-based analysis for improved interpretation of material behaviour.

2 Materials and Experimental Procedure

2.1 Material

The material investigated in this study was DC01 low-carbon sheet steel, which is widely used in industrial applications due to its good formability, weldability, and balanced mechanical properties [10]. This material is commonly applied in cold-forming processes, automotive components, and structural elements where reliable mechanical performance is required.

The sheet steel used in the experimental investigation had an approximate thickness of 2.4 mm. The mechanical behaviour of DC01 steel is characterized by relatively low yield strength, high ductility, and stable plastic deformation, making it suitable for tensile testing analysis under different deformation conditions [10].

The selection of this material allows for a clear observation of deformation mechanisms and strain-rate sensitivity effects, which are essential for analysing the influence of testing speed on tensile behaviour.

2.2 Specimen preparation

The tensile specimens were prepared according to standard geometry for sheet materials, ensuring reliable and comparable results during testing [1,2]. The specimen geometry and testing procedure were defined in accordance with ASTM E8/E8M standard [2]. A flat dog-bone specimen configuration was adopted in order to achieve uniform stress distribution within the gauge section and to ensure that failure occurs in the central region of the specimen.

The geometry of the specimens is presented in Figure 1. The specimens were designed with a gauge length of approximately 50 mm, while the overall length and width were defined in accordance with standard tensile testing recommendations [1,2]. The width and thickness of each specimen were measured using a digital calliper prior to testing in order to accurately determine the cross-sectional area.

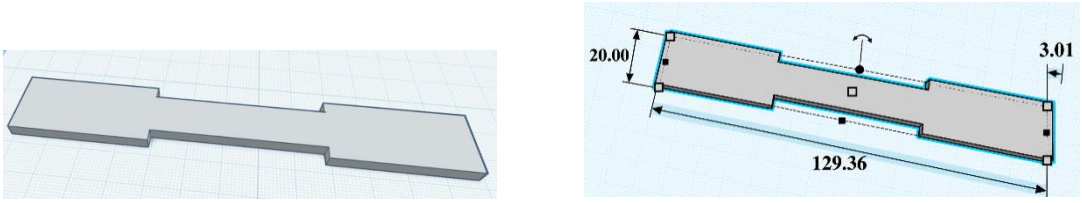


Fig. 1 Geometry of the specimens

The digital model of the specimen was developed for visualization purposes, providing a clear representation of the geometry used in the experimental procedure [4]. The adopted geometry ensures consistent deformation behaviour and minimizes the influence of geometric irregularities on the test results.

2.3 Tensile testing procedure

The tensile tests were conducted at the Laboratory for Mechanical and Thermal Testing, Faculty of Mechanical Engineering, Goce Delcev University, Stip, North Macedonia, using an electromechanical universal testing machine under controlled laboratory conditions. Prior to testing, a small preload was applied to eliminate slack and ensure proper alignment of the specimen.

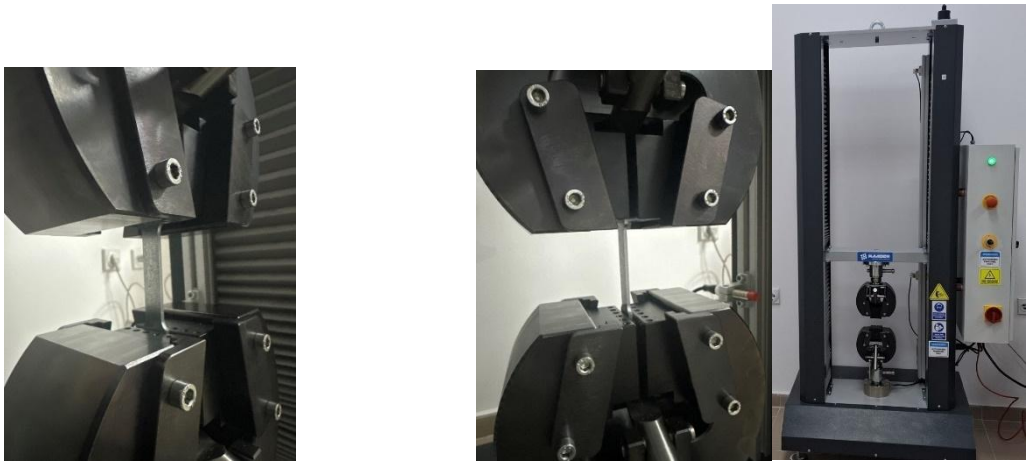
The tests were conducted at three different crosshead speeds in order to investigate the influence of testing speed on the mechanical behaviour of the material. The selected testing speeds were:

- 2 mm/min
- 5 mm/min
- 10 mm/min

Two specimens were tested for each speed level, resulting in a total of six experiments. This approach was adopted to improve the accuracy and repeatability of the obtained results.

During testing, the applied force and displacement were continuously recorded. Based on these measurements, engineering stress–strain curves were constructed, and key mechanical parameters such as ultimate tensile strength (UTS), yield strength, and elongation were determined.

The experimental setup used for tensile testing is shown in Figure 2.



a b

Fig. 2 Experimental setup: (a) electromechanical universal testing machine and (b) tensile specimen mounted in the grips during testing.

2.4 Data Processing and Visualization Approach

The primary objective of data processing in this study is to enable advanced visualization of tensile behaviour through a multi-parameter approach. Particular emphasis is placed on the development of three-dimensional surface representations that allow simultaneous analysis of testing speed and elongation. In this context, regression-based modelling is used only as a supporting tool to assist interpretation of the experimental data, rather than as the main analytical framework.

In addition to conventional experimental analysis, the obtained data were further processed to enable advanced visualization of tensile behaviour. The experimental results were organized into a structured dataset, allowing simultaneous analysis of the relationship between testing speed, elongation, and tensile strength. A 3D surface visualization approach was applied, where testing speed and elongation were treated as independent variables, while maximum stress (UTS) was defined as the response variable. Interpolation techniques were used to generate a continuous surface from the discrete experimental data.

Furthermore, a simplified empirical relationship between testing speed, elongation, and tensile strength can be assumed in the form of a response surface model. The generated 3D surface can therefore be interpreted as an implicit representation of this functional relationship, enabling approximation of the material response within the investigated parameter range.

Contour plots were additionally developed to provide a two-dimensional representation of the stress distribution across the investigated parameter space. This facilitates clearer interpretation of interaction effects between testing parameters and supports the identification of characteristic regions of material behaviour. The applied visualization methodology complements traditional experimental analysis and provides enhanced insight into the combined influence of deformation parameters on tensile behaviour.

Although the relationship between testing speed, elongation and tensile strength can be described using empirical or regression-based models, the primary focus of this study is placed on visualization and interpretation of experimental data.

The developed 3D surface can be interpreted as an implicit representation of the relationship between the investigated variables, enabling qualitative analysis of interaction effects without introducing an explicit mathematical formulation. This approach allows for clear identification of trends and dependencies within the investigated parameter range, while maintaining a strong connection to experimentally obtained results.

In addition to visualization, the applied approach can be interpreted as an interpolation-based modelling framework. The generated 3D surface represents a continuous numerical approximation of the experimental data, enabling modelling of the relationship between testing speed, elongation and tensile strength within the investigated parameter range.

Unlike classical regression-based models, this approach does not rely on explicit analytical expressions, but instead provides a data-driven representation of material behaviour, suitable for qualitative and semi-quantitative analysis.

3 Results and Discussion

3.1 Stress–strain behaviour

The engineering stress–strain curves obtained from the tensile tests are presented in Figure 3. These curves illustrate the mechanical response of DC01 sheet steel under different testing speeds.

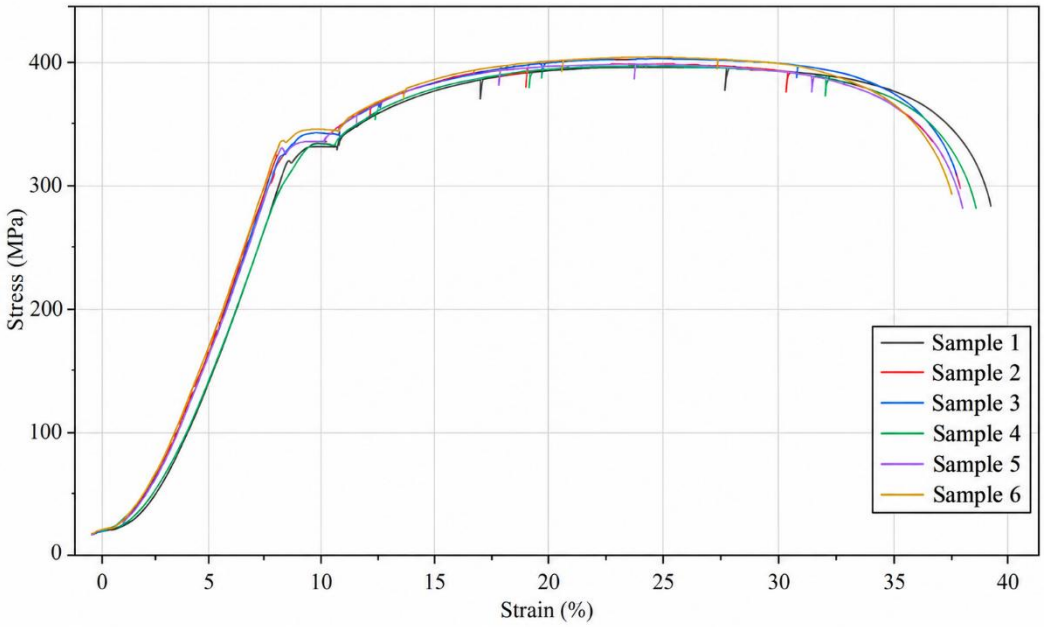


Fig. 3 Stress–strain curves obtained from six tensile tests of DC01 steel.

All tested specimens exhibited typical ductile behaviour characterized by an initial linear elastic region, followed by yielding and plastic deformation. After yielding, the material underwent strain hardening until the maximum stress was reached [6].

The general shape of the stress–strain curves remained consistent for all testing speeds, indicating stable material behaviour within the investigated range. However, slight variations in the maximum stress values were observed, suggesting a measurable influence of testing speed on tensile properties. This behaviour is characteristic of low-carbon steels, which exhibit significant plastic deformation prior to failure, as also reported in previous studies investigating strain-rate effects [6,7,13].

3.2 Tensile strength analysis

The main mechanical parameters obtained from the tensile tests include maximum force and ultimate tensile strength (UTS). The results are summarized in Table 1.

The obtained tensile strength values ranged between approximately 393 MPa and 402 MPa. A slight increase in tensile strength was observed with increasing testing speed, indicating a strain-rate effect. Although the variation in UTS values is relatively small, the trend is consistent across all tested specimens. The increase in tensile strength with increasing testing speed can be attributed to the reduced time available for dislocation motion, resulting in higher resistance to plastic deformation [6]. Although the absolute differences in UTS are modest, they exceed the experimental variability, indicating a consistent and physically meaningful trend rather than random scatter.

The increase in tensile strength between the lowest and highest testing speed was approximately 1.9%, confirming a moderate strain-rate strengthening effect. At the same time, elongation shows a slight decreasing trend with increasing testing speed, suggesting reduced plastic deformation capability at higher deformation rates.

This behaviour is characteristic of low-carbon steels, where increased strain rate leads to higher flow stress and slightly reduced ductility due to limited dislocation mobility [6]. From an engineering perspective, even small variations in tensile strength may be relevant in forming processes, where strain rate variations can influence material response and process stability.

Table 1. Mechanical properties obtained from tensile tests

Specimen	Speed (mm/min)	t (mm)	b (mm)	A (mm²)	Fmax (N)	σy (MPa)	UTS (MPa)	Elongation (%)
S1	2	2.40	12.55	30.12	11838	310.19	393.03	39.2
S2	5	2.41	12.53	30.19	11960	—	396.06	38.0
S3	10	2.42	12.53	30.32	12140	334.73	400.36	38.0
S4	2	2.40	12.52	30.04	11833	—	393.80	38.6
S5	5	2.41	12.54	30.22	11959	320.14	395.71	39.3
S6	10	2.39	12.52	29.92	12020	328.91	401.70	37.5

Note: σy – yield strength; UTS – ultimate tensile strength.

This behaviour confirms a strain-rate strengthening effect and highlights the sensitivity of DC01 steel to variations in deformation rate. The simultaneous increase in tensile strength and slight reduction in elongation indicate a transition towards reduced plastic deformation capability at higher testing speeds.

3.3 Mean response analysis

To further analyse the influence of testing speed, mean values of tensile strength were calculated for each speed level. The results are presented in Table 2 and Figure 4. The mean tensile strength increased from approximately 393 MPa at 2 mm/min to 401 MPa at 10 mm/min. This trend confirms the influence of testing speed on the mechanical response of the material.

Table 2. Mean tensile strength values

Testing speed (mm/min)	Mean UTS (MPa)	Mean Yield strength (MPa)	Standard deviation	Mean elongation (%)
2	393.42	310.19	0.54	38.9
5	395.89	320.14	0.25	38.7
10	401.03	331.82	0.95	37.8

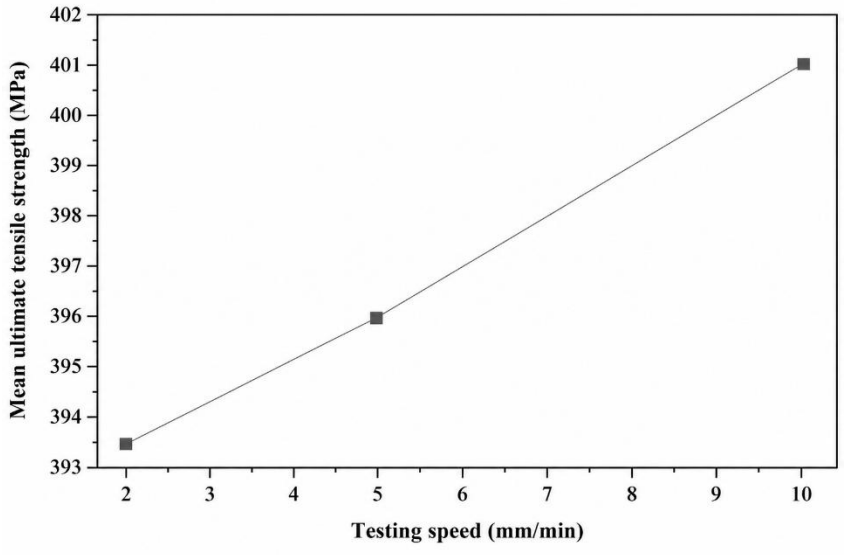


Fig. 4 Main effects plot showing the influence of testing speed on mean ultimate tensile strength.

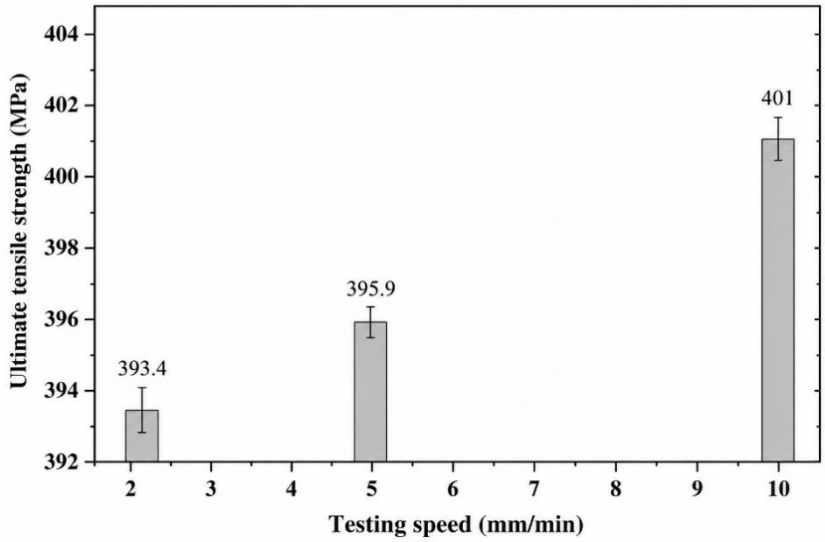


Fig. 5 Comparison of ultimate tensile strength values at different testing speeds (mean ± standard deviation).

The results clearly show a slight increase in tensile strength with increasing testing speed. The relatively small standard deviation values indicate good consistency of the experimental data [3,10]. This trend is consistent with previously reported studies investigating the influence of process parameters in engineering materials [11].

A slight decrease in elongation was observed with increasing testing speed, indicating reduced ductility, which agrees with previously reported trends [11]. The elongation values remained within the range of approximately 37% to 39%, confirming the ductile nature of the material. Although the variation in tensile strength is relatively small, the differences between the investigated testing speeds exceed the standard deviation, indicating a consistent and statistically meaningful trend. This confirms that the observed increase in tensile strength is not due to experimental variability but reflects the strain-rate sensitivity of the material.

3.4 3D Surface Visualization of Tensile Behaviour

To provide a more comprehensive understanding of tensile behaviour, a three-dimensional (3D) surface visualization was developed based on experimental data. Testing speed and elongation were treated as independent variables, while maximum stress (UTS) was used as the response variable. The surface was generated using interpolation techniques to enable a continuous representation of the experimental dataset [8,9].

The 3D surface plot enables simultaneous observation of the combined influence of testing speed and elongation on tensile behaviour. The results show a clear increasing trend in tensile strength with increasing testing speed, while elongation reflects the corresponding deformation behaviour. The observed increase in tensile strength from approximately 393 MPa to 401 MPa across the investigated testing speeds quantitatively confirms the strain-rate strengthening effect.

The 3D surface visualization represents the central contribution of this study. Unlike conventional two-dimensional plots, this approach enables simultaneous observation of parameter interaction, revealing trends that are not directly observable through standard regression or stress–strain analysis.

This trend is directly attributed to strain-rate sensitivity of the material, where higher deformation rates increase resistance to plastic flow [6,7].

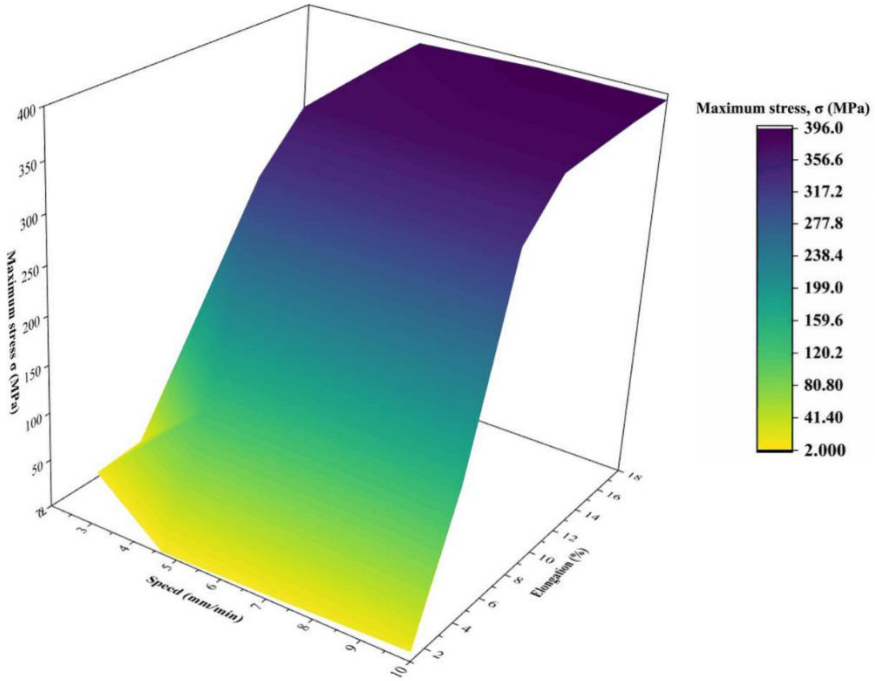


Fig. 6 3D surface visualization of tensile behaviour of DC01 sheet steel showing the combined effect of testing speed and elongation on maximum stress.

The surface enables identification of regions of increased sensitivity, which cannot be clearly distinguished using conventional two-dimensional plots.

At low elongation values, the stress remains relatively low regardless of testing speed, indicating that the material response is dominated by the initial stages of deformation. As elongation increases, the influence of testing speed becomes more pronounced, suggesting enhanced strain hardening effects. At higher elongation values, the surface approaches its maximum stress levels, indicating the transition towards stable plastic deformation [6].

The results also reveal a significant interaction effect between testing speed and elongation. The influence of testing speed becomes more pronounced at higher elongation levels, indicating increased strain-rate sensitivity during advanced stages of deformation. This behaviour reflects the characteristic response of low-carbon steels, where increasing deformation rates lead to higher flow stress while simultaneously reducing ductility [6,7].

From an engineering perspective, this behaviour is particularly relevant in forming and manufacturing processes, where variations in deformation rate can significantly influence the accuracy of material characterization and the performance of final components [5].

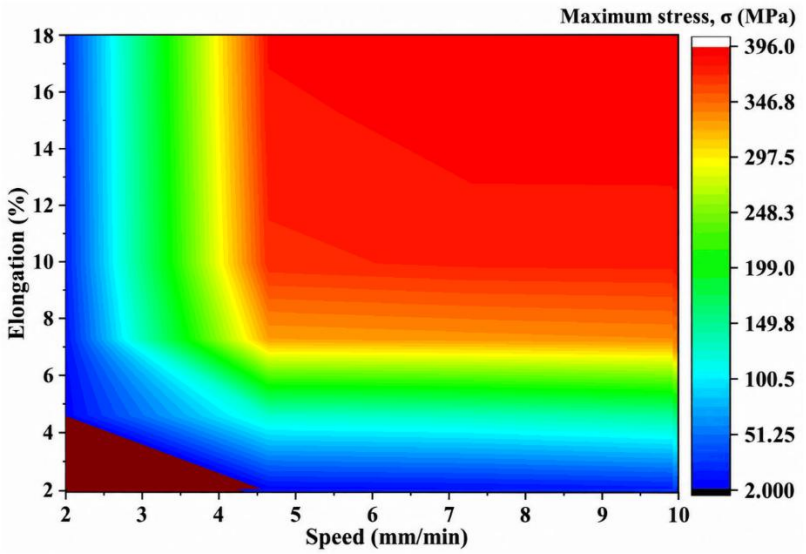


Fig. 7 Contour plot of tensile strength as a function of testing speed and elongation.

Compared to conventional two-dimensional plots, the combined use of 3D surface and contour visualization provides a more effective tool for analysing complex relationships between variables. These visualization techniques allow identification of interaction trends that are not easily observable in standard stress–strain analysis [9].

Although the dataset is limited, the consistency of the observed trends supports the reliability of the presented analysis. The smooth transition of the surface further indicates stability of the experimental data and suitability of the interpolation approach for representing the material response.

The combination of 3D surface and contour visualization provides a powerful tool for identifying parameter interaction zones, which can support future modelling, optimization, and process control strategies [8,9]. The presented approach also establishes a foundation for the development of predictive models based on experimental data.

From an engineering perspective, the ability to visualize interaction effects between testing speed and elongation is particularly valuable in forming and manufacturing processes, where accurate prediction of material behaviour under varying deformation rates is essential for process optimization and component reliability.

3.5 Interpretation of interaction effects

In addition to the descriptive analysis, the 3D surface visualization represents the central contribution of this study, providing a comprehensive interpretation of the interaction between testing speed and elongation on tensile behaviour. Unlike conventional two-dimensional analysis, this approach enables simultaneous observation of parameter interaction, revealing trends that cannot be directly identified from standard stress–strain curves or regression models.

This behaviour confirms that the material response is governed not only by individual parameters, but also by their combined interaction, which becomes evident through multi-parameter visualization.

The results further demonstrate that tensile strength increases with increasing testing speed, while elongation reflects the corresponding deformation behaviour. However, the 3D surface further reveals that the influence of testing speed is not uniform across the deformation range. At lower elongation levels, the variation in stress remains relatively limited, indicating that the material response is dominated by the initial elastic and early plastic deformation stages.

As elongation increases, the sensitivity of tensile strength to testing speed becomes more pronounced. This indicates that strain-rate effects intensify during advanced stages of plastic deformation, where strain hardening mechanisms play a dominant role. The observed interaction suggests that testing speed has a greater influence on material behaviour under conditions of higher deformation.

This interaction-based interpretation cannot be clearly identified using conventional two-dimensional plots, highlighting the advantage of the proposed visualization approach. The combined use of 3D surface and contour plots enables identification of regions of increased sensitivity and transition zones in material behaviour.

From an engineering perspective, these findings are particularly relevant for forming and manufacturing processes, where variations in deformation rate may significantly influence material response, process stability, and final component performance. The ability to visualize interaction effects provides a valuable tool for improved material characterization and process optimization.

3.6 Regression Analysis of Tensile Behaviour

To complement the visualization-based analysis, a regression modelling approach was applied as a secondary method for quantitative approximation of the observed trends.

Previous research on DC01 sheet steel investigated the relationship between testing speed and ultimate tensile strength using linear and quadratic regression models [15].

The regression model was developed by considering testing speed (v) and elongation (ε) as independent variables, while the ultimate tensile strength (UTS) was treated as the response variable. Based on the experimental dataset, a second-order polynomial model was adopted to capture potential nonlinear interactions between variables [8,9].

$$UTS = \beta_0 + \beta_1 v + \beta_2 \varepsilon + \beta_3 v^2 + \beta_4 \varepsilon^2 + \beta_5 v\varepsilon \quad (1)$$

where β_0–β_5 represent regression coefficients determined from the experimental data.

The selection of a quadratic model is justified by the observed trends in the experimental results, particularly the slight nonlinear increase in tensile strength with increasing testing speed and the interaction between deformation parameters observed in the 3D surface visualization [9].

The regression model provides a mathematical representation of the material response within the investigated parameter range. Unlike pure interpolation, this approach enables approximation and prediction of tensile behaviour for intermediate values of testing speed and elongation [8].

The obtained model confirms that testing speed has a positive contribution to tensile strength, while elongation exhibits an inverse relationship, indicating reduced ductility at higher deformation rates. This behaviour is consistent with the strain-rate sensitivity of low-carbon steels reported in the literature [6,7].

The interaction term (vε) reflects the combined influence of deformation parameters, which becomes more pronounced at higher elongation levels.

To evaluate the accuracy of the regression model, predicted UTS values were compared with experimental results. A good agreement was observed, indicating that the model is suitable for describing the tensile behaviour within the investigated range. Minor deviations can be attributed to experimental variability and the limited dataset.

The developed regression model enables estimation of tensile strength for intermediate testing conditions, providing a useful tool for engineering applications where experimental testing of all parameter combinations is not feasible.

Furthermore, the regression-based approach enhances the interpretation of the 3D surface visualization by providing a mathematical basis for the observed trends. This integration of experimental data, visualization, and modelling contributes to a more comprehensive understanding of the strain-rate sensitivity of DC01 sheet steel. The regression coefficients were determined using least-squares fitting [8].

The regression model is not intended as the primary contribution of this study, but rather as a supplementary tool supporting the interpretation of the visualization results.

3.7 Model Validation and Prediction Capability

Although model validation confirms good agreement, the primary objective of this study remains the visualization and interpretation of interaction effects.

The accuracy of the model was evaluated using the coefficient of determination (R^2), which represents the proportion of variance in the experimental data explained by the regression model [8].

$$R^2 = 1 - \frac{\sum(UTS_{exp} - UTS_{pred})^2}{\sum(UTS_{exp} - \overline{UTS}_{exp})^2} \quad (2)$$

The obtained R^2 value above 0.9 indicates strong predictive capability of the model. A high R^2 value indicates good agreement between predicted and experimental results, confirming the capability of the model to represent the observed material behaviour [8,9].

In addition to R^2, the average prediction error was evaluated to quantify the deviation between model predictions and experimental values. The obtained results show that the prediction error remains within a small range, indicating satisfactory model accuracy despite the limited number of experimental data points.

The comparison between experimental and predicted UTS values demonstrated consistent agreement across all testing conditions. Minor deviations observed in certain cases can be attributed to experimental uncertainties and natural material variability.

Furthermore, the developed regression model was used to estimate tensile strength at an intermediate testing speed not included in the experimental dataset. For example, at a testing speed of 7 mm/min, the model predicts a UTS value within the expected range defined by the experimental results at 5 mm/min and 10 mm/min.

This demonstrates the predictive capability of the model and its applicability for estimating material behaviour under untested conditions, which is particularly important in engineering design and material selection processes [5].

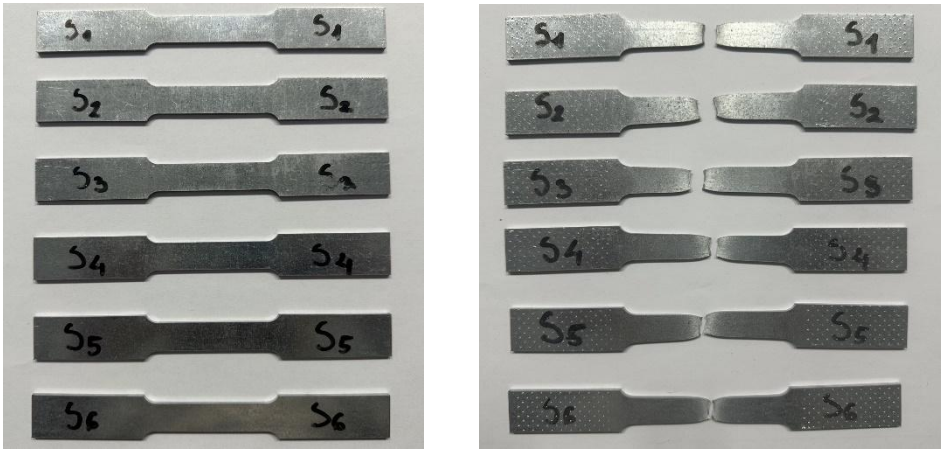
Although the dataset used for model development is relatively limited, the obtained results indicate that the regression approach provides a reliable approximation of tensile behaviour within the investigated parameter range.

The validation results confirm that the integration of experimental data with regression modelling and 3D visualization provides a robust framework for analysing tensile behaviour of engineering materials. The developed model can be further refined and extended by incorporating additional experimental data and parameters, enabling improved predictive accuracy and broader applicability [9].

3.8 Discussion of deformation behaviour

During tensile loading, all tested specimens exhibited visible necking prior to fracture, which is typical for ductile metallic materials. Fracture occurred within the gauge region, confirming proper experimental conditions.

Representative tensile specimens before and after testing are shown in Figure 8.



a b

Fig. 8 Tensile specimens of DC01 steel: (a) before testing and (b) after fracture, showing localized necking and ductile failure behaviour.

The fractured specimens clearly exhibit localized necking in the gauge region, which is characteristic of ductile materials. The fracture occurred in the central region of the specimens, confirming proper alignment and uniform stress distribution during testing. The observed fracture morphology is consistent with the stress–strain curves presented earlier.

The obtained tensile strength values are within the expected range for DC01 sheet steel, indicating consistency with literature data. The results confirm that DC01 steel exhibits stable plastic deformation behaviour, with moderate sensitivity to strain rate within the investigated testing range.

CONCLUSION

This study presented a visualization-oriented approach for analysing the tensile behaviour of DC01 sheet steel under different testing speeds. The results confirmed that testing speed has a measurable influence on the mechanical response of the material, with a gradual increase in ultimate tensile strength and a slight reduction in elongation at higher deformation rates, indicating moderate strain-rate sensitivity.

The primary contribution of this work lies in the application of three-dimensional (3D) surface visualization for the interpretation of tensile behaviour. The developed visualization framework enabled simultaneous analysis of testing speed and elongation, revealing interaction effects and sensitivity variations that are not clearly observable using conventional two-dimensional methods.

The results demonstrated that the influence of testing speed becomes more pronounced at higher elongation levels, indicating increased strain-rate sensitivity during advanced stages of plastic deformation. This interaction-based insight provides a more comprehensive understanding of material behaviour and highlights the importance of considering combined parameter effects in mechanical analysis.

Although regression modelling was applied to support quantitative interpretation, the main focus of this study remains on visualization and interaction analysis. From an engineering perspective, the ability to identify regions of increased sensitivity is particularly relevant for forming and manufacturing processes, where deformation rate variations can significantly influence material performance and process stability.

Despite the limited dataset, the consistency of the results confirms the reliability of the proposed approach. Future work will focus on expanding the experimental range and incorporating additional parameters in order to further enhance the predictive and analytical capabilities of the methodology.

REFERENCES

[1] ISO, "ISO 6892-1: Metallic materials – Tensile testing – Part 1: Method of test at room temperature", ISO, Geneva, Switzerland, **2019**.

[2] ASTM International, "ASTM E8/E8M-20: Standard Test Methods for Tension Testing of Metallic Materials", ASTM International, West Conshohocken, USA, **202**0.

[3] Callister, W. D., Rethwisch, D. G. "Materials Science and Engineering: An Introduction", 10th ed., Wiley, New York, USA, **2018**.

[4] Dieter, G. E. "Mechanical Metallurgy", 3rd ed., McGraw-Hill, New York, USA, 1986.

[5] Hosford, W. F., Caddell, R. M. "Metal Forming: Mechanics and Metallurgy", 4th ed., Cambridge University Press, Cambridge, UK, **2011**.

[6] Wagoner, R. H., Chenot, J. L. "Metal Forming Analysis", Cambridge University Press, Cambridge, UK, **2001**.

[7] Khan, A. S., Huang, S. "Continuum Theory of Plasticity", Wiley, New York, USA, **1995**.

[8] Montgomery, D. C. "Design and Analysis of Experiments", 9th ed., Wiley, New York, USA, **2017**.

[9] Myers, R. H., Montgomery, D. C., Anderson-Cook, C. M. "Response Surface Methodology", Wiley, New York, USA, **2016**.

[10] ASM International, "ASM Handbook, Volume 1: Properties and Selection: Irons, Steels, and High-Performance Alloys", ASM International, Materials Park, OH, USA, **1990**.

[11] Srebrenkoska, S., Kochoski, F., Srebrenkoska, V., Risteska, S., Kotynia, R. "Effect of Process Parameters on Thermal and Mechanical Properties of Filament Wound Polymer-Based Composite Pipes", Polymers 15 (13), **2023**. DOI: 10.3390/polym15132829

[12] Mijajlovikj, M., Srebrenkoska, S., Cekerovska, M., Risteska, S. "Application of Taguchi Method in Production of Samples Predicting Properties of Polymer Composites", Balkan Journal of Applied Mathematics and Informatics, **2018**.

[13] Wang, L., Zhang, Y., Li, H. "Effect of strain rate on tensile properties of low carbon steel", Materials Science and Engineering A, 620, pp. 10–15, **2015**.

[16] Singh, R., Kumar, A. "Application of response surface methodology for modelling mechanical properties of materials", Materials Today: Proceedings 5(2), pp. 4560 – 4567, **2018**.

[17] Mijoski, A., Srebrenkoska, S., Risteska-Kamceski, A., Krstev, D., Nikolova, S. "Mathematical Modelling and Prediction Analysis of the Tensile Strength of DC01 Sheet Steel Based on Testing Speed", Balkan Journal of Applied Mathematics and Informatics 9 (1), pp.71 – 80, **2026**. DOI: 10.46763/BJAMI269171m

[18] Mánek, M., Fusek, M. "Comparison of Measurement of Aluminium Alloy in High Strain Rate", Strojnícky časopis – Journal of Mechanical Engineering 73 (2), pp. 99 – 106, **2023**. DOI: 10.2478/scjme-2023-0025

[19] Dung, H. T., Trinh, V.-L., Ngo, Q.-T. "Study on Influencing of Processing Parameters on Tensile Strength of 3D Printing Sample", Strojnícky časopis – Journal of Mechanical Engineering 75(1), pp. 27 – 38, **2025**. DOI: 10.2478/scjme-2025-0004