Minisample tensile-compression testing for sheet metal mechanical characterization

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Introduction

The growing application of lightweight metals in combination with the increased complexity of components provides new challenges to the sheet metal forming industry. In some metal forming operations, the material flow involves a series of bending and unbending loadings which may lead to tensile and compressive plastic deformation. In sequences with this type of reverse loadings, the materials tend to soften, resulting in a decrease in yield stress. This phenomenon is known as the Bauschinger effect [1].

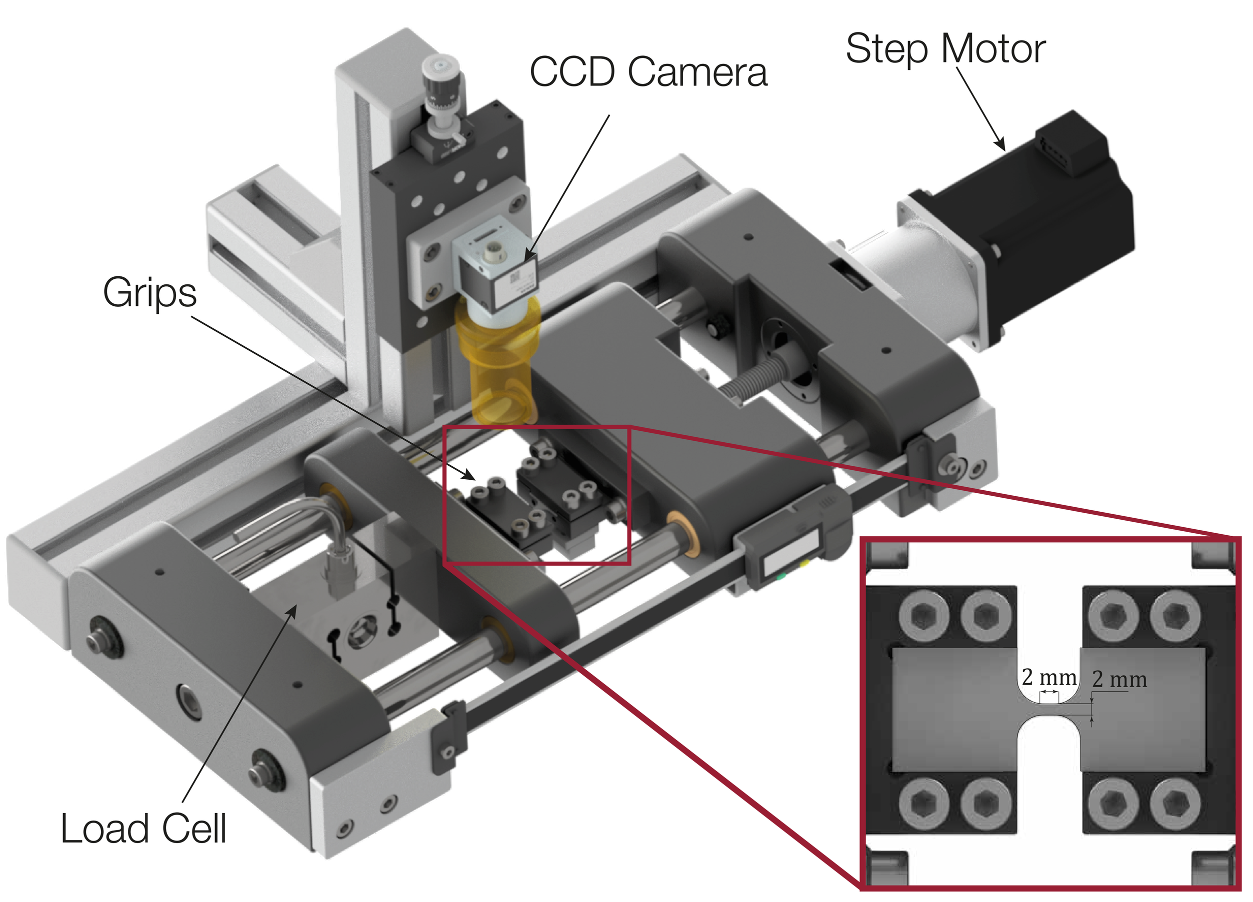
This work presents an experimental methodology developed for the determination of the mechanical behaviour of sheet metal materials during reverse loadings.

Developed System

An new experimental equipment - *Mini Sample Tester Device* - was developed to perform uniaxial tensile-compression tests with direction reversal in sheet metal materials [2].

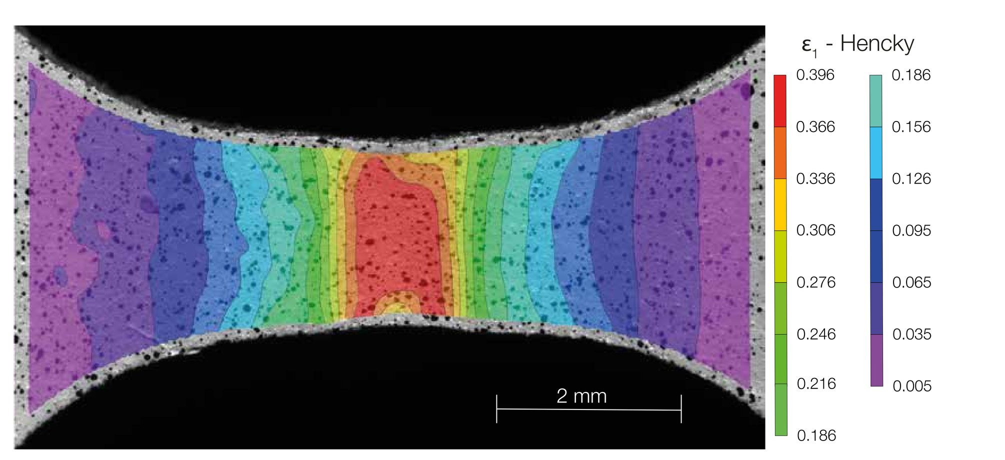
In order to prevent the buckling phenomenon in the length direction of the specimen in compression loadings, the equipment use miniaturized samples with a width and a uniform length of two millimetres (SS2x2).

This prototype was designed with a maximum axial cacapacity of 2.5 kN and is capable of performing quasi-static tests with a strain rate approximately equal to 10^{-3} s^{-1} .



Mini Sample Tester Device

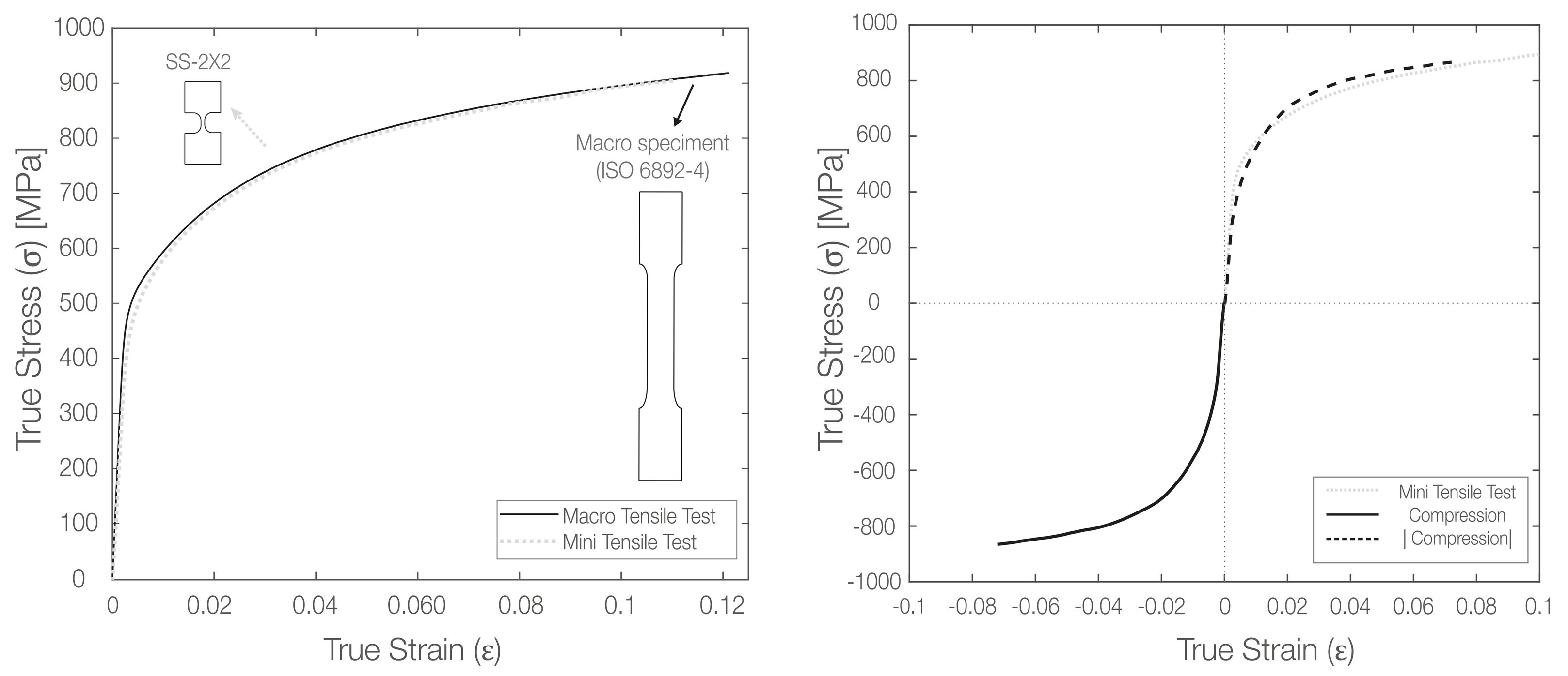
Digital Image Correlation (DIC) was used to obtain the elongations in the uniform section of the specimen and therefore measuring of corresponding strains. This technique is adequate for this type of scale and provides detailed results of strain fields in different directions, longitudinal (ε_1) and transversal (ε_2), during mechanical tests.



Digital Image Correlation (DIC) technique

Experimental Results

In the experimental tests was used a Dual-Phase steel (DP780) with 0.8mm of thickness. In order to evaluate the monotonic behaviour of the material, tensile and compression uniaxial tests were performed.

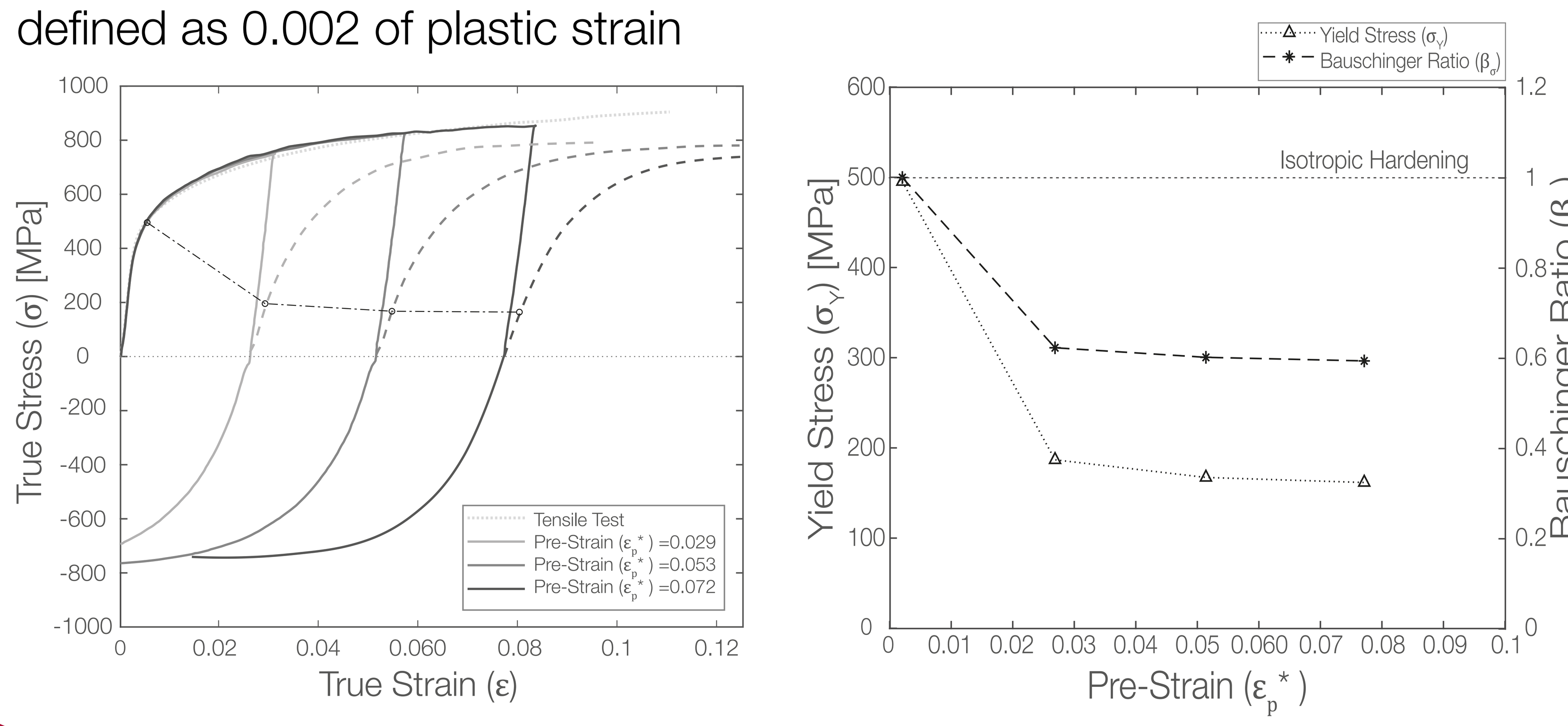


The Bauschinger effect was evaluated by uniaxial tension-compression tests that includes one tensile step (for a given pre-strain, ε_p^*) follow by a compressive step (until the buckling phenomenon starts to be evident). Therefore, three ranges of pre-strains were selected – 0.03, 0.05, 0.07.

The Bauschinger effect can be quantify by the Bauschinger Ratio (β_σ), defined by:

$$\beta_\sigma = \frac{\sigma_{max} + |\sigma_Y|}{2\sigma_{max}}$$

where σ_{max} is the maximum pre-stress, and σ_Y is the yield stress at the compression stage. With the smaller Bauschinger ratio, the Bauschinger effect becomes larger [3]. In the follow results, the reverse loading curves, during compression, are rotated as shown in the dotted line. The yield points were defined as 0.002 of plastic strain



Conclusions

- The monotonic tensile test indicates that the miniaturized specimen provides an excellent approximation of the material behaviour and can be easily compared with the macro tensile test (IS0 6892-4).
- The monotonic compression tests show that DP780 steel has a similar hardening evolution in compression and tensile solicitations. However, in compression the true-strain value reached is lower than in tensile due to premature buckling phenomenon in the thickness direction.
- The tension-compression tests show an obvious Bauschinger effect for the studied material because, for all pre-strains the yield stress is significatly reduced. The Bauschinger, for higher pre-strains tends to stabilize, which is according to several authors [4].
- The developed system shows promising results to evaluate the mechanical behaviour of sheet metal materials under monotonic and reverse loading tests, having a great potential to evaluate phenomena such as Stress Diferencial (SD) and the Bauschinger effect, characteristics of load path change.

References

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Acknowledgments

The authors gratefully acknowledge the financial support of the Portuguese Foundation for Science and Technology (FCT) under the projects POCI-01 0145-FEDER-031243, POCI-01-0145-FEDER-030592, by UE/FEDER through the program COMPETE 2020. The third author is also grateful to the FCT for the Doctoral grant SFRH/BD/146083/2019 under the program POCH, cofinanced by the European Social Fund (FSE) and Portuguese National Funds from MCTES.