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Material flow analysis in indentation process by 3D Digital Image Correlation

C. Bermudo*[(a)], S. Martín-Béjar[(b)], F.J. Trujillo[(c)], G. Castillo[(d)], L. Sevilla[(e)]

Department of Civil, Material and Manufacturing Engineering. EII, University of Malaga
C/ Dr. Ortiz Ramos s/n, E-29071 Malaga, Spain
[(a)]bgamboa@uma.es; [(b)]smartin@uma.es; trujillov@uma.es[(c)]; gcastillo@uma.es[(d)]; lsevilla@uma.es[(e)]

Abstract

Focusing in the application of the 3D Digital Image Correlation technique, this work proposes a material flow analysis in an indentation process. The study establishes the methodology for the calibration and implementation of the 3D image sensing technology for deformation measurements. The purpose is to continue with the validation of the DIC application to the indentation processes, where a deep penetration is achieved and extensive material flow is produced. With the 3D DIC technique is possible to perform accurate deformation measurements in not planar specimens and study the material emerging towards the exterior of the tested specimen, which is not possible with the 2D DIC technique. Although previous 2D studies were efficient detecting the flow field and von Mises strains on the specimens tested, the bulge emerging under the punch on the front surface (dead zone) could not be studied due to its predominantly 3D character. Therefore, present work implements a 3D methodology that carries out a complete study of the deformation, including the material flow that occurs on the Z axis, towards the exterior of the tested specimen, optimizing previous analyses.

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Keywords: Digital Image Correlation; experimental methodology; incremental forming; plastic deformation

1. Introduction

Leading to understand the materials behavior, different techniques have been developed in order to have efficient tools to study elastic and plastic deformation. Within high deformation ranges, there are several efficient analysis tools that can be taken into consideration for strain measurements. The Digital Image Correlation technique (DIC) is a procedure that is currently attracting attention in the field of material deformation measurements. It has certain advantages to consider, among which can be highlight that it is a non-contact optical method that reduces the specimens interaction and provides wide measurement ranges with high resolution [1]. DIC technique offers the

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after the indentation teste, presenting an average displacement of 3.07 mm, being the error with the correlation displacement results of 2.67% on average.

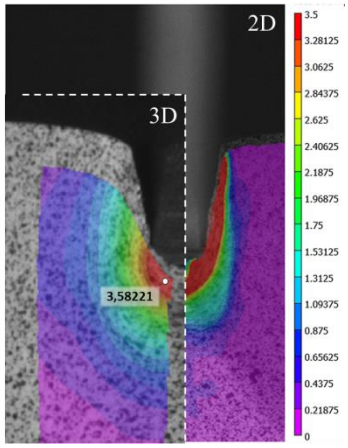

Fig. 10. Vic 2D and 3D analysis comparison.

4. Conclusions

The main purpose of present work is to implement the 3D DIC technique, improving the material flow analysis in an indentation process. Present analysis validates the 3D image sensing technology application in order to achieve adequate results in large plastic deformations processes.

The non-contact 3D technique is presented as an efficient method for the identification of the flow field and von Mises strains. The 3D von Mises results show a good correlation with the 2D results obtained in previous studies, 3.58221 versus 3.5 respectively.

Also, the bulge emerging under the punch on the front surface (dead zone) can be analyses due to the 3D technology, presenting an average displacement in the Z axis of 2.99 mm versus the average of 3.07 mm measured in the tested specimens. Individually, the error is usually contained below a 10%, expect in one of the samples (sample 4), which rises up to 17%. This rise may be due to errors in the speckle conferred to the specimen.

This analysis confirms that the 3D DIC application can provide full strain fields and can be used to examine manufacturing processes. Also, after the necessary image treatment, DIC offers the possibility to obtain different types of information such as damage, stress distribution, or the stress-strain curve.

Future work

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References

[1] Pan B, Qian K, Xie H, Asundi A. Two-dimensional digital image correlation for in-plane displacement and strain measurement: a review. Meas Sci Technol. 2009 Jun 1;20(6):062001.

[2] Sousa PJ, Barros F, Tavares PJ, Moreira PMGP. Displacement measurement and shape acquisition of an RC helicopter blade using Digital Image Correlation. 2017;

[3] Ho C-C, Chang Y-J, Hsu J-C, Kuo C-L, Kuo S-K, Lee G-H. Residual Strain Measurement Using Wire EDM and DIC in Aluminum. Inventions. 2016 Mar 4;1(1):4.

[4] Bruck HA, McNeill SR, Sutton MA, Peters WH. Digital image correlation using Newton-Raphson method of partial differential correction. Exp Mech. 1989 Sep;29(3):261–7.

[5] Park J, Yoon S, Kwon T-H, Park K. Assessment of speckle-pattern quality in digital image correlation based on gray intensity and speckle morphology. Opt Lasers Eng. 2017;91:62–72.

[6] Roux S, Réthoré J, Hild F. Digital image correlation and fracture: an advanced technique for estimating stress intensity factors of 2D and 3D cracks. J Phys D Appl Phys. 2009 Nov 7;42(21):214004.

[7] Fayyad TM, Lees JM. Application of Digital Image Correlation to reinforced concrete fracture. Procedia Mater Sci. 2014;3:1585–90.

[8] McCormick N, Lord J. Digital Image Correlation. Mater Today. 2010 Dec 1;13(12):52–4.

[9] Hao Kan W, Albino C, Dias-da-Costa D, Dolman K, Lucey T, Tang X, et al. Fracture toughness testing using photogrammetry and digital image correlation. MethodsX. 2018 Jan 1;5:1166–77.

[10] Nguyen V-T, Kwon S-J, Kwon O-H, Kim Y-S. Mechanical Properties Identification of Sheet Metals by 2D-Digital Image Correlation Method. Procedia Eng. 2017 Jan 1;184:381–9.

[11] Chen F, Chen X, Xie X, Feng X, Yang L. Full-field 3D measurement using multi-camera digital image correlation system. Opt Lasers Eng. 2013 Sep 1;51(9):1044–52.

[12] Chen Y, Wei J, Huang H, Jin W, Yu Q. Application of 3D-DIC to characterize the effect of aggregate size and volume on non-uniform shrinkage strain distribution in concrete. Cem Concr Compos. 2018 Feb 1;86:178–89.

[13] Aydin M, Wu X, Cetinkaya K, Yasar M, Kadi I. Application of Digital Image Correlation technique to Erichsen Cupping Test. Eng Sci Technol an Int J. 2018 Aug 1;21(4):760–8.

[14] Helfrick MN, Niezrecki C, Avitabile P, Schmidt T. 3D digital image correlation methods for full-field vibration measurement. Mech Syst Signal Process. 2011 Apr 1;25(3):917–27.

[15] Tang Z, Liang J, Xiao Z, Guo C. Large deformation measurement scheme for 3D digital image correlation method. Opt Lasers Eng. 2012 Feb 1;50(2):122–30.

[16] Guo X, Liang J, Xiao Z, Cao B. Digital image correlation for large deformation applied in Ti alloy compression and tension test. Opt - Int J Light Electron Opt. 2014 Sep 1;125(18):5316–22.

[17] Fragapane S, Giallanza A, Cannizzaro L, Pasta A, Marannano G. Experimental and numerical analysis of aluminum-aluminum bolted joints subject to an indentation process. Int J Fatigue. 2015 Nov 1;80:332–40.

[18] Marannano G, Pasta A, Parrinello F, Giallanza A. Effect of the indentation process on fatigue life of drilled specimens. J Mech Sci Technol. 2015 Jul 11;29(7):2847–56.

[19] Marannano G, Virzì Mariotti G, D'Acquisto L, Restivo G, Gianaris N. Effect of Cold Working and Ring Indentation on Fatigue Life of Aluminum Alloy Specimens. Exp Tech. 2015 May 1;39(3):19–27.

[20] Ichihara H, Sekiguchi A. Development of elastomer-based incremental sheet forming method for curved products. Procedia Manuf. 2018 Jan 1;15:1184–91.

[21] Bagudanch I, Centeno G, Vallellano C, Garcia-Romeu ML. Revisiting formability and failure of polymeric sheets deformed by Single Point Incremental Forming. Polym Degrad Stab. 2017 Oct 1;144:366–77.

[22] Marín MM, Camacho AM, Sebastián MA. Study of the indentation process under specific technological parameters. Procedia Eng. 2013 Jan 1;63:616–22.

[23] Bermudo C, Sevilla L, Castillo G. Material flow analysis in indentation by two-dimensional digital image correlation and finite elements method. Materials (Basel). 2017;10(6).

[24] Correlated Solutions. VIC-3D Reference Manual [Internet]. [cited 2018 Dec 19]. Available from: http://www.correlatedsolutions.com/supportcontent/VIC-3D-8-Manual.pdf