185 Assessment of the effect of hole/specimen ratio when using DIC

K. Ghods[1], S.J.C. Matthews[1], N.J. Saiger[1], C. Foreman[1], and D.A. Jesson[1a]

[1] Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey, GU2 7XH, UK

[a]d.jesson@surrey.ac.uk

Abstract. Digital image correlation is a powerful tool for the assessment of material properties and the performance of structures, providing full-field strain measurement. However, due to the way that a grid is applied to the images being assessed in order to produce subsets, and the way in which the subset is stepped across the surface, there is usually a one subset wide border to any area of interest assessed. In the majority of cases this is not particularly problematic, but when considering issues arising from edge effects, or in the case of a hole arising from, for example, impact damage or placed deliberately for fixings, the ability to assess the strain field close to the hole is compromised. This paper begins by considering the extent of the problem by thinking in terms of the ratio of the size of the hole to the size of the specimen, which can be scaled when dealing with larger specimens. Following this a methodology is proposed which goes some way to addressing the problem.

Introduction

Digital image correlation (DIC) is a powerful tool for the assessment of material properties and the performance of structures, providing full-field strain measurement [1]. The recent publication of a Good Practices Guide [2] consolidates much knowledge from the community, and represents the effective standard for undertaking DIC. However, there remain issues with the technique which are fundamental to the process of collecting and analysing images in order to determine a strain field. One of these arises from the way in which unique features (speckles) are tracked. A grid of subsets is applied to the area of interest (AOI) and strain data determined for each subset. The size of the subset is measured in pixels and is dependent on the size of the speckles that have been placed: the smaller the speckles, the smaller the subset can be made, although there is a limit in that the smaller the speckles, the less likely they are to be identified as unique and hence the problem of aliasing can arise. One way in which information density can be increased is by stepping the subset grid across the surface. Whilst this can be done pixel by pixel, this is not helpful as the limited variation between one calculation and the next can give rise to spurious results on the one hand, and increase processing time considerably for little benefit on the other. Typically a step of 1/4 - 1/3 of the subset size is recommended. However, there remains a problem in that it is not possible to get closer than one subset to any edges that occur within the area of interest. In many circumstances edge effects can be ignored, but when it comes to holes, which typically are the focus of stress concentrations, there can be a problem in quantifying the effect properly, due to the rapid reduction in stress concentration as you move away from the hole. This paper considers this problem, first by quantifying the problem by examining the results of testing coupons with a range of hole diameter to specimen width ratios and secondly by presenting a proposed methodology that can be used in some circumstances to overcome this problem.

Methodology

15 specimens with a thickness of 4.75 mm, width of 25 mm and length of 250 mm, and with hole sizes of 4, 6 and 8 mm were prepared based on ASTM D3039/D3039M. After identifying the optimal speckle pattern using the reference grid, the chosen speckle size and density were used for speckle generation in Correlated Solution's speckle generation software (SpeckleGen v1.0.5). Three different speckle densities were considered. The generated pattern was printed upon self-adhesive transfer paper, manufactured by Sunnyscopa, using a Samsung MultiXpress X7400GX laser printer. Following the transfer process detailed by Sunnyscopa, the pattern was applied to the acrylic test specimens. One set of samples were spray painted instead to produce the speckle pattern. The specimens were loaded using an Instron 5285 universal testing machine with a 100 kN load cell, controlled by Instron's Bluehill 3 software. The initial loading was in the form of a tensile test to failure, with a crosshead displacement rate of 0.20 mm/min, within the parameters of ASTM D638—14. DIC images were captured using a dual-camera system (Allied Vision Manta G-917B), each with a LINOS smart focus lens (80 mm/1.4f) attached via a 50 mm tunnel. The cameras were mounted on a tripod and activated via a Correlated Solutions master/slave controller connected to a VIC-3D control system. The tripod was placed 440 mm from the component, with two Hedler DX15 lights set 160 mm further away. Throughout testing, images for DIC were captured at one second intervals using a fixed aperture at f/5.6 and a shutter speed of 1.2 ms. Analysis was carried out using VIC-3D (Correlated Solutions).

Results and Discussion: A total of four different speckle patterns were used in this experiment with a variation of density and subset size. Average elongation at break of 0.3604 % and 0.3822 % was found for the hole size of 4 mm and 6 mm respectively. Speckle pattern 4 had the lowest average static noise level with a value of 0.053 µm. The analysis showed that by increasing the density of the speckle pattern from 40% for pattern 3 to 75 % for pattern four the noise level could be decreased dramatically as illustrated in the table below. Also by increasing the subset size the amount of fluctuation in stress-strain curves was increased. Therefore the subset size has to be minimised as much as possible, although, if the subset size is set to be too small (speckle pattern 2: spray paint pattern), the risk of aliasing increases. A more balanced pattern can be defined as pattern 4 where the subset size, and density is adjusted based on the analysis from pattern 1-3. [1, 4, 5]

Table 1 – Summary of test data

Hole Size (mm)	W/D ratio	Test number	Speckle pattern	Ultimate Stress (MPa)	Average static noise (mm)	Average Ultimate stress (MPa)	Elongation at break (%)	Average Elongation at break (%)
4	6.250	3	1	10.11	0.00094	10.322	0.342	0.3604
		6	2	9.56	0.00089		0.341	
		9	3	9.88	0.00199		0.391	
		12	4	11.34	0.00064		0.368	
		15	4	10.72	0.00059		0.360	
6	4.167	2	1	24.30	0.00078	22.673	0.842	0.8483
		5	2	N/A	0.00107		N/A	
		8	3	33.14	0.00124		1.366	
		11	4	10.58	0.00061		0.337	
		14	4	N/A	0.00039		N/A	
8	3.125	1	1	8.34	0.00087	8.382	0.295	0.3822
		4	2	8.38	0.00092		0.295	
		7	3	8.42	0.00161		0.306	
		10	4	7.71	0.00044		0.712	
		13	4	9.06	0.00051		0.303	

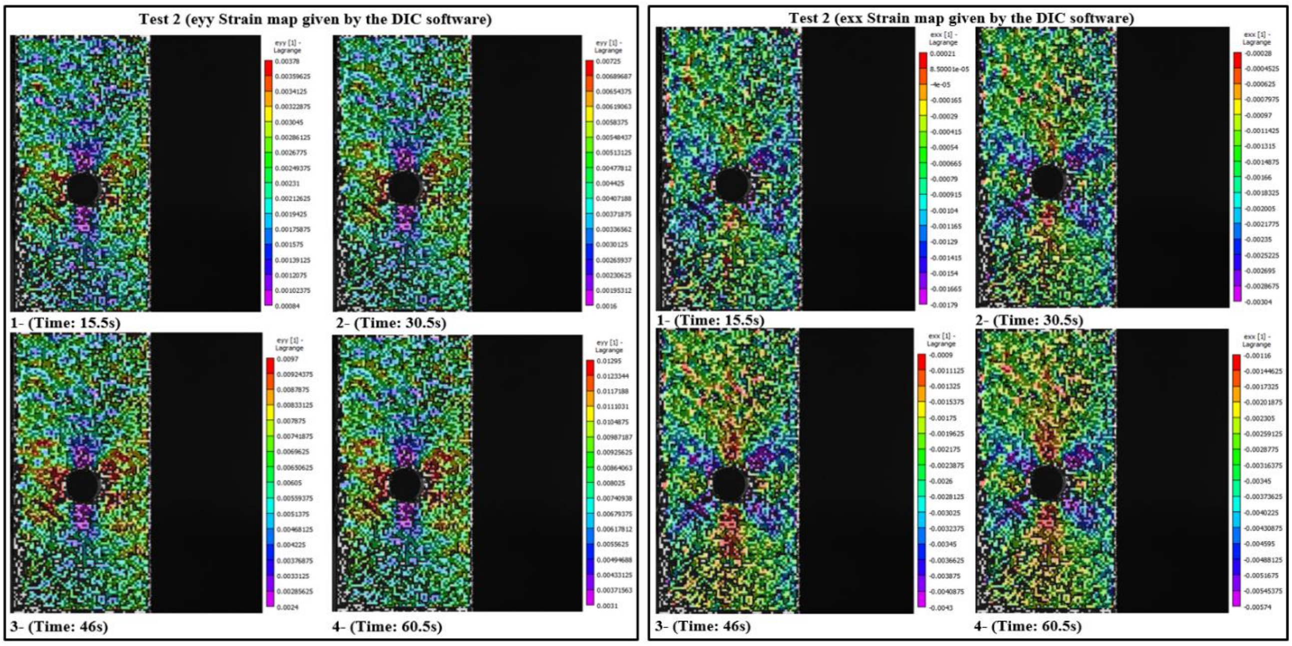

Figure 1 – Examples of strain outputs from the testing.

Concluding Remarks: A limitation of DIC is in the assessment of strain around holes, because of the problem of getting information close to edges. By minimising the subset size and increasing the density of the speckle pattern, more data can be collected at critical points like edges of a notch. However, there is a trade-off between the aliasing effect and the subset size which must be taken into consideration. This problem has been quantified by having the speckle pattern covering the hole surface and by manually cutting the hole surface using the VIC-3D software.Whilst not suitable in every circumstance, the use of transfer paper to apply a speckle pattern, rather than a rolled-on or spray-painted pattern removes the edge and allows information to be gathered from the whole area of interest. .

References

[1] M. A. Sutton, J.-J. Orteu, and H. Schreier, Digital image correlation for shape and deformation measurements. Springer, 2009.

[2] International Digital Image Society, A good practices guide for digital image correlation, no. 1. iDICs, 2018

[3] S.J.C. Matthews, B.J. James, R.L. Livesey, M.J. Oldfield, P.A. Smith and D.A. Jesson, A practical method for producing optimised and consistent speckle patterns for digital image correlation, in preparation

[4] B. Pan, H. Xie, Z. Wang, K. Qian, and Z. Wang, Study on subset size selection in digital image correlation for speckle patterns. Optics Express, 2008.

[5] A. Khechai, A. Tati, B. Guerira, A. Guettala, and P. Mohite, Strength degradation and stress analysis of composite plates with circular, square and rectangular notches using digital image correlation. *Composite Structures*, 185, pp.699-715, 2018.