Defect detection in wood-plastic composites using shearography

Mohsen Barmouz[a], Amir Hosein Behravesh[a] , Farshid Reshadi[b]
[a]University of Tarbiat Modares, Tehran, 14115-111, Iran
[b]University of Tehran, Tehran, 11155-4563, Iran.

Abstract:

Shearography is a laser-based technique for full-field, non-contacting measurement of surface deformation, defect detection, residual stress measurement. There are several reports on the variety of composites shearography but there is no previous report on the wood-plastic composites shearography. The main aim of this research is assessment of shearograghy capability in these kinds of composites. Firstly for achieving this goal, a hole was inserted on the wood-plastic composite and shearography test was done after performing the thermal loading on the specimen. The results were indicating the formation of fringe pattern in derived images which showed that this method is reliable for these kinds of composites. In the next step three wood-plastic composites with different volume fraction of wood were tested by shearography method for determination of the probable defects. The results showed that the specimen with higher wood volume fraction has a defect in sub-surface which could be attributed to the low processability of this composite compared to the others.

Keywords: shearography, wood-plastic composite, extrusion, injection molding

Introduction:

Using the non-destructive tests (NDTs) for finding out defects has been always attractive for the researchers [1,2,3]. Digital technology of shearography records media and processes obtained data by video sensors. This method has some advantageous such as avoiding the use of consumable needed, reconstruction of fringe pattern without rely on Fourier filtering and real-time measurement and inspection [4,5]. Hung et al. [6] used shearography as a non-contacting optical strain rosette for determination of residual stress in plastic and composites. The development of shearography as a NDT method leads to use of holography stressing method for it [7]. The different ways of creating reasonable rigid-body motion for these methods have been pressure, vacuum, thermal and acoustical and mechanical excitations [4]. Some of important applications of this NDT method could be categorize as follows: reveal crack, reveal several areas of separation due to fatigue damage, inspection of adhesive-bonding composites assemblies [8,9,10,11].

Wood-plastic composites are one of the most practicable composites which widely are growing in various fields. Lots of plastics such as polyethylene, polypropylene, and PVC can be used as a matrix in this kind of composites [12,13]. The broad range of its applications is reported in previous researches which some of them are columns and timber in building sectors, load transportation (pallets) and etc [14].

The methods that can be used for fabrication of wood-plastic composites are extrusion and injection molding. The most usual method is extrusion which in it the premixed or separate polymer and wood components are fed into the extruder with additives and melted together

*A.H. Behravesh: Address: Faculty of Engineering, Department of mechanical Engineering Tarbiat Modares University, Tehran Iran. **E-mail address:** amirhb@modares.ac.ir

and shaped by passing through the die [12-14]. The injection molding method is also used for the premixed wood and plastic component using for fabrication of some other high applicable geometry which cannot be produced by extrusion [15].

In this research, it is tried to use of the shearography method for inspection of the wood-plastic composites. Then first step was the evaluation of possibility of performing shearography as a NDT method for this kind of composites. Subsequently after reaching this importance, three different wood-plastic composites were tested for detection of probable defect on them. It is worth mentioning that, there is no previous report on using the shearograpgy for inspection of wood-plastic composites.

Materials and methods:

The instruments used for shearography of the specimens are presented in the figure 2 which containing the anti-vibration table, Instron tensile test machine to constrain the specimens, 10 mv laser light source with the wave length of 632.8 nm, two mirror with Al coating , 1 in diameter and 9 mm thickness for bilateral radiation, two mirror with Al coating , 2 in diameter and 4.5 mm thickness for using in michelson interrupter, two cave-flat lens with 0.5 inch diameter to scatter the light and light beam separator with dimension of 20×20×20 mm. Also the CCD camera (ARTRAY 320P) was used for taking and recording the high quality images. Thermal stressing by heat radiation was used for creation of strain in the specimens. for improvement of the contrast in the shearography fringe pattern all the specimen surface tested were painted with white spray paint before test.

The polymeric matrix, high density polyethylene (HDPE), produced by Arak Petrochemical Complex, Iran, was used. Sieved oak wood sawdust, with sizes up to 30-40 mesh pine, was used as the wood component. Three volume fractions of wood powder including 10%, 25% and 40% (figure 1b-1d) were used to fabricate the wood-plastic composite by injection molding. Also one wood-plastic composite with volume fraction of 60% and polyethylene (HDPE) as a matrix was fabricated by extrusion to primary shearography test (figure 1a).

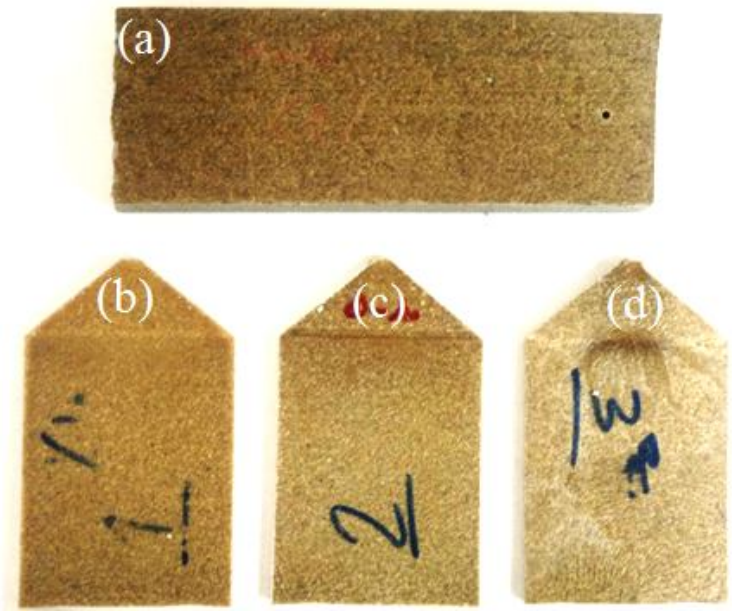

Figure1. Specimens fabricated by (a) extrusion containing 60% wood and (b-d) injection molding containing 10, 25 and 40% wood, respectively.

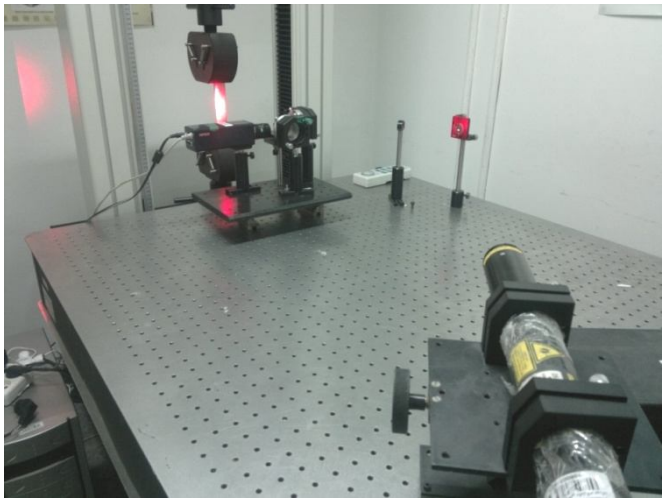

Figure2. The shearography test instruments

Result and discussion:

As mentioned above the specimen fabricated by extrusion used for assessment of defect detection via shearography in wood-plastic composites. In order to gain this aim the constrained specimen was loaded by creation of thermal strain resulting from heat-radiation in it. The result which is shown in figure 3a presenting presence no defect in the specimen due to the formation of parallel dark line in the filtered image. However to insurance of obtained results, a hole with 1 mm diameter was drilled on one side of this specimen and the shearography process was done again. Figure 3b shows the obtained result for this step which formation of fringe pattern in the image is indicating of defect (the hole which inserted on it) presence in it. As a result, it could be concluded that; shearography is a promising method for defect detection in the wood-plastic composites.

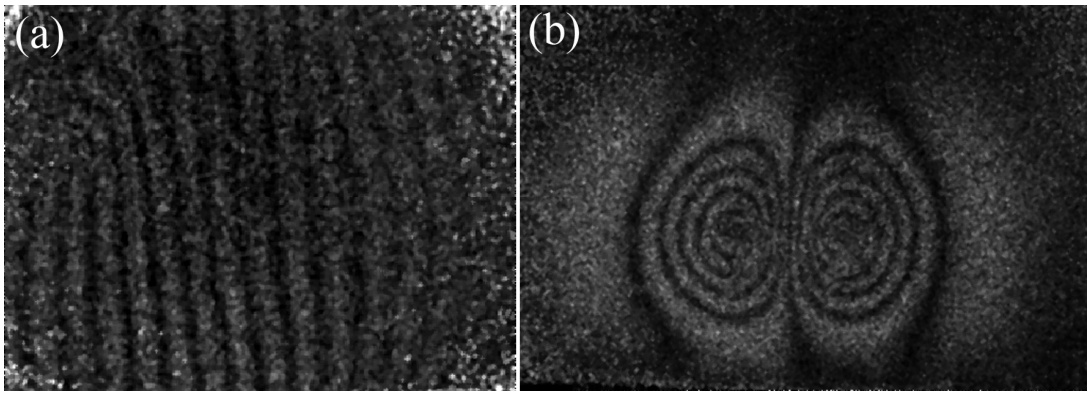

Figure3. (a) Parallel dark line resulted from extruded composite and (b) fringe pattern in dark lines in drilled specimen

Then, in the next step specimens fabricated by injection molding were underwent the shearography evaluation on the aim of discovering the probable defect on them. Figures 4a-4d show the shearography test results in 1, 2, 3 and 4 second after unloading of first specimen (figure 1b) which exploring the absence of any defect on it. As it is seen in these images, the vertical dark lines in different times remain parallel and just are being close to each other without deviation. This result was expectable because of low volume fraction of the wood (10%) in it which may leads to; 1) facilitate the material flow as a result of low viscosity of composite during process and 2) good dispersion of the wood in the polymer matrix.

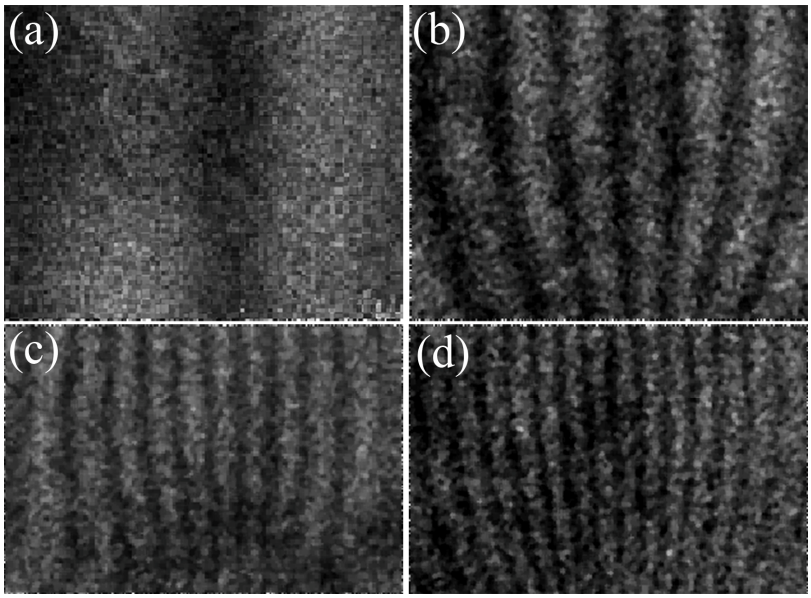

Figure4. parallel dark lines resulted from injection molded specimens with 10% wood in (a-d) 1-4 second after unloading, respectively.

Subsequently, Second specimen (figure 1c) containing higher amount of the wood (25%) in matrix in comparison with first specimen was also evaluated by shearography. Figures 5a-5d show the obtained shearography results in 2, 4 and 6 second after unloading for this specimen.

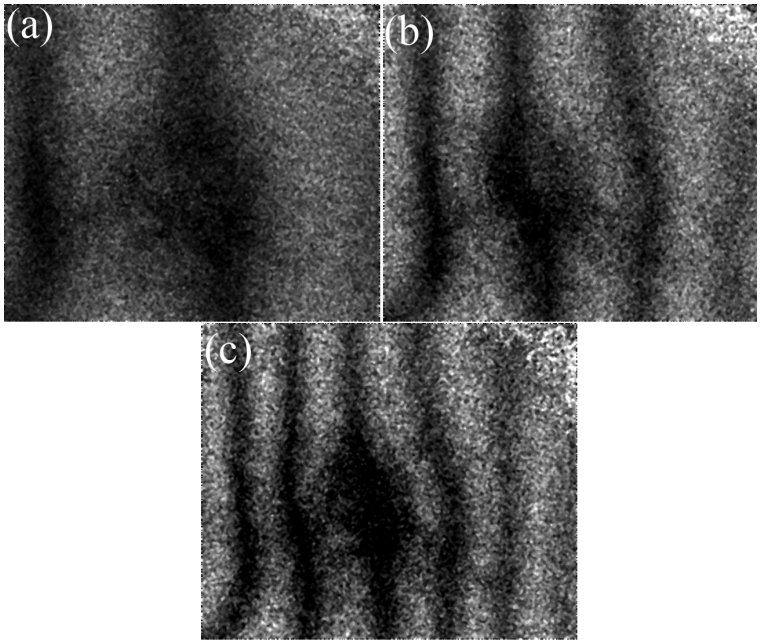

Figure5. Dark lines patterns resulted from the shearography test of the injection molded composite with 25% wood. (a-c) 2,4 and 6 second after unloading, respectively.

The images showing the vertical dark lines which are closing to each other with time passing, however there is small deviation of vertical dark lines which could be due to wood powder agglomeration. As it was discussed more in previous reports the higher volume fraction of fillers in the composites lead to reduction of separation quality in the particles.

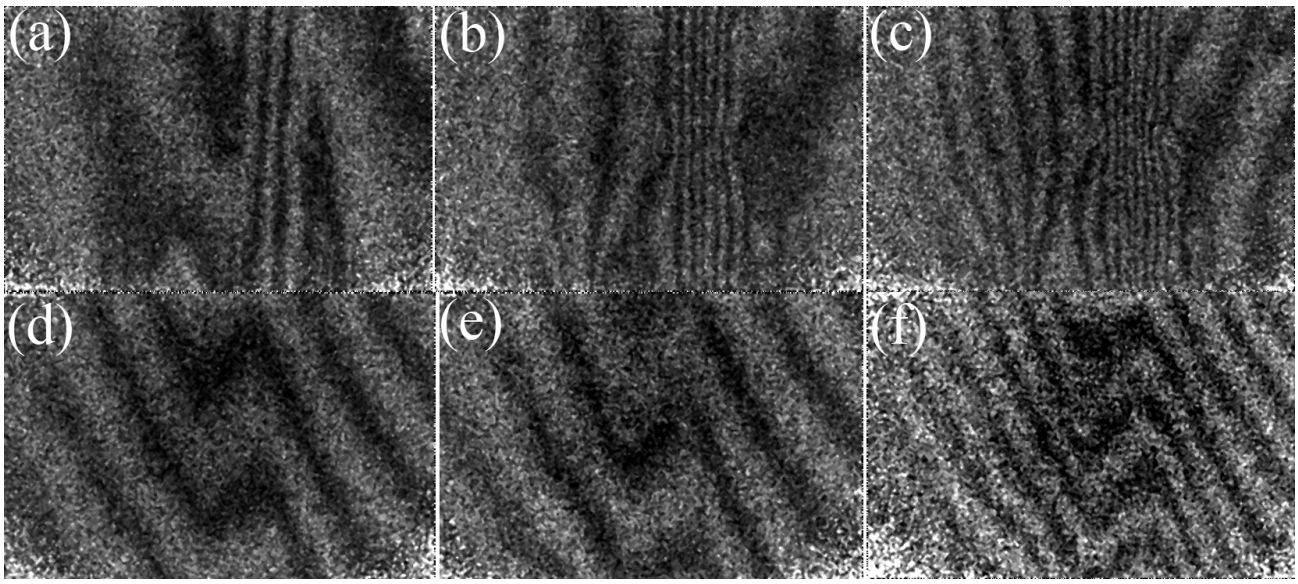

Figure6. dark lines patterns resulted from the shearography test of the injection molded composite with 40% wood. (a-c) 1,2 and 3 second after unloading, respectively; for the bilateral constraining and (d-f) 1,2 and 3 second after unloading, respectively; for the one end constraining.

The specimen with the highest volume fraction of the wood powder (figure 1d) is the next step for shearography test. At first, the specimen was constrained like the previous ones and took the images for 1, 2 and 3 second during the unloading as they are shown in figure 6a-6c. It is clear that there is a heterogeneous pattern in the dark vertical lines with time passing. The dark lines are erratically forming through the unloading process and it can be seen that the distance between the lines are not the same. Also some of dark lines are deviated and are not parallel with each other which all of this observation allude to presence of serious defect in this composite.

In order to evaluation of accuracy of the obtained results the other way of limitation on the specimen was also examined. The specimen was constrained in one end and the other one was free. The loading condition was the same as previous experiments which thermal stressing by heat radiation was applied on it.

Figures 6d-6f show the shearography results for this kind of limitation and as it is clear, the images inferred the presence of crack in the subsurface layers of the composites. The broken dark lines present the disintegration of the composite structures in sub-layers which lead to the deviation of reflected lights from the specimens' surface.

The reasons for this phenomenon could be accompanying of the some challenging difficulties in composites fabrication and could be categorized as follows: 1) the composites with higher volume fraction of the fillers have higher viscosity which this problem makes the fabrication of them difficult as a result of low tendency of material to flow. 2) As it was discussed above the higher content of wood powders makes the separation of them hard. This surely leads to agglomeration of the wood powders in the matrix which forms the de-bonding and crack in composites structure.

Conclusion:

In this research the shearography was successfully used as a NDT method for wood-plastic composites inspection. Then the wood-plastic composites with different volume fraction of wood powder were underwent the shearography test. Some of interesting results are presented briefly below:

1) The shearography of the holed wood-plastic specimen shows the formation of the fringe pattern in filtered images which was the deal for successful application of this method for inspection of the wood-plastic composites.
2) The wood-plastic composites with different volume fraction of filler show various pattern of vertical dark lines presenting the presence or absence of defect in them.
3) The specimen with lower fraction of wood shows no defect due to the high processibility of it resulted from the high viscosity and good dispesion of wood powders.
4) The specimen with highest fraction of the wood has low viscosity and heterogeneous dispersion of the wood powder which leads to presence of sub-layer crack.

References:

[1] M. Paul, B. Haberer, W. Arnold, Mater Sci Eng: A, 168(1993) 87-92

[2] V.L.A Freitas, V.H.C. Albuquerque, E.M Silva, A.A Silva, J.M.R.S. Tavares, Mater Sci Eng: A, 527(2010) 4431-4437.

[3] H. Mei, H. Li, X. Deng, L. Cheng, Mater Sci Eng: A, 553(2012) 45-50.

[4] Y.Y. Hung, H.P. Ho, Materials Science and Engineering: R 49 (2005) 61–87.

[5] Y. Zhang, T. Li, Q. Li, Defect, OPT LASER TECHNOL, 47(2013) 64-71.

[6] Y.Y. Hung, H.M. Shang, L. Lin, Y. Zhang, X. Wen, , SAE Paper #1999-01-1254, 1999 SAE International Congress and Exposition, Detroit, ichigan, March 1–4, 1999.

[7] R.K. Erf (Ed.), Holographic Nondestructive Testing, New York, Academic Press, 1974.

[8] Y.Y. Hung, in: Proceedings of the 1997 SEM Spring Conference, Bellevue, Washington, June 2–4, 1997, pp. 98–99.

[9]Z. Liu, J. Gao, H. Xie, Ph. Wallace, OPT LASER ENG, 49 (2011) 1462–1469.

[10] C. Garnier, M-L. Pastor, F. Eyma, B. Lorrain, Compos Struct, 93(2011)1328–1336.

[11] F.C. Catalan, A.M.S. Maallo, P.F. Almoro, Opt Commun, 285(2012)4223–4226.

[12] A. H. BEHRAVESH, E. SHAKOURI, A. ZOLFAGHARI, M. GOLZAR, J COMPOS MATER, 44(2010)543-549.

[13] E. SOURY, A.H.BEHRAVESH, H. G. NASRABADI, A. ZOLFAGHARI, J. Reinf. Plast. Compos, 28(2009) 439–451.

[14] B-J. Kim, F. Yao, G. Han, Q. Wang, Q. Wu, Composites Part B: Engineering, 45(2013) 1040-1048.

[15] N. M. Stark, L. M. Matuana, Polym. Degrad. Stab. 92 (2007) 1883-1890.