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Research article

Assessment of Fevicol (adhesive) Drying Process through Dynamic Speckle Techniques

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Abstract: Dynamic laser speckle (or biospeckle) analysis is a useful measurement tool to analyze micro-motion on a sample surface via temporal statistics based on a sequence of speckle images. The aim of this work was to evaluate the use of dynamic speckles as an alternative tool to monitoring Fevicol drying process. Experimental demonstration of intensity-based algorithm to monitor Fevicol drying process is reported. The experiment was explored with the technique called Inertia Moment of co-occurrence matrix. The results allowed verifying the drying process and it was possible to observe different activity stages during the drying process. Statistical Tukey test at 5% significance level allowed differentiating different stages of drying. In conclusion, speckle activity, measured by the Inertia Moment, can be used to monitor drying processes of the Fevicol.

Keywords: dynamic speckle; Inertia Moment; Fevicol; drying; activity

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1. Introduction

Fevicol is a brand of adhesives owned by the Indian company Pidilite. It is one of the largest selling adhesives brands in Asia. Fevicol MR (white adhesive) is a product introduced to the bonding, which are exposed to high humidity and water. Fevicol MR (white adhesive) can resist under water for more than 48 hours and 1 hour in boiling water. It is used to bond things very quickly, binds itself in 2 hours and dry to form an invisible layer. It strongly binds wood, plywood, laminate, veneers, MDF and all types of boards, cork etc. and is responsible to produce durable world class furniture. Termites cannot attack the furnitures if Fevicol MR (white adhesive) is used to manufacture the furniture.

The short drying times of Fevicol MR (white adhesive) are of great benefit in some applications, and this property allows for applying it over almost immediately. However, this fast-drying process precludes following it using conventional techniques. In this work, we therefore have used the dynamic speckle phenomenon to follow the drying process.

Dynamic laser speckle analysis is a useful measurement tool which can be used to analyze micro-motion on a sample via temporal statistics based on speckle images over time. This statistical method known as dynamic laser speckle analysis can be used in many fields such as measuring surface activity of the viable material [1], plant seed activity analysis [2], blood flow detection [3–5], visualization of tissue perfusion [6], monitoring paint drying process [7,8], in identification of fungi [9], fruit maturation and quality monitoring [10–12] sensing activity of growing roots [13] etc.

The evaluations of dynamic speckle activity can be carried out using numerical as well as graphical methods. Numerical approaches include Inertia Moment [14], Absolute Values of Difference [15,16] etc. whereas methods such as Generalized Difference [17] and Fujii [18,13] give the activity maps of biological activity. The method of Inertia Moment (IM) is based on the generation of a gray level matrix called time history of speckle pattern (THSP) which contains information about the activity on a sample. It gives comparatively better results when the THSP matrix store data at high frequencies, i.e. when the sample exhibit bigger activity [19].

In this paper, experimental demonstration of the dynamic speckle processing methods to monitor Fevicol drying process are reported. Numerical approach of Inertia moments has been used to monitor the drying process.

2. Materials and Method

2.1. Experimental

The experiment related to the drying process was conducted with a coin completely covered by a thick layer of Fevicol MR (White Adhesive, Pidilite Industries, India) as sketched in Figure1b. The coin with its areas of different activities, the process of Fevicol drying was illuminated by the backscattering approach as presented in Figure 1a. The painted coin was placed inclined at an angle of about 5^0 with the horizontal in order to monitor downward streaming of wet Fevicol along with the drying process.

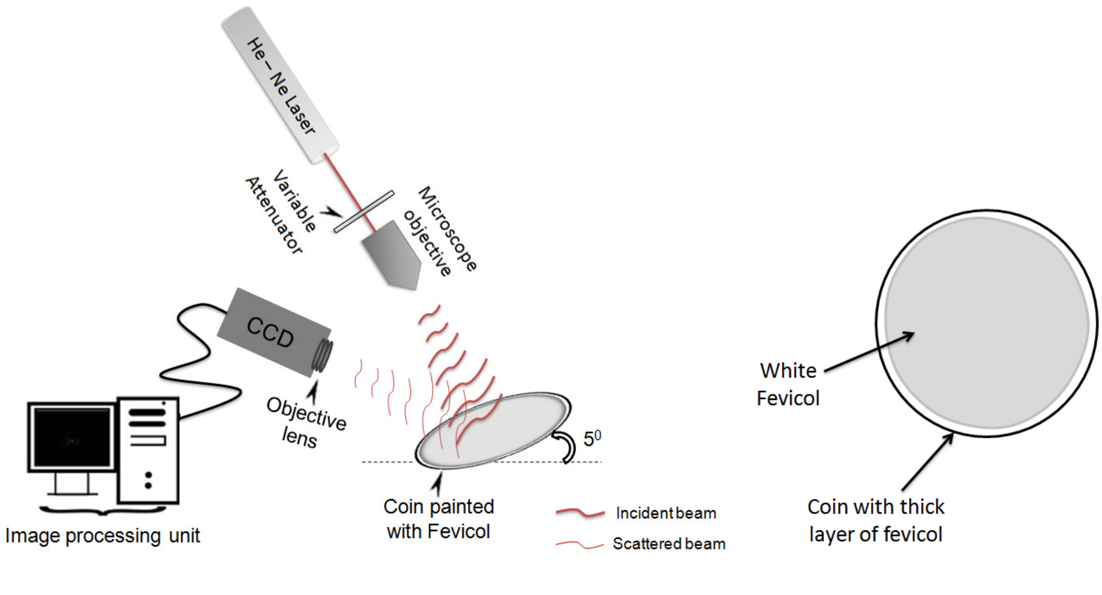
For the experiment, a collection of 130 speckle images were acquired every 0.08 s with a CCD camera (Basler, Germany). Consecutive speckle images were sent to the computer where they were processed using the algorithms mentioned in Section 2.2. Samples were illuminated with a 3 mW, He-Ne laser, operating at 632.8 nm, spatially filtered and expanded to cover the sample. The images were collected in a CCD camera (Basler, Germany) with resolution of 1294 × 964 pixels, frame rate 32 fps and 3.75 × 3.75 pixel size. The camera exposure time was typically 3.6 ms.

2.2. Dynamic laser speckle-processing techniques: Inertia Moment

An alternative way to characterize speckle time evolution is based on the co-occurrence matrix of the intensity in the time domain. Co-occurrence matrix (COM) is defined as

$$COM = [N_{ij}] \tag{1}$$

The involved N values are the occurrences of a certain gray value i followed in the next time step by a value j in the time history speckle pattern (THSP) as described by Ansari & Nirala [12,14].



(a) (b)

Figure 1. (a) Backscattering speckle laser schematics adopted in painted coin, (b) Schematic of painted coin with white Fevicol.

When the intensity does not change, the only nonzero values of this matrix belong to its principal diagonal. As the sample shows activity, intensity values change in time, the number N outside the diagonal increases, and the matrix resembles a cloud. For normalization purposes, it is convenient to divide each row of this matrix by the number of times that the first gray level appears [1].

$$M_{ij} = \frac{N_{ij}}{\sum_{j} N_{ij}} \tag{2}$$

Then, the sum of the components in each row equals 1. M_{ij} is modified co-occurrence matrix (MCOM).

Figure 3 shows the two situations—(a) high and (b) low activity—co-occurrence matrices, corresponding to the two examples shown in Figure 2 and representing a wet and an almost dry Fevicol. It can be seen that when the phenomenon is very active, the associated cooccurrence matrix is spread; otherwise, it is concentrated around the principal diagonal.

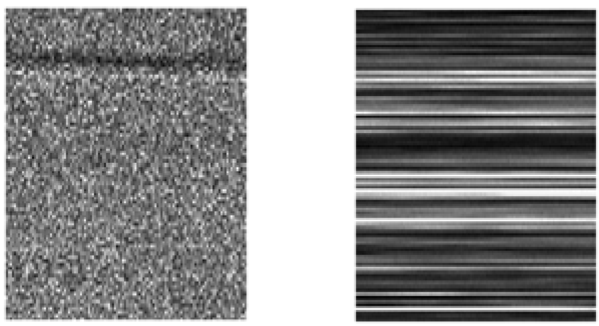
A measurement of the spread of the M values around the principal diagonal with these features can be constructed as the sum of the matrix values times its squared row distance to the principal diagonal. This is a particular second order moment called the inertia moment (IM) of the matrix, with respect to its principal diagonal in the row direction.

So, inertia moment (IM) is defined as

$$IM = \sum_{ij} M_{ij}(i-j)^2 \tag{3}$$

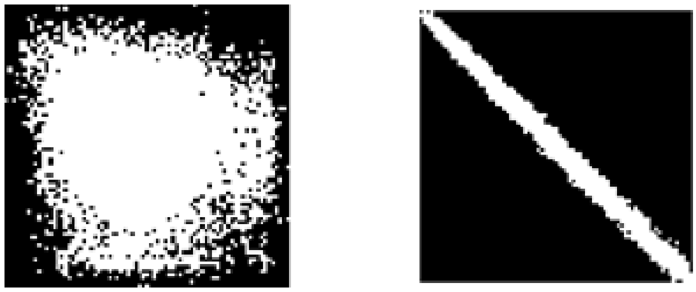
3. Results and Discussion

The dynamic speckle patterns corresponding to different drying stages in the coin with Fevicol were registered by a CCD camera, digitized to 8 bits by a frame grabber and stored in the computer memory. For every state of the phenomenon being assessed, 130 successive images of 190 × 170 pixels were registered and a certain column, (for example middle one) selected in each of them and a new 130 × 170 pixels composite image, called THSP, then constructed. This procedure was same that we used in previous works [12,14].



(a) (b)

Figure 2. THSPs of two different states of drying of Fevicol. (a) High activity; (b) Low activity.



(a) (b)

Figure 3. Modified co-occurrence matrices for two stages in Fevicol drying, related to the THSPs presented in Figure 2. (a) High activity; (b) Low activity.

Figure 4 presents the evaluation of transient process during Fevicol drying on a coin through the construction of temporal history of speckle pattern (THSP). Just after paint, the THSP shows its resemblance with ordinary spatial speckle pattern. The corresponding modified co-occurrence matrix (MCOM) presents points spread around the main diagonal. As the Fevicol dry, the THSPs resemble elongated shape with corresponding MCOM presents points very near to main diagonal (Figure 4C). The complete dry of the Fevicol imply horizontal parallel bar shaped pattern of the THSP with its MCOM presenting points on the main diagonal only (Figure 4D). At 60 minutes of drying, it is possible to monitor the slow streaming of Fevicol (Figure 4C and 5) from the coin surface.

The mere look of the THSP image gives an idea of how active is the sample. Figure 6 shows the THSP images of different possible states of the drying of Fevicol and one typical line for each that shows both profiles.

Figure 6 shows different activities characterized by the line profiles. The fast variations of amplitude of gray values are responsible to raise the value of MI [1]. In Figure 6 it is exemplified with respective IM values representing the major influence of high frequencies in IM values.

The quantitative measure of the dispersion of points around the main diagonal is characterised by the so called “Inertia Moment (IM)”. Figure 7 presents the plot of speckle activity measured through IM with spatial frequency. The IM values increases rapidly with frequency up to 30 minutes and then decreases till the Fevicol completely dry. The complete dry correspond to IM values of 0 as shown using solid line of the curve (Figure 7).

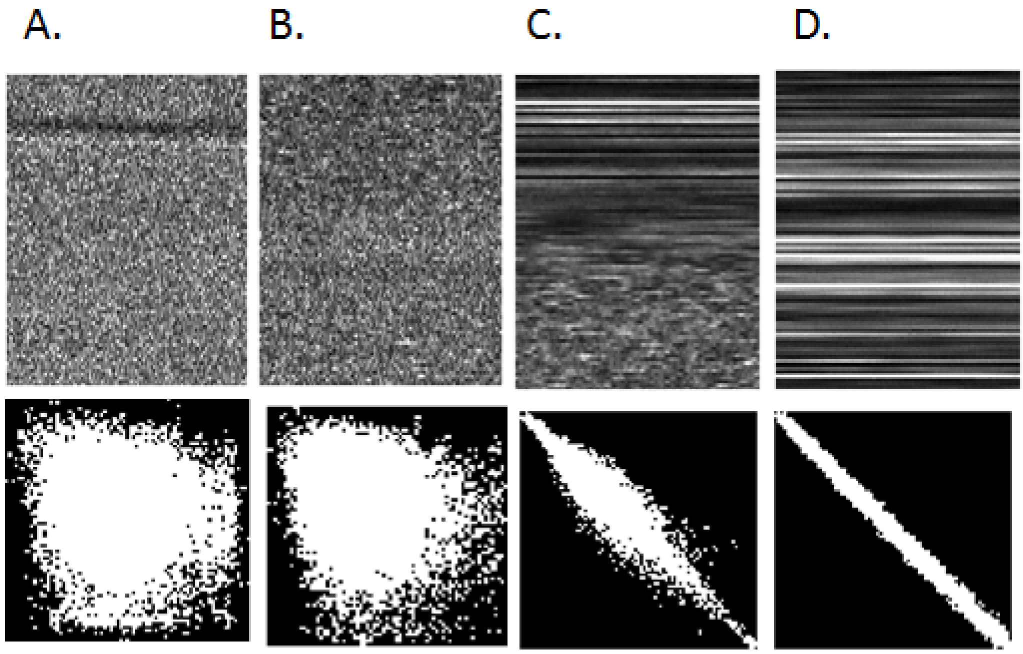


Figure 4. THSPs and corresponding modified co-occurrence matrices (MCOM) during drying of Fevicol painted on a coin at 0 min (just after paint), 30 mins, 60 mins and 120 mins respectively. Bigger velocities of scatterers (for example just after paint) imply more randomly THSPs. The corresponding co-occurrence matrices present spread points around the main diagonal. Low-level activity generates THSPs similar to patterns of horizontal parallel bars with co-occurrence matrix presents points along the main diagonal only.

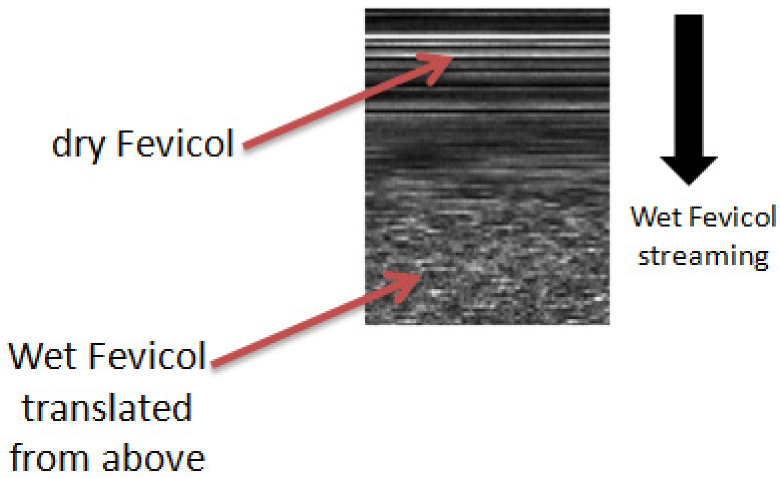
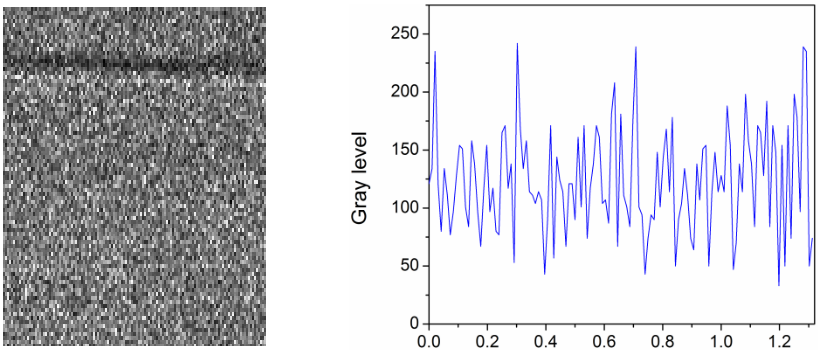
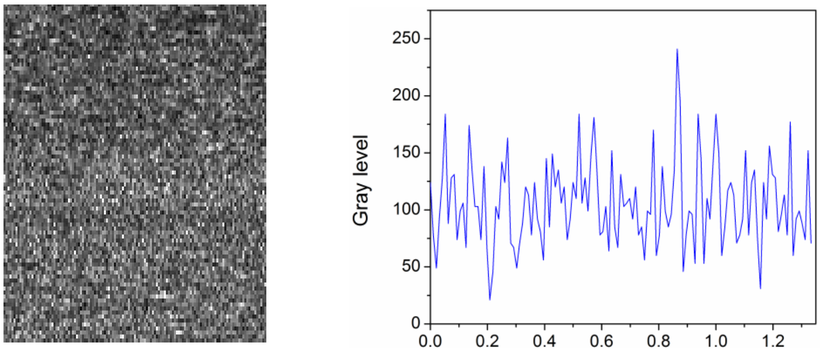


Figure 5. Time evolution of drying of slowly streaming Fevicol painted on a coin at 60 min. Fevicol streaming from above leave the area with less concentration of scatterers and drying process is comparatively fast here which is represented by parallel bar shaped lines.


Gray level
0
50
100
150
200
250
0.0 0.2 0.4 0.6 0.8 1.0 1.2

(a)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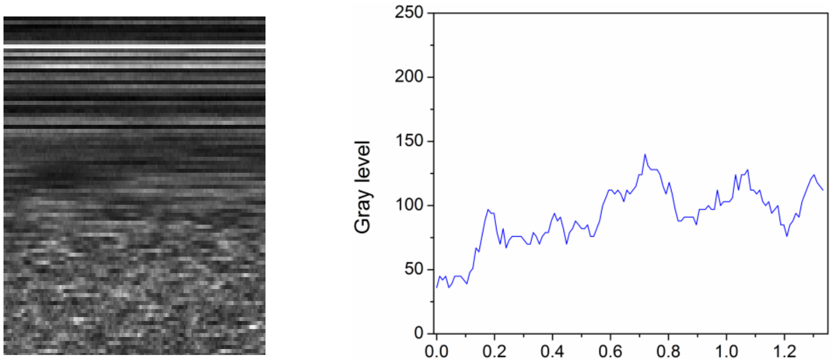
(b)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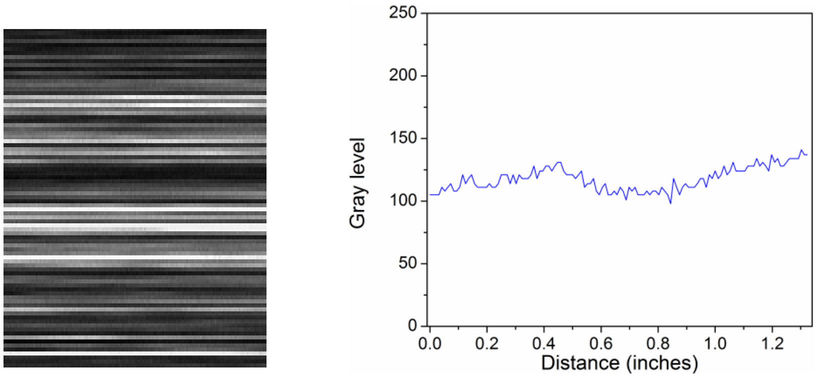
(c)


Gray level
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50
100
150
200
250
0.0 0.2 0.4 0.6 0.8 1.0 1.2
Distance (inches)

(d)

Figure 6. THSPs of different states of drying of Fevicol and their profile lines, respectively. Notice the major influence of high frequencies on IM values: (a) IM = 18291, (b) IM = 9474.9, (c) IM = 636.14, and (d) 83.83.

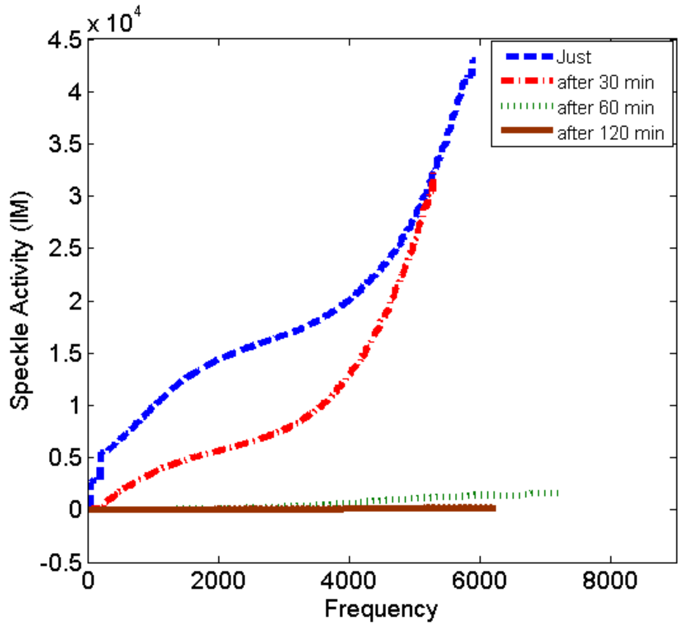

Figure 7. Speckle activity in terms of IM values versus frequency.

In Figure 8, experimental results of the quantitative IM speckle activities are plotted vs the time of the Fevicol drying. It shows a sharp fall of IM values in a short time. The result thus suggests a correlation of the speckle activity with drying process of the Fevicol according to the textural properties of the sample.

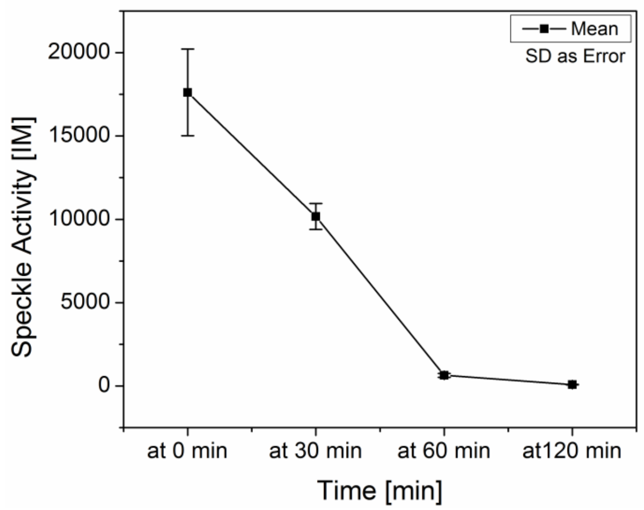

Figure 8. Inertia moment (IM) of THSP during drying process of Fevicol painted on coin. Error bars correspond to standard deviation.

Figure 9 presents the statistical variance analysis for the mean values of inertia moments during drying. For the variance analysis, IM values were measured for six different THSP images of the registered speckle patterns. Mean values of IM were calculated and submitted to statistical Tukey test. Figure 9 demonstrates that there are differences between the mean values of IM evaluated through the Tukey's test at 5% significance level. However, there are no significant differences observed for the average values of IM at 60 minutes and 120 minutes of drying which could be due to very slow process of the phenomenon at 60 minutes (see Figure 7 and 8). It can be concluded that the speckle activity, measured by the IM, can be used to monitor the drying processes of the Fevicol.

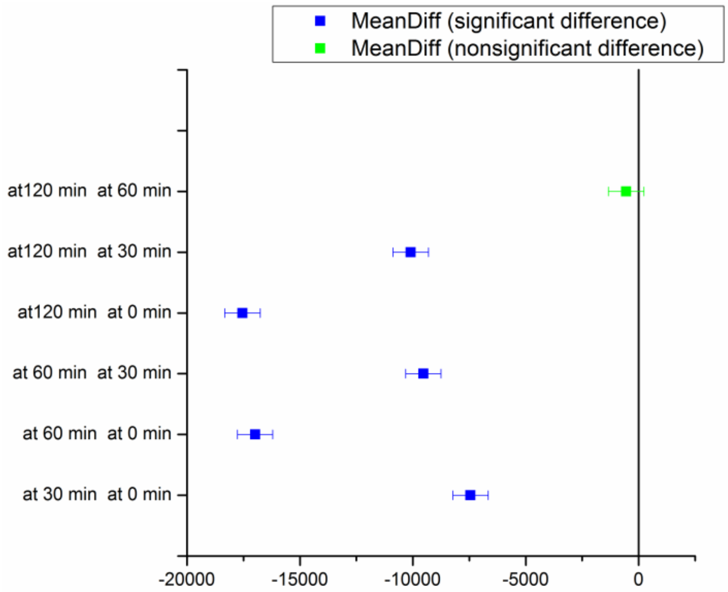

Figure 9. Statistical Tukey test for the mean values of IM at 5% significance level.

4. Conclusions

We have presented the application of intensity-based method of "inertia moment" using dynamic speckle techniques to study the drying of Fevicol MR (white adhesive). The method of Inertia Moment of co-occurrence matrix has been found useful to quantify the speckle activities of the Fevicol during its drying process. The results allowed verifying the drying process and monitoring different activity stages during drying.

Conflict of Interest

There is no conflict of interest.

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