# DETERMINING OF STRAIN RATIO IN TENSILE TEST USING BY IMAGE PROCESSING

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***Abstract:*** *In tensile machines to measure the change in length of the specimen during the stress, most time extensometer and various contact methods and tools, such as strain gauges are used, but these methods have limitations and low accuracy that cause unexpected and different results from the theoretical values for the strain. In this paper, to address this shortcoming and improve strain measurement, a non-contact method using image processing techniques in the MATLAB environment is introduced. for this purpose after capturing a move of tensile test and converting that in to some high quality pictures and using image processing we put some pattern in the first image and with using a special algorithm with name of Digital Image Correlation (DIC) detect that patterns until the last image then we can use of displacement algorithm and calculate change in the specimen's length and after that we can also have "Strain" with using these values.*

*KEYWORDS: DIGITAL IMAGE CORRELATION, PATTERN RECOGNITION, STRAIN*

***Introduction:*** Nowadays we can see in order to perform strain test and record strain-stress changes, many of corporations or Academic Centers use of tensile machines. In these devices two different mechanisms measure the force and length change. For measure of the force they use of the change in length of the spring or use of force meters. Also the general mechanism for measuring the change in length of the specimen is using of strain gauge or Shaft encoder or Extensometer that all of these conventional instruments have special limitation for themselves. Therefore, in this study, to reducing these deficiencies in tensile testing machine we prepare a new and non-contact method that use of image processing to solve these problems. Fig 1)

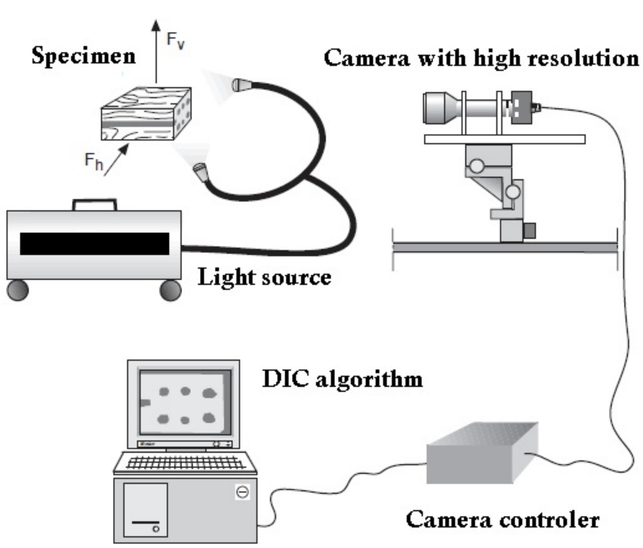


***Fig. 1:*** *A schematic overview of research*

As you see tensile test specimen is connected to the machine and after that a camera with a high speed shooting capture movie as our specimen tolerate a force Then algorithms for image processing and digital image correlation function in MATLAB environment, measure variability of the sample. New method for detecting changes in the length is using of digital image correlation [1]. Image processing is a new and very powerful technique in computer science and electronics which has been implemented in several studies in various fields. For example, Shell and Nicola have used this method to achieve their goals [2,3].The use of image processing has many advantages, for one it is not difficult like conventional methods and also it has good accuracy. We can say there are several algorithms for computing the strain of an object that most common of them is based on image correlation. Correlation or cross-correlation between two images is a standard approach for the detection of object features which has also been widely used to measure the surface deformation. This method of analysis is called digital image correlation (DIC) which can detect form of shape and its movement. DIC is an optical metrology based on digital image processing and numerical computing. It was first developed by a group of researchers at the University of South Carolina in the 1980s [4–8] when digital image processing and numerical computing were still in their infancy [8]. In this technology some spot (like black and white points) will be selected in the surface of specimen and then we will take a picture. Now our pattern is ready. Many of these patterns will be prepared before deformation and also after deformation. These patterns will be then sent to the computer after digitization. In the next step digital images will be compared with each other. Generally a subset of pixels (30 × 30 or 40 × 40) from original picture will be selected. The algorithm works like this:

Position of the subset in the first picture will be searched in the second picture with matching of Gray Levels and for each point will be calculated a level of Gray light intensity and therefore we can find the closest match points in the second image with the original image subsets. Thus, the position of the points in the secondary image is obtained. After getting these subsets in the second picture we can have movement amount of specific points. Fig 2 can show an overall view of this topic:

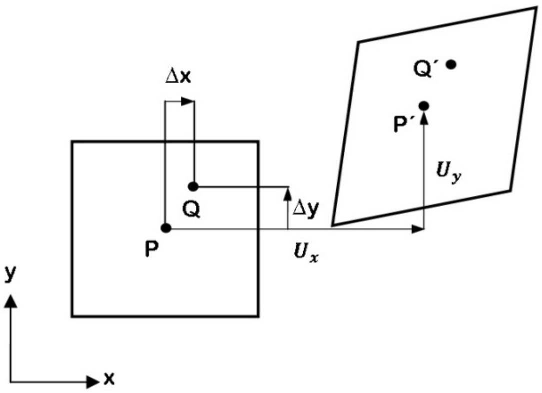


***Fig 2.*** *Moving points in successive images*

In order to better estimate the displacement, one particular factor “S” is defined as the normalized cross-correlation:

$$(1) \qquad s\left(x,y,u_x,u_y,\frac{\partial u_x}{\partial x},\frac{\partial u_x}{\partial y},\frac{\partial u_y}{\partial x},\frac{\partial u_y}{\partial y}\right)=1-\frac{\sum I_u(x,y)I_d\left(x^*,y^*\right)}{\sqrt{\sum I_u(x,y)^2\sum I_d\left(x^*,y^*\right)^2}}$$

here $u_x$ and $u_y$ are movement parameters in the center of subset. $I_u$ and $I_u$ show Gray levels from Original image and the deformed image respectively. $(x,y)$ and $(x^*,y^*)$ are Coordinates of the point before and after deformation. So that the Coordinate of $(x^*,y^*)$ after deformation is related to $(x,y)$ before deformation.

$$(2) \qquad x^* = x + u_x + \frac{\partial u_x}{\partial x}\Delta x + \frac{\partial u_x}{\partial y}\Delta y$$

$$(3) \qquad y^* = y + u_y + \frac{\partial u_y}{\partial x}\Delta x + \frac{\partial u_y}{\partial y}\Delta y$$

We should also mention that all of this work can be performed in the MATLAB environment. In other words, we can advance our project with help of image processing toolbox functions and there is no need for the user to use more complex formulas.

The core of the correlation tool is based upon a Matlab routine which uses a normalized cross correlation to correlate a part of the source image with the target image (Fig 3). This routine uses the grey scale levels of the pixels in the area of interest. The routine returns for each pixel in the target image a correlation value between -1 and 1. The value 1 means that the part of the source image is exactly the same as the area in the target image, 0 means that no correlation exists and -1 means that the analysed area in the target image is a negative of the source image. Because DIC is an image based technology, a pixel based coordinate system is used. In this correlation tool the X and Y coordinate within an image are defined as shown in Fig. 3. The correlation square is always uneven with the pixel of interest exactly in the centre of this square. The size of the square must be such that enough detail of the specimen surface is included such that the square is unique. For instance if only one pixel is taken in the example, many locations exist in the target image which are the same. In the correlation tool the size of this square can be adapted.

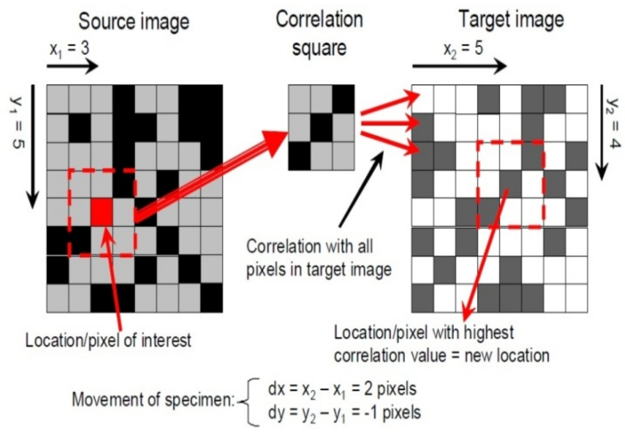


***Fig 3.*** *Correlation process for one pixel*

The correlation square is compared with all the pixels in the target image, returning a correlation value for each pixel, resulting in a data set as illustrated by Fig 4. The location in the target image that corresponds best to the correlation square is clearly recognized by the peak with the highest correlation value. However, the new coordinate has an accuracy of 1 pixel which is not accurate enough for strain measurements. To get higher accuracy a method was developed which uses the correlation values around the peak to get sub pixel level accuracy. To obtain that a 6th degree polynomial surface is fitted through the correlation values of the pixels around the pixel with the highest correlation value, using a least squares approach. By filling a grid of sub pixel coordinates into the function of the fitted polynomial surface, a new maximum can be obtained at sub pixel level. In the correlation tool the resolution in which the coordinates are given is 0.01 pixels. It was found that a higher resolution did not further contribute to the accuracy of the measurement [19].

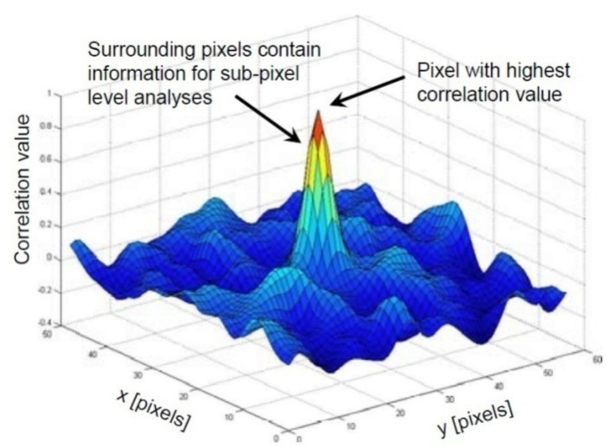


***Fig 4.*** *Correlation values for an area in a target image*

## *Implementation:*

The main processing in this test is defined like this:

For the first step we should prepare some pictures from our specimen before deformation. In this test, in order to remove possible vibrations, for example vibrations caused by the tensile test machine, we use of video camera. Finally, we can prepare some good pictures without any vibration. For this purpose we use a software that is suitable for video cameras (Fig 5). Other available software may be used for the purpose of this research.

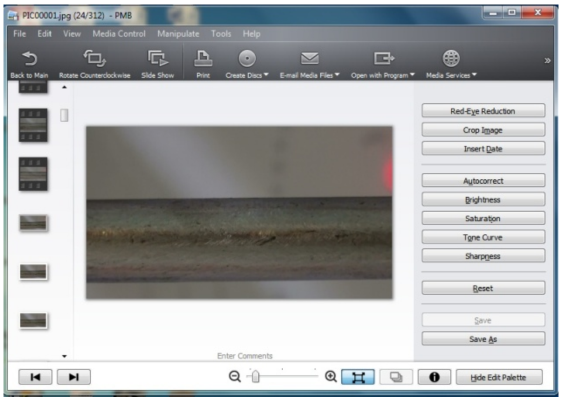


***Fig 5.*** *PMB software from "SONY" corporation*

as we mentioned we have a video camera that its specifications is as follows(Fig 6):

Lens: Carl Zeiss® Vario-Tessar / 30m
Zoom Ratio (Optical) 25X
Zoom Ratio (Digital) 300X

In the next step the prepared images should be processed. For this purpose all pictures are sent to the MATLAB environment. After this the first image will be called for processing. With help of written codes we can select a desire region for processing. We will do that with making a rectangle region (Grid) that can be processed. In simple terms, the image processing code will only focus on these points. Fig7 and demonstrate an example of this way.

***Fig 6.*** *Shoot picture with XR150E.*

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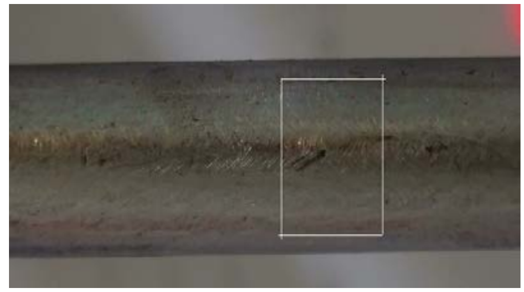

***Fig 7.*** *Select the desired region for processing*

As it can be seen in Fig 8 we have some yellow points for processing although in this level we can increase a points density which will be more accurate. However, the processing time will increase. In fact we can say processing time relates both parameters. First number of pictures and second point density

In the third phase, correlation algorithm starts and searches points in the first image onto the second image. This is done using “Cpcorr” function in the MATLAB environment. This function using normalized image correlation algorithm and match its input arguments that they have acquired from both pictures first, before deformation and second, after deformation. As a result, coordinates of specified points in the first picture will be emerged in the second picture. (To learn more about this function refer to the MATLAB Help). Although it is noteworthy we should have image processing toolbox in MATLAB. After finding the location of specified points in the second picture they will save and process will be continued in the third picture and like this process will be gone until the final stage. It should also be noted that if “Cpcorr” function cannot detect the position of some points it will return points to its previous position. In this case some points that are static in their position during the processing will be demonstrated. Also we should say if we increase the points density in the first stage its probability will be less that “Cpcorr” function don’t be able to detect position of points or in other word Noises will decrease dramatically. However, processing some area like this will require a computer system with powerful processors. Two different phases of image processing are visible in Fig 8

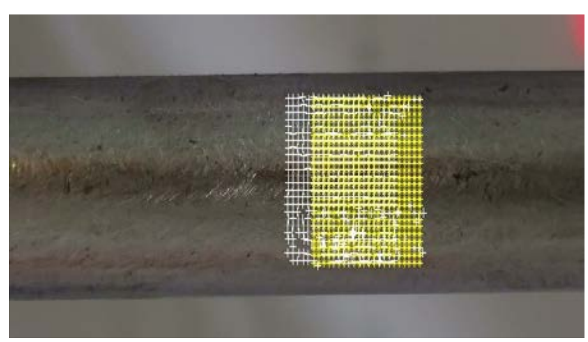

***Fig 8.*** *Coordinates of the points in picture 32*

In the fourth phase we can get the desired amount of displacement or traction during the test using the coordinates of points obtained for each image and processing and mathematical calculations on them. The result of the process will have two matrices. A matrix for the x coordinates of the points in each image and also other matrix y coordinates for the points in the same image. (Fig 9)

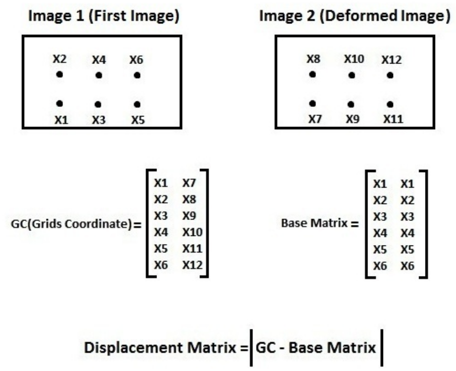


***Fig 9.*** *Calculating displacement matrix in X dimension*

Now with caring that the displacement matrix is available, we can calculate strain. It can be said the core of this research at this stage will implement like this:

It uses “GC” matrix, Displacement Matrix, and also a function with name of “Lsqcurvefit” in “matlab” optimization toolbox to calculate optimal strain. Optimal strain for processed pictures will fit with a liner function and then strain amount for each picture will detect.

***Result:*** With caring to image correlation Algorithm and also calculations the results will be presented like bellow: The plot (Fig 10) is related to the strain in the tensile direction. As shown, the strain is specified for each image.

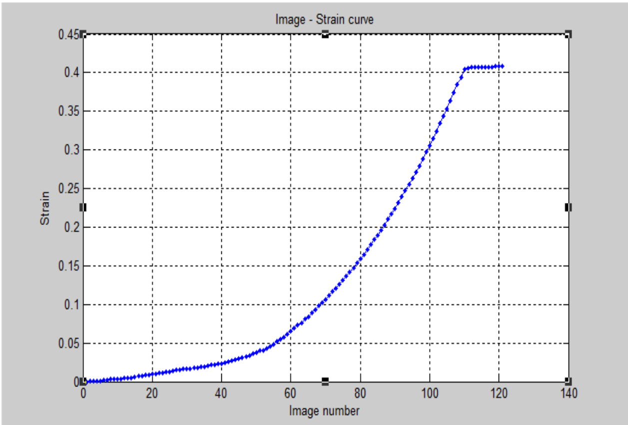


***Fig 10.*** *Strain plot in a tensile direction*

***Conclusions:*** With considering the results that are obtained through image correlation Algorithm and using of image processing techniques we can say although this method needs more accuracy during test but obtained results show our information after test can be reliable and even sometimes it can compete with conventional methods. So we can use of this method for an alternative ways for calculating Poisson’s ratio.

## *References:*

[1] Bing Pan, Kemao Qian, Huimin Xie and Anand Asundi. (2009), “Two-dimensional digital image correlation for in-plane displacement and strain measurement”,Measurement Science and Technology., 20, 062001

[2] Nicolella D.P., Nicholls A.E, Lankford J.and, 2001,Davy D.T, Machine Vision Photogrammetry: a technique for measurement of microstructural strain in cortical bone, journal of Biomechanics, 34,135-139.

[3] G’Sell C., Hiver J.M. and Dahoun A.,2002, Experimental characterization of deformation damage in solid polymersunder tension, and its interrelation with necking, International journal of Solids and Structures 39,3857 3872.

[4] PetersWH and RansonWF 1981 Digital imaging techniques in experimental stress analysis Opt. Eng. 21 427–31

[5] Chu T C et al 1985 Applications of digital-image-correlation techniques to experimental mechanics Exp. Mech.25 232–44

[6] Sutton M A et al 1986 Application of an optimized digital correlation method to planar deformation analysis Image Vis. Comput 4 143–50

[7] Peters W H et al 1983 Application of digital correlation methods to rigid body mechanics Opt. Eng. 22 738–42

[8] Sutton M A, McNeill S R, Helm J D and Chao Y J 2000 Advances in two-dimensional and three-dimensional computer vision Topics in Applied Physics 77, 323–72