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Measuring Deformation of Deep Drawing of Various Alloys by Image Processing using Matlab

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Abstract

Measuring deformation mostly is based on the contact type of measurements which utilize the gauges and instruments. But this type of contact will lead to error in the precise measurement because of errors by the contact, measuring instruments, and human. So, feel proud to introduce image processing in the field of measurement. Here, this study deals with the measurement of deformation of deep drawing specimen by image processing which is called as contact free method. This is invasive method of measurement in two dimensions. Deep drawing process is an important sheet metal forming in which flat sheet metal had been forced through the die in association with the forward punch force and opposing blank holder force. As the blank passes through the tool set converts 2D bank into 3D cup formation. The process of achieving the required diameter of the cup can be produced in single stage or multistage operation. In this study, experimental study had been conducted on single stage deep drawing process for assessment of deformation and strain in aluminum alloy, copper alloy and brass alloy. Cylindrical cup deep drawing experimental tests were performed with blank of 60 × 60 square plate with 1 mm thickness. Eventually this new approach will help to optimize the geometry parameters deep drawing specimen correlation with the Matlab results.

Keyword: *Deep drawing, Strain, Deformation, Image processing, Matlab, Alloys.*

1.0 Introduction

Conventional strain measurement methods are based on the dial gauge and it can only measure deformations at specified points of interest with limited testing environment. The conventional methods are also depending on the external boundary factors like under temperature, pressure, fluid, vibration etc.

Strength of any material is based on its properties to resist against failure. Among many properties the strain is unique because based on strain value most of all other mechanical properties like Modulus of elasticity, Poisson's ratio and stress etc., are found. Strain value is a base element for material testing, design optimization, process as well as product optimization, etc. So strain plays virtual role for engineers to introduce a system to find such property which can suit for all field environment [1] with robust, easy and latest technological way. Studies on metals and non-metals are carried out for its strength and based on the test results the other properties of those materials are realized. In

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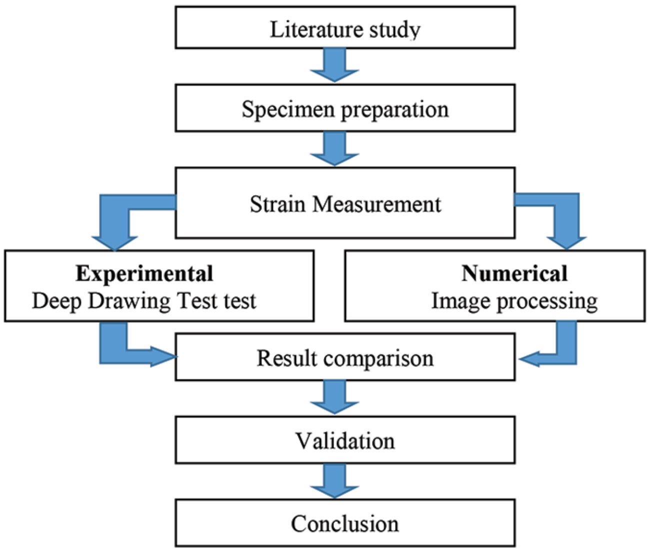
conventional method strain on deep drawing is measured by the most common method of devices designed referred to as strain gauge [2].

2.0 Process Methodology



3.0 Experimental Procedures

The first step of the experiment is material preparation for test. Three specimens in each alloy with uniform dimensions were selected. Measure the specimens and mark the surface pattern on it. Square sheet of 60 mm × 60 mm of 1 mm thickness in aluminum, copper and brass alloy martials were prepared for

Figure 1: Universal testing Machine

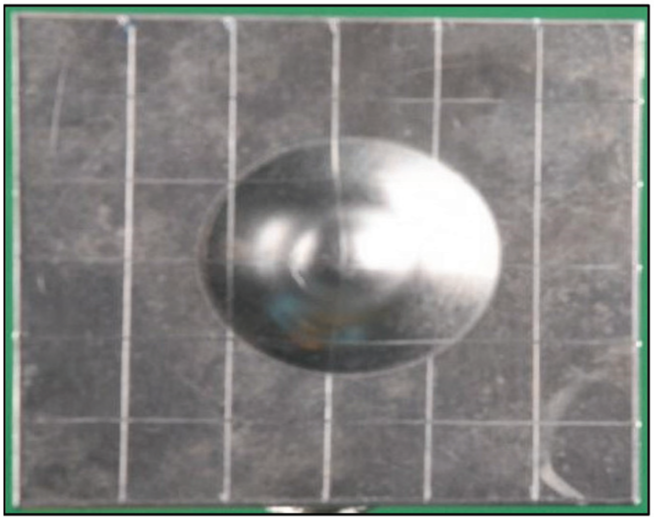


Figure 2: Al sheet metal with 10 x 10 mm square pattern

this research purpose. 10 mm × 10 mm square grid pattern was marked (Fig.2) on each material for analyzing the beep drawing behaviour and also to measure strain. The deformation of this square grid pattern after the deep drawing would be referral mark on the surface for measuring the positive and/or negative strain on the surface of interest.

Then, proper die and punch have been selected for the deep drawing experiment is shown in Fig.3. After selecting the tools, fix the sheet in universal testing machine. Then, open the universal test software and write the materials properties. Start testing by applying force on the sheet by the punch using the force control lever, stop moving the lever when the

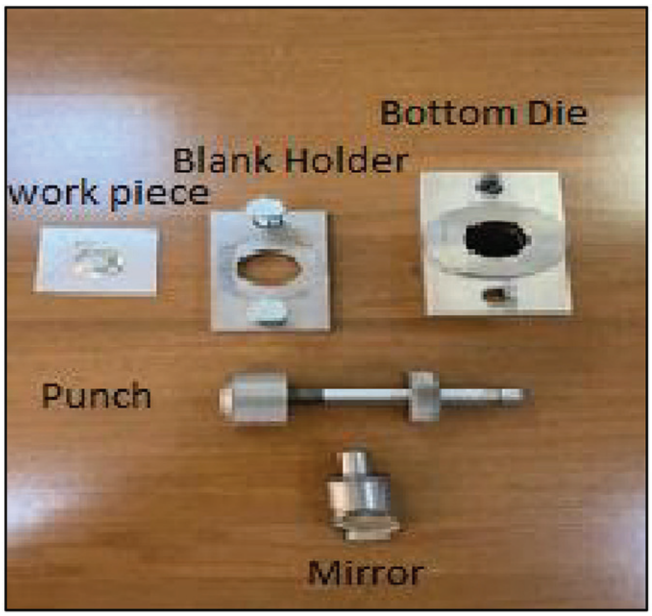


Figure 3: Deep drawing tools

Figure 4: Experimental setup

sheet is cracked up. Save the reading on the computer. Finally, measure the change in the circles dimension. And find the major and minor strains. Gradually the force is applied for slow steady deformation of material until it gets crack on the body.

The response of increment of 0.5kN is recorded and tabulated for all three materials. Applied load and deformation are measured accurately the help of data acquisition system and computer as shown in Fig.1. The Table 1 below shows the breaking load and the maximum deformation attained by each material. It is observed that from the experimental results of ductile materials of copper, brass and aluminum, the brass material has more stiffness than other two. The stiffness of a component is the amount of deformation or deflection by applied load. Actually it is depending on the Young's modulus of the material. In deep drawing process the stain property also should be considered. Moreover, brass and copper has close value in young's modulus but brass has higher value in strain. This is reflected in Table 1 and both

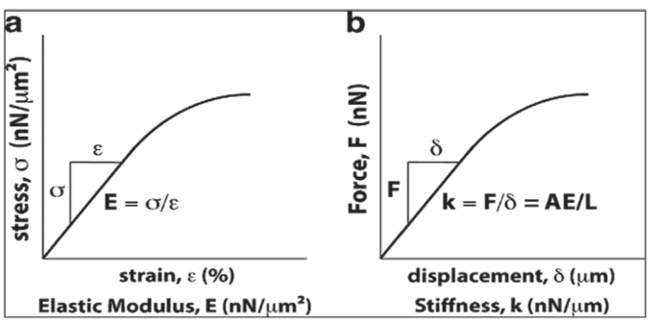


Figure 5: Definitions of (a) the elastic modulus, (b) stiffness

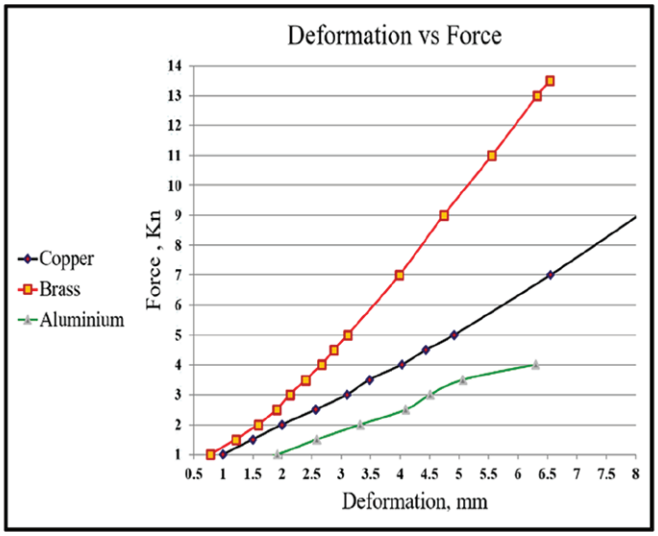


Figure 6: Result force Vs deformation

brass and copper are belonging to metal and its alloy as shown in Fig.6. So, among the three-specimen brass took the highest force applied. Therefore, it is considered as high strength and less deformation.

Image processing

Image processing is the contemporary analyzing technique to revel the necessary information or data from the 2D images some time from the 3D images also. This is non-invasive processes in mechanical and instrumentation engineering as well as more comfortable for prospective engineers working with CAD and CAM. In our research we are using Matlab programme for analyzing 2D images and these 2D images were captured in a proper manner to get better quality.

Images from DSLR camera

Using digital SLR camera randomly but our blank is a 60 × 60 mm square specimen so, images were taken only four sides from the normal direction. Hence, each specimen was taken only on the four sides.

Explanation of Matlab programme

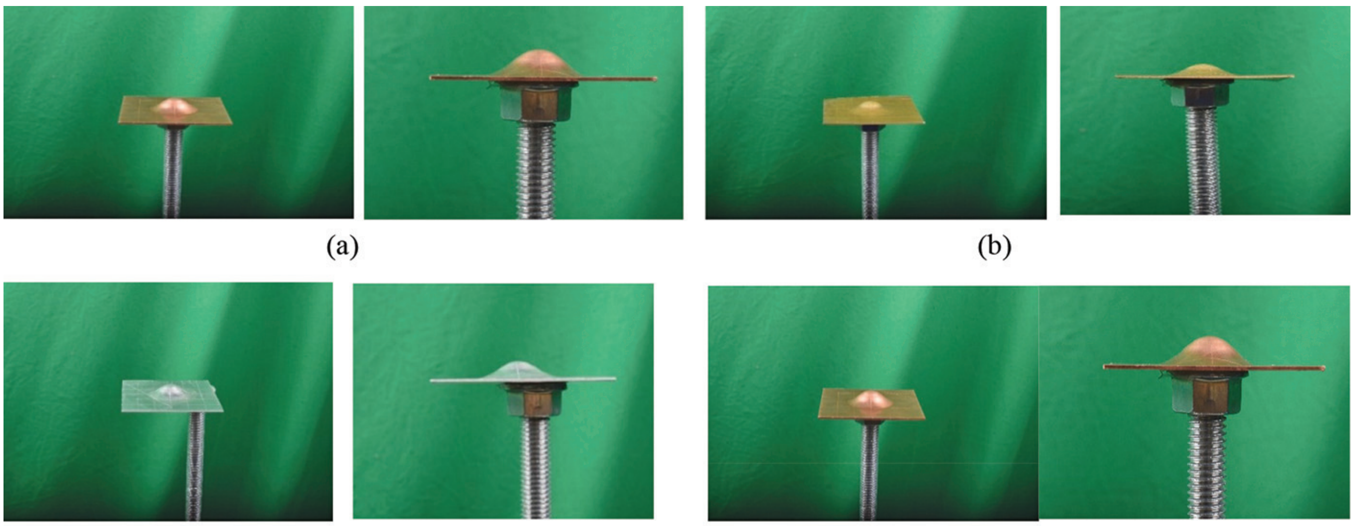
Stage 1; Stacking the image in Matlab

```
a = imread ('Al01.jpg');
imshow(a);
[rowa, cola] = size(a);
sprintf ('The size of image al01 matrix is %dx%d.',rowa, cola)
```

The above Matlab code is used to load the image A101.jpg (Aluminium) from the storage and indicates its matrix size as 3D form. Similar way all other images were stacked in

Table 1: Experimental results

Sl.No	Force	Matrial: Copper		Material: Brass		Material : Aluminium	
		Deformation	Stiffness	Deformation	Stiffness	Deformation	Stiffness
Unit	Kn	mm	N/mm	mm	N/mm	mm	N/mm
1	0.5	0.53	943.39	0.31	1612.9	1.06	471.69
2	1	1	1000	0.78	1282.05	1.92	520.83
3	1.5	1.5	1000	1.21	1239.6	2.59	579.15
4	2	2	1000	1.59	1257.86	3.33	606.06
5	2.5	2.57	972.76	1.91	1308.9	4.1	609.75
6	3	3.1	967.7	2.13	1408.4	4.51	665.18
7	3.5	3.48	1005.74	2.4	1458.3	5.07	690.33
8	4	4.03	992.5	2.67	1498.12	6.3	634.92
9	4.5	4.44	1013.5	2.88	1562.5		
10	5	4.92	1016.2	3.11	1607.7		
11	7	6.55	1068.7	3.99	1754.3		
12	9	8.05	1118.01	4.74	1898.7		
13	11			5.56	1978.4		
14	13			6.33	2053.7		
15	13.5			6.54	2064		



(a) (b) (c) (d)

Figure 7: (a) copper (b) brass and (c) aluminium-Random image and normal image

the Matlab programme. At the end it shows the matrix form of the converted image as shown above and it revels the message as 'The size of image matrix is 4016 × 6016 × 3.' Moreover, Matlab has limitation to display the elements only up to 524288 elements. Actually this is not an error. Viewing a large 3D array as a table in the workspace browser is simply not useful and avoided in consequence.

Stage 2; 3D image to 2D image conversion

b=rgb2gray(a);

imtool(b);

[rowb,colb]=size(b);

sprintf('The size of rgb2gray image matrix is %dx%d.',rowb, colb)

The above Matlab code is used to convert the colour image which is 3D in nature into grey colour image which is in 2D. This converted grey image will be shown in the separate tool window. Similar way all other images will be shown if different materials were converted. At the end it shows the matrix form of the converted image as shown above and it revels the message as 'The size of rgb2gray image matrix is 4016 × 6016.'

Stage 3; Resizing the image to ROI

c=imcrop(b);

imshow(c);

imtool(c);

[rowc,colc]=size(c);

sprintf(' The size of croped image matrix is %dx%d.',rowc, colc);

imwrite(c,'Al01corp.jpg');

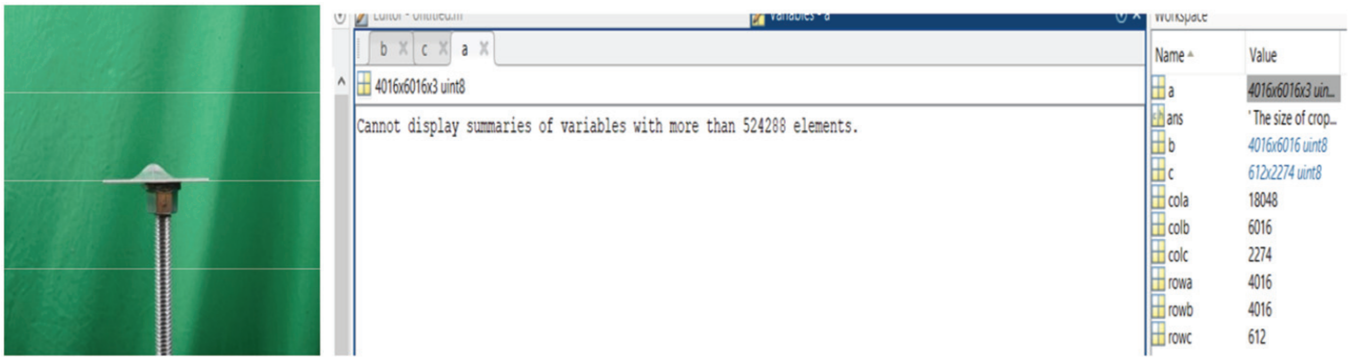


Figure 8: Matlab Image and its matrix size

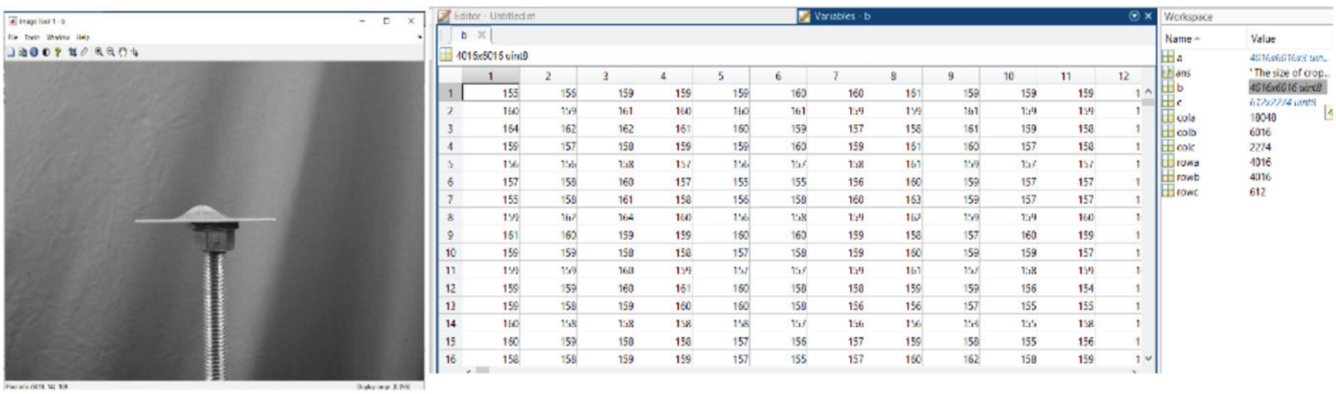


Figure 9: Matlab 2D Image and its matrix size

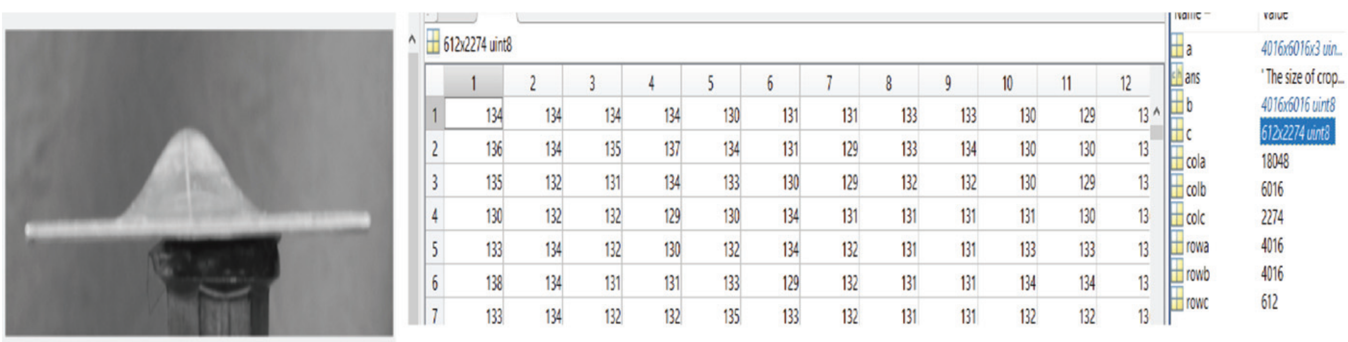


Figure 10: Matlab Crop 2D Image and its matrix size

The above Matlab code is used to crop the region of interest (ROI) where the data to be extracted. Cropping the image will boost the processing time and unveiling the result will be very quick and fast because image processing is consisting of more image with different dimensions and resolution. Hence this process is inevitable one. This cropped grey image will appear in another separate tool window. Similar way all other images will appear if different materials were converted. At the end it shows the matrix form of the converted image as shown above and it revels the message as 'The size of rgb2gray image matrix is 612 × 2274'

Measurement and scale ratio

The above cropped image in the Matlab image tool box is measured using tools available.

Initially the length of the specimen is measured in Matlab as in terms of pixels and it is related to the measurement taken before the experiment with Vernier caliper. This comparison measurement will bring the scale ratio of each pixels in terms of unit millimeters. By using the is scale ratio in the deformation of deep drawing specimen from the initial state is measured as Pixels then this value will be interpreted to unit millimeters. Doing this so, the strain of each material is calculated and material properties were evolved.

Table 2: 60 × 60 Specimen Measurement of length using digital Vernier caliper

Material	Specimen	Length in mm (Vernier)			Avg
		Trial–1	Trial–2	Trial–3	
Aluminium	Al S2	60.25	60.28	60.25	60.26
	Al S4	59.22	59.24	59.24	59.233
	Al S1	60.41	60.39	60.35	60.383
	AL S3	58.83	58.84	59.93	59.2
Copper	Co S03	61.44	61.42	61.39	61.4167
	Co S02	60.36	60.34	60.31	60.3467
	Co S04	61.43	61.47	61.42	61.44
	Co S01	60.32	60.35	60.36	60.3333
Brass	Br04	56.71	56.84	56.7	56.75
	Br03	59.53	59.46	59.52	59.503
	Br02	58.65	58.31	58.61	58.523
	Br01	59.57	59.5	59.49	59.52

Data collection from Matlab Tool

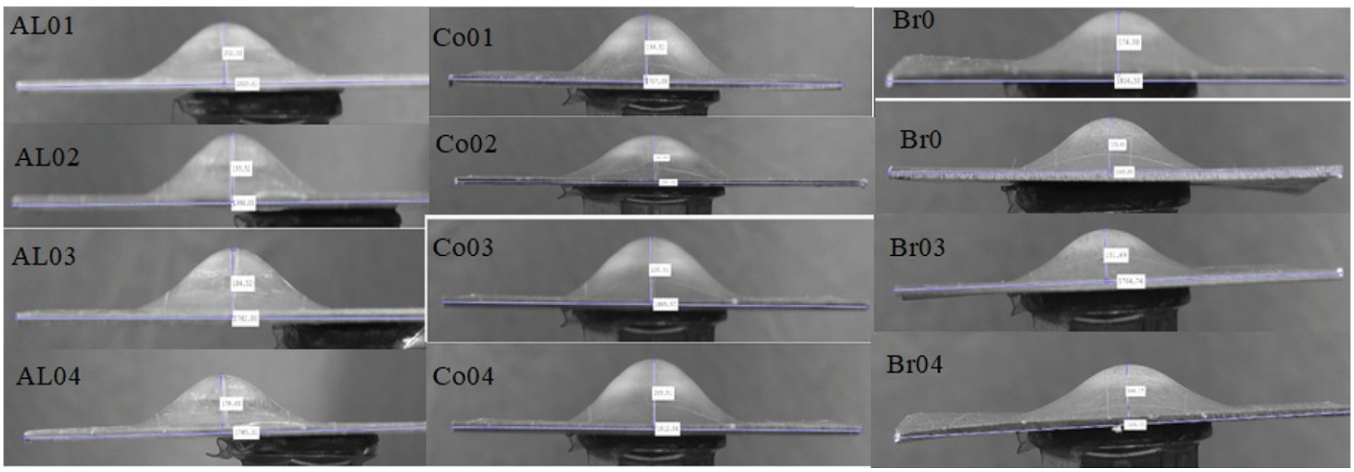


Figure 11: Matlab Crop 2D Image and its matrix size

Table 3: Measurement of pixels and deformation

Material	Specimen	Avg Length in mm (Vernier)	Length in Pixels	Length in mm	Deformation in Pixels	Deformation in mm	Avg Deformation (mm)	Actual Deformation by test (mm)
Aluminium	Al S1	60.383	2020.61	0.02988	202.52	6.052	5.985999	6.3
	Al S2	60.26	1998.05	0.03015	193.52	5.83645		
	Al S3	59.2	1782	0.03322	184.52	6.129957		
	Al S4	59.233	1785.3	0.03317	178.6	5.925589		
Copper	Co S01	60.3333	1641.0	0.03676	199.51	7.335131	7.064968	8.05
	Co S02	60.3467	1707.0	0.03535	191.07	6.754444		
	Co S03	61.4167	1812.0	0.03389	220.51	7.473895		
	Co S04	61.44	1885.57	0.03258	205.51	6.696402		
Brass	Br01	59.52	1816.5	0.03276	174	5.70133	5.19	6.54
	Br02	58.523	1645	0.03557	129.03	4.59		
	Br03	59.503	1764.7	0.03371	151.69	5.1146		
	Br04	56.75	1526.7	0.03717	144.17	5.36		

Validating the results

Table 8: Result validation of alloys

Material	Deformation in mm		% of error
	Experiment	Numerical	
AL	6.3	5.985999	4.98
Copper	8.05	7.064968	12.23
Brass	6.54	5.19	20.64
Average	12.62		

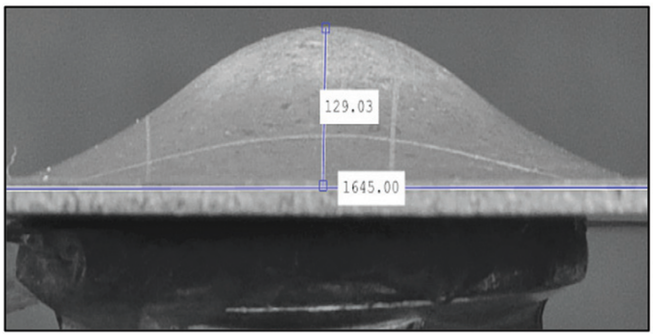


Figure 12: Matlab Crop 2D Image and its matrix size

Experimental strain values and numerical method of image processing strain values are tabulated and percentages of variation in the results were found. From the result comparison it is evident that experimental and numerical results are almost same. But the percentage of error in some cases is near the marine of safe level. Especially brass material has 20 per cent of error which is not relay and it is because of specimen inaccuracy in geometrical tolerance. The geometrical inaccuracy is clearly seen in Fig: Br01 and Br04. Next, copper material also exhibits 12 per cent of error which is acceptable but in long run and in need high precision this also not in acceptable range. The major reason for this is due to image resolution and orientation with camera, and minor influence of dimensional and geometrical error.

4.0 Conclusion

Moreover, aluminium material reveals better results that other ones of illumination effect in image. Also it has almost free from dimensional and geometrical errors. The geometrical tolerance plays major role in the image processing measurement rather than colour of the material. Matrial colour has no role in the image processing because colour - 3D image is converted to grey – 2D image. So, all coloured material will look like same in grey image but with little variation in illumination. May be this illumination will offer 2 to 5 percentage of error in image processing. From the above table it is very prominent that the process of finding the strain using the image process technique is valid. Moreover, the percentage of error is less than the allowable range of 20 per cent. Hence the image processing using MATLAB is recommended to implement. The percentage of brass is more may be because of manual and instrumental error. This can be eliminated by iteration process with some more specimens and material with excellent geometrical tolerance. Error is not based on the material type it is purely based on the process only and handling the instruments and Matlab tool.

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