

A Non-Contact Visual Measurement System Integrating LabVIEW with Matlab*

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The recent trend in the field of on-line inspection has shown a growing need for a non-contact visual-based measurement system. A systematic development of a real-time inspection system can bring about an increase in productivity and effectiveness during in-process monitoring. This paper discusses the development of a typical real-time measurement system used for different industrial applications, with a specific example of volumetric shrinkage measurement. The volume shrinkage measurement system described in this paper is based on a procedure of obtaining the cross-sectional information of the sample of the product (adhesive droplet) before and after the product is subjected to shrinkage. A specialized laser system, rotary mechanism, imaging system and virtual instrument are used to compute the shrinkage percentage of the droplet.

NEED FOR VIRTUAL INSTRUMENTATION

THE RAPID GROWTH in experimental methodologies has created special challenges for academic institutions. One area of concern for engineering institutions is the need to provide meaningful and relevant practical experience for students. There is an ongoing need to update and augment the contents of courses and to keep pace with the introduction of laboratory hardware. One possible way this problem can be addressed is the use of computer-based techniques to interface with the physical world, with suitable front-end design to provide sophistication and increased flexibility [1].

Many academic courses in the area of mechatronics have already begun incorporating computer-based educational tools for student use in the lecture format, in laboratory practices, or both. Due to recent technological advances in computer technology and software, it is now feasible to implement more advanced, more efficient, highly interactive and very user-friendly systems without using expensive custom-written software and tools. In laboratory applications, all the engineering problems deal with physical elements such as temperature, speed, position, current, voltage, pressure, force, torque, etc. A computer equipped with suitable data acquisition systems and software and interface hardware can provide a visual look at these, and can process the acquired data.

With an appropriate introduction to the apparatus and the virtual instrument, students can

immediately begin collecting data. This process allows other experimental topics such as calibration or uncertainty analysis to be the central theme of the laboratory experience [2, 3].

VOLUME SHRINKAGE MEASUREMENT SYSTEM

The product under consideration is a liquid drop that shrinks with time due to chemical reaction. The process is to measure the drop before and after shrinkage and calculate the percentage of shrinkage. The experimental method also demonstrates the advantages of using Matlab in a LabVIEW environment. IMAQ Vision is used to obtain a digital image of the drop and then Matlab is used to manipulate the image data and find the volume of the drop [4].

The initial approach is to obtain the cross-sectional image of the drop at various angles and then integrate these to find the total volume. A line laser is placed vertically above the drop and the drop is viewed horizontally using the digital camera. The image obtained is then manipulated using IMAQ and LabVIEW software to obtain the cross-section coordinates. Then these coordinates are used to fit to a polynomial curve and integrated over the required angle to calculate the volume. A schematic diagram showing the sequence of operations is shown in Fig. 1.

VI DESCRIPTION

The VI acquires the image and performs the thresholding and edge detection using the IMAQ

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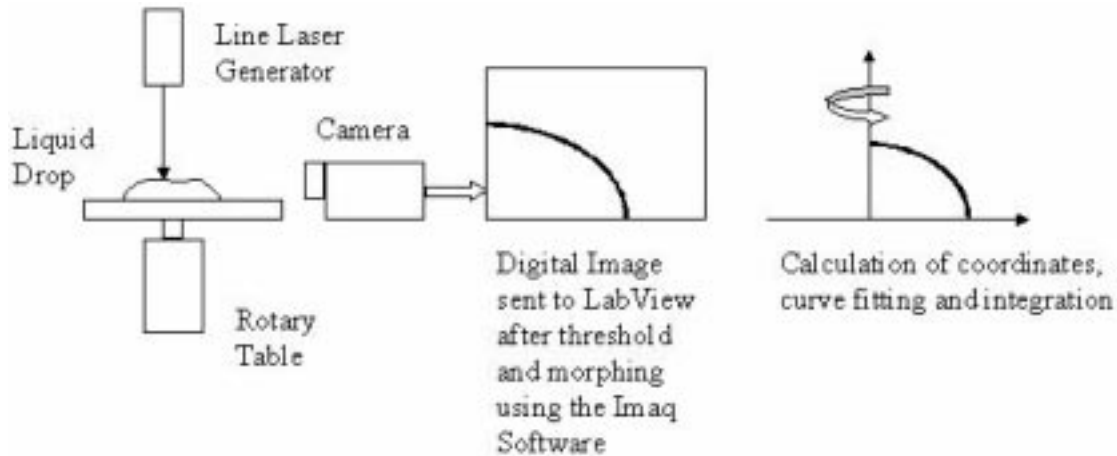


Fig. 1. Schematic diagram.

vision system. Calculation of the cross-sectional area and analysis is done with the Matlab script in the block diagram. The front panel consists of an intensity chart and graph for displaying the liquid profile and digital indicators for representing volume as well as shrinkage percentage (Figs 2a and 2b).

INITIAL ERROR BUDGET ALLOCATION

The maximum permissible error is 0.001 cubic inches. The possible error accumulating nodes are:

- error in rotation (repeatability of the angular movement);
- error due to specimen base plate thickness unevenness;
- error due to specimen's misalignment with the motor's axis;
- error due to image manipulation and image correction;
- error due to fluctuations in the light source; and
- error due to the thick band of reflected light from the drop's profile.

Error in rotation cannot be neglected, so it has to be minimized by using the high-resolution motor and having a minimal number of components between the motor and the drop. The error induced due to the base plate thickness deviation is negligible as the same error will be present before and after shrinking. Also, the algorithm would be created such that individual datum is calculated to minimize the chance of error.

The error induced due to the misalignment of the specimen base plate with the motor's rotary axis would cause an error of around 10% on individual volume calculations, but since we are calculating the percentage shrinkage, individual errors get cancelled.

The error induced due to image manipulation is difficult to measure since it is influenced by various other errors as well. Fewer filters and built-in functions were used in order to reduce the error

to a minimum. After the algorithm is checked for typical liquid profile, the identified parameters and other built-in functions are fine tuned so that the repeatability is improved. The error induced due to the external light sources has to be minimized by keeping the entire set up in a dark and enclosed area [5–7].

ALGORITHM

The basic steps in the algorithm are:

1. Get the image in eight-bit format.
2. Threshold the image for set grayscale setting.
3. Erode the image to remove noise and use edge detection function to get the edges of the thick band of reflected light over the drop's profile.
4. Convert the image to binary file.
5. Check each column and identify the first non-zero array index.
6. Translate the drop profile to the set datum.
7. Calculate the volume for an individual sector using the formula

$$V_s = \int x^2 y \partial x$$

8. Rotate the drop by six degrees and repeat 40 times steps 1 to 7.
9. Add individual sector volumes to get the total volume V_1 .
10. Do the ultraviolet curing.
11. Repeat steps 1 to 9 and get the new volume V_2 .
12. Calculate the volume shrinkage using the formula,

$$S_P = \frac{V_1 - V_2}{V_1} \times 100$$

SYSTEM TESTING

The motor spindle is attached to a circular plate. Another thin metal plate is glued on top of the

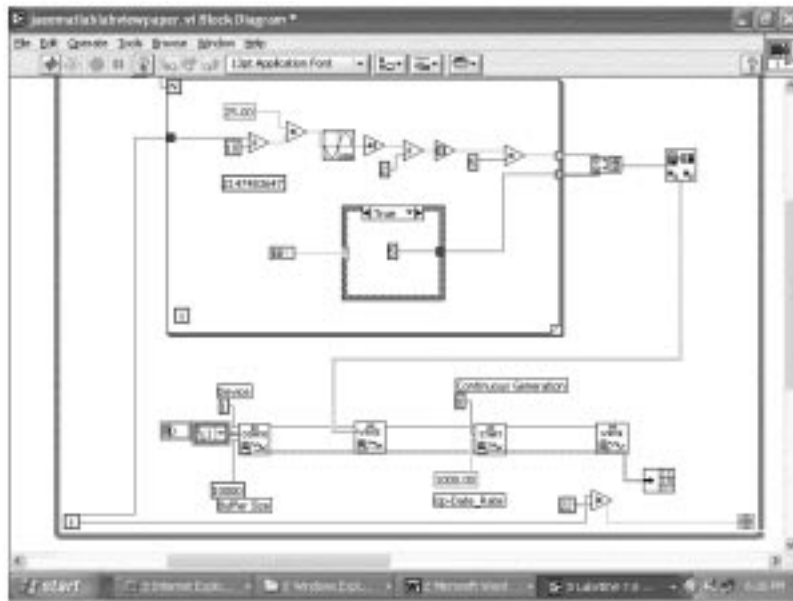


Fig. 2a. Labview VI for experimental evaluation.

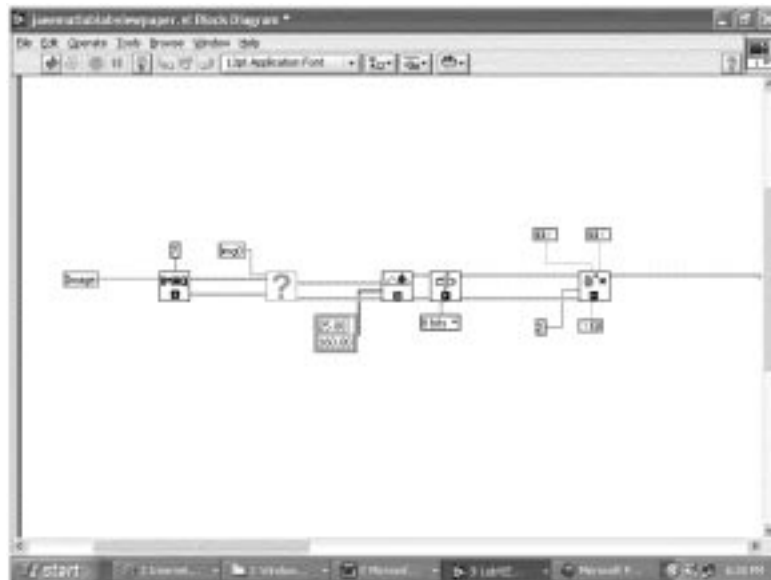


Fig. 2b. Labview VI for experimental evaluation.

plate. The metal plate is marked with cross hairs that were aligned visually with the incident line laser. The liquid drop is placed at the intersection point of the cross hairs. The rotary table is shown in Fig. 3. The liquid drop with the incident line laser is shown in Fig. 4.

The image obtained did not have a uniform light band, resulting in an uneven edge profile data. The actual image is shown in Fig. 5. The image obtained after thresholding and edge detection is shown in Fig. 6. The Matlab file used to find the sector volume is given below with corresponding comments in square brackets.

[The input image array is called 'totalimage.' It is transposed to get the required array format. Then each column is checked to find the row

where a non-zero number exists. The row index for a i^{th} column gives the height of the droplet at that i^{th} spacing from the central axis.]

```

convertimage=totalimage';
y=[ ];
for i=1:1:640
    for j=1:1:480
        if convertimage(j,i)>0
            y(i)=j;
            j=480;
        end
    end
end
end
    
```

[Due to variations in lighting conditions, a dark band sometimes occurs. In order to account for

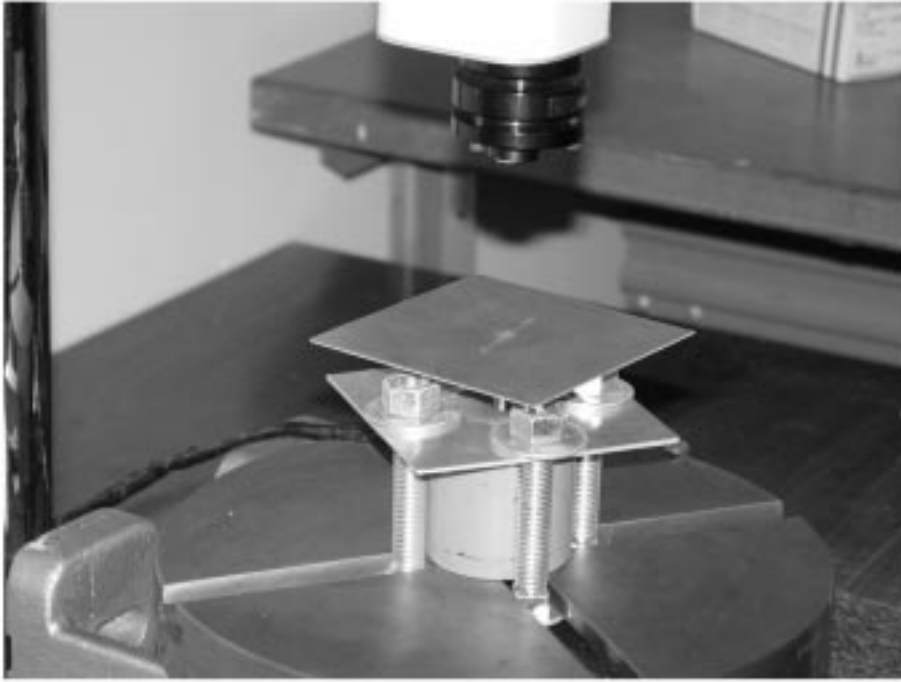


Fig. 3. Rotary stage setup.

this, a new For loop is added to eliminate the wrong height values.]

```

ynew=[ ];xnew=[ ];
yfinal=[ ];xfinal=[ ];yfit=[ ];xfit=[ ];j=1;
for i=1:1:640
    if y(i)~=0
        ynew(j)=y(i);
        xnew(j)=i-1;
        j=j+1;
    end
end
end

```

[The corrected y coordinates are then translated to a new datum by subtracting the minimum observed height from the individual heights. The x and y coordinate values are used to find a 6th degree binomial which would fit the profile.]

```

ynew=ynew-min(ynew);
n=max(xnew);
p=polyfit(xpfinal,ypfinal,6);
v1=p(1); v2=p(2); v3=p(3); v4=p(4); v5=p(5);
v6=p(6); v7=p(7);
for m=1:1:n-1

```

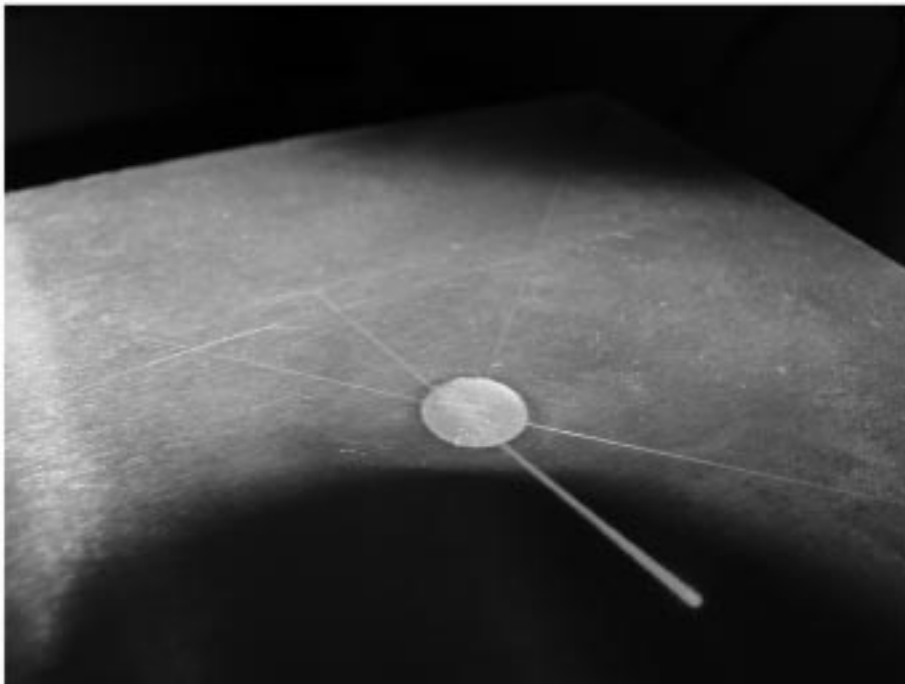


Fig. 4. Liquid drop with incident line laser.

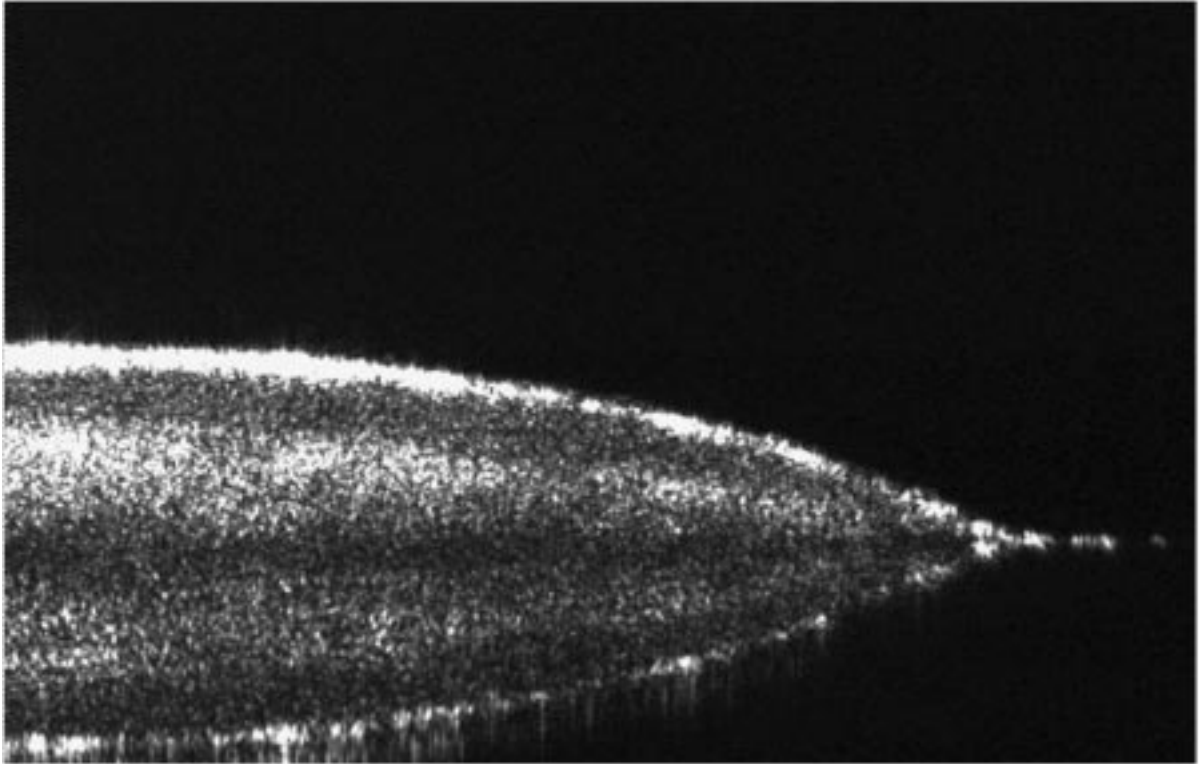


Fig. 5. Actual image.

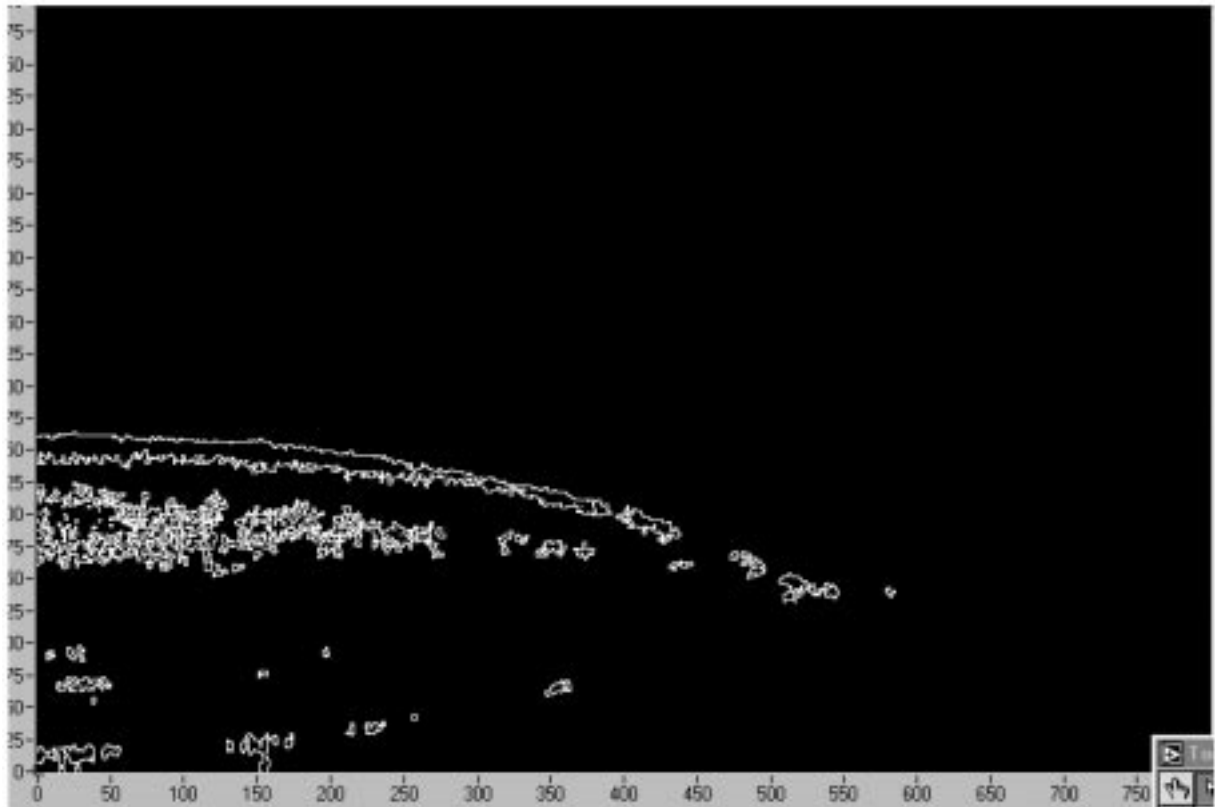


Fig. 6. Image after thresholding and edge detection.

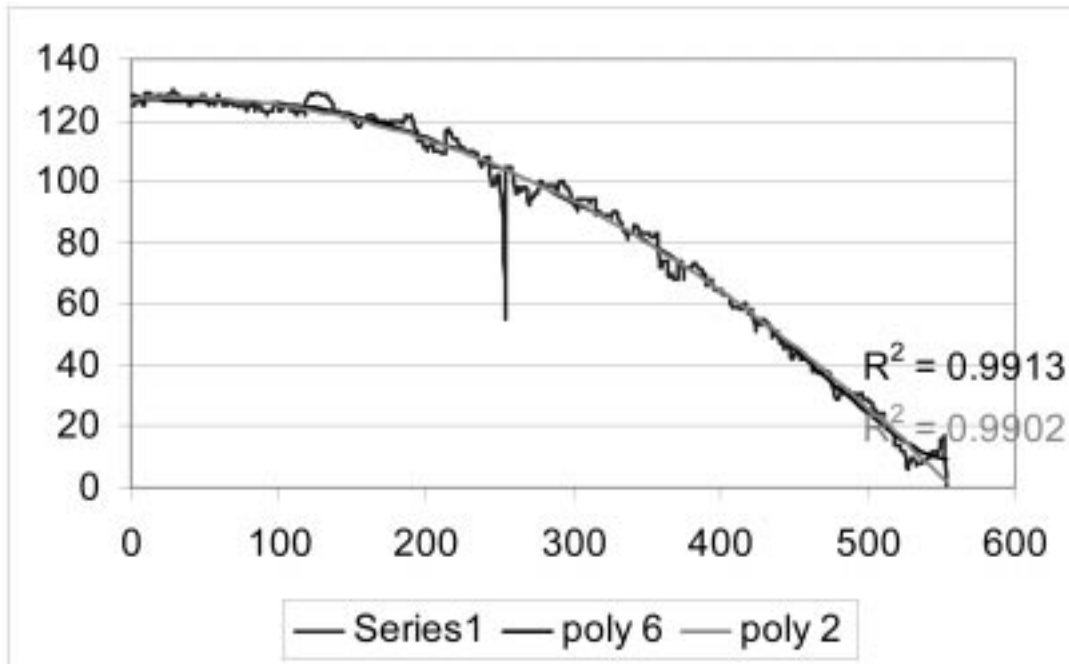


Fig. 7. Edge profile with curve fitting.

```

xfit(m)=m-1;
yfit(m)=((m^6)*v1)+((m^5)*v2)+((m^4)*v3)+((-
m^3)*v4)+((m^2)*v5)+(m*v6)+v7;
end
j=1;

```

[The fit profile is again translated to a new datum by subtracting the minimum value to individual y coordinates. The profile is trimmed up to the first point where the profile touches zero. This is done to eliminate variations induced by undulations in the base plate. Then the sector volume is calculated.]

```

yfit=yfit-min(yfit);
for i=1:1:n-1
if yfit(i)~=0
yfinal(j)=yfit(i);
xfinal(j)=xfit(i);
j=j+1;
else
i=n-1;
end
end
sectorvol=(pi/40)*trapz(xfinal,xfinal.*yfinal);

```

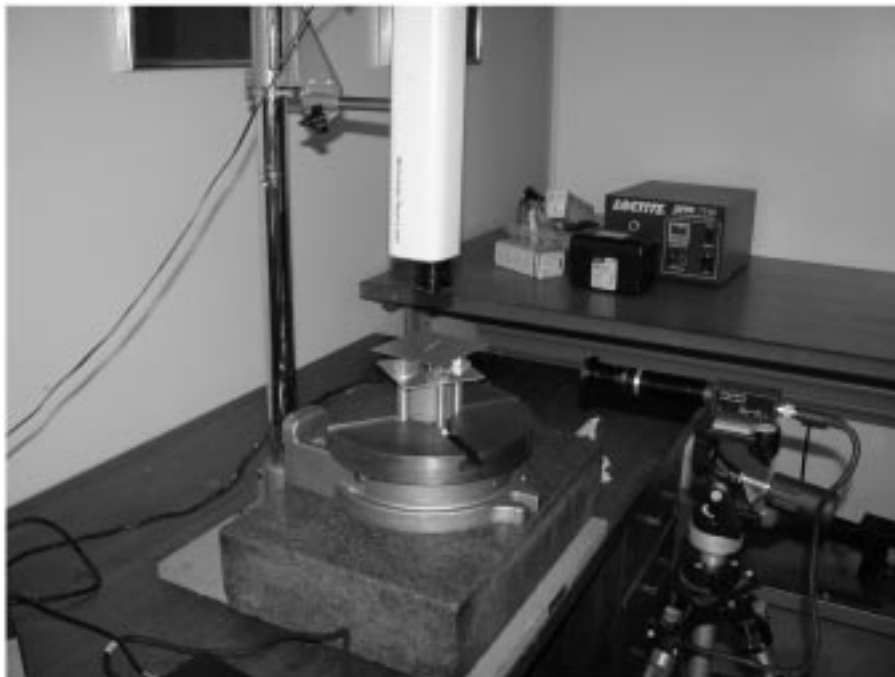


Fig. 8. Total setup.

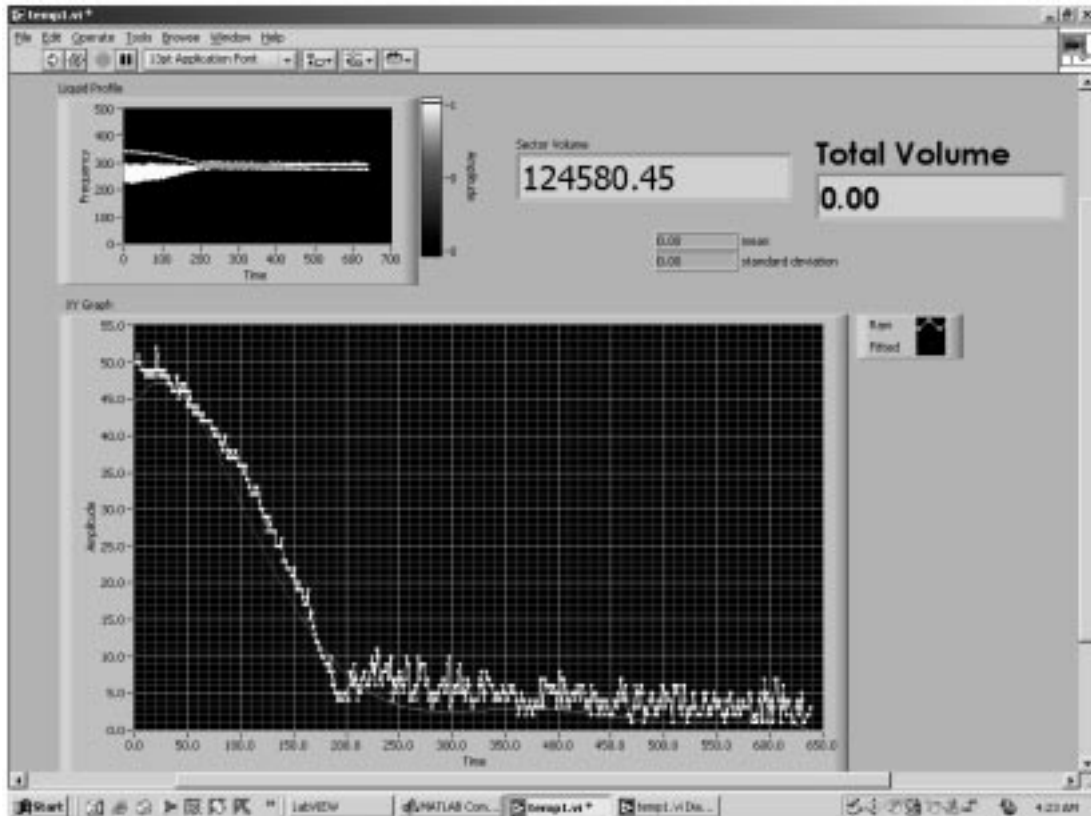


Fig. 9. Front panel.

[The individual sector volumes are then added to find the total volume.]

The fitted curve is shown in Fig. 7. The actual profile of the drop has to be uniform and not like that of the profile obtained before curve fitting. Also, curve fitting reduces the error induced by the uncertainty in determining the datum. The errors were calculated and checked for error accumulation. To reduce the mechanical system errors, the entire setup was mounted on a marble table and all the accessories of the system were removed from the measuring table. The setup is shown in Fig. 8. The front panel is shown in Fig. 9.

EXPECTED SKILLS OUTCOME

During the design phase of this experiment, the students learn the need for error budget allocation and parts selection based on the error allocation. Then, during the setup phase, they utilize the basic components that were presented in the Mechatronics course. During the testing phase, they learn

the basics of lighting strategy and image manipulation methods. They also learn the impact of image manipulation on the uncertainty of the system.

CONCLUSION

The use of virtual instrumentation is an effective way of supporting interdisciplinary hands-on learning. Using virtual instrumentation in the laboratory provides dramatic improvement in mechatronics education. LabVIEW's ease of use for building a virtual instrument, its flexibility and power are significant advantages in developing hands-on learning experiences. The experiment described in the paper enables students to utilize their Matlab skills in laboratory research. The students can be trained to explore the uncertainty of the system and suggest ways of improving performance characteristics.

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