Stress Analysis of V Notches on the Components
Using Photo elasticity and FEM

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Abstract -The paper presents the results of numerical and experimental linear elastic analyses carried out to investigate the stress gradient of notched V-shaped specimens. Specimens with different V-shaped notch geometry subjected to uniaxial tensile loading have been considered. It was shown that the stress fields around the notch-tip are similar to each other regardless the notch shape. The most familiar analytical functions describing the stress field at the notch-tip have been presented. Some of the available approximation formulas are verified with the obtained numerical data. Finite Element Method (FEM) is used for the numerical stress analysis and photoelasticity is applied for the experimental investigation of the stress field. The experimental results of the maximum dimensionless stress derived from the photoelasticity experiments are compared to the respective theoretical stress results of the finite element analysis. In this study, understand the aspect of FEA as well as Experimental Stress Analysis with the help of one mechanical component in various literatures. The investigate the state of stress around the v-notch tip in the several photoelastic strips with different sizes of v-notches were prepared. The resulting photoelastic fringe patterns were obtained by the time-averaged photoelastic technique. In addition, commercially available finite element method (FEM) software package ANSYS was employed to verify the experimental results. Very well-matched results between the photoelastic and FEM were obtained. The von Mises stress distribution ahead of the notch tip was also calculated by ANSYS to evaluate the appropriateness of the dimensions of the v-notch.

Keywords: Notches, FEM, Photoelasticity, Ansys.

I. INTRODUCTION

There are various mechanical integral and necessary components in our everyday lives. They are present in the automobiles and bicycles we travel with, satellites we communicate with, and computers we work with. They have been around for hundreds of years and their shapes, sizes, and uses are limitless. For the vast majority of our history mechanical components have been understood only functionally. That is to say, the way they transmit power and the size they need to be to transmit that power have been well known for many years. It was not until recently that human began to use mathematics and engineering to more accurately and safely design mechanical components.

Photoelasticity is an experimental technique for stress and strain analysis that is particularly useful for members having complicated geometry, complicated loading conditions, or both. For such cases, analytical methods (that is, strictly mathematical methods) may be cumbersome or impossible, and analysis by an experimental approach maybe more appropriate. While the virtues of experimental solution of static, elastic, two-dimensional problems are now largely overshadowed by analytical methods, problems involving three-dimensional geometry, multiple-component assemblies, dynamic loading and inelastic material behaviour are usually more amenable to experimental analysis.
The name photoelasticity reflects the nature of this experimental method: *photo* implies the use of light rays and optical techniques, while *elasticity* depicts the study of stresses and deformations in elastic bodies. Through the photoelastic-coating technique, its domain has extended to inelastic bodies, too. Photoelastic analysis is widely used for problems in which stress or strain information is required for extended regions of the structure. It provides quantitative evidence of highly stressed areas and peak stresses at surface and interior points of the structure — and often equally important, it discerns areas of low stress level where structural material is utilized inefficiently.

This paper is intended to introduce the basic concepts — to emphasize those elements that are fundamental to the photoelastic method. The details involving characteristics of specific photoelastic materials — their formulation, optical and mechanical properties, machining techniques, etc. — and the details involved in the use of specialized auxiliary instruments and accessories are not included. While such information is vitally important to the student of photoelasticity, it quickly becomes obsolete and is better disseminated by current technical papers and current manufacturers’ literature.

II. METHODS

### Numerical Analysis of Notch Stresses

Usually, the notch stress is computed numerically using the finite element or the boundary element method. As an alternative, published parametric formulae are available for standard cases which have been derived mainly from numerical analyses. Both cases are considered in this Section.

#### Numerical Methods (FEM, BEM)

The objective of the numerical analysis is the computation of the stress concentration in the fatigue-critical notch under specified loads assuming linear-elastic material behaviour. This is a relatively simple task in view of the powerful methods available today, requiring mainly a sufficiently fine discretization of the structure in the notch area. A linear-elastic analysis is in most cases sufficient. However, effects of large displacements on the structural stress might be important, particularly in thin-walled structures, in which case geometrically non-linear structural stress analysis would be required. Contact problems may also require a non-linear analysis. However, contact between non-welded root faces is not usually assumed, leading mostly to conservative results.

It is a technique for modelling a complex structure. When the mathematical model is subjected to known loads, the displacement of the structure may be determined. The FEA principle is used to determine various critical areas where stresses are induced. This makes use of ANSYS software, the first step to conduct a successful Finite Element Analysis is to create an accurate geometry for the type of analysis you wish to consider. A solution using the Finite Element Analysis (FEA) will also be developed for comparison to the calculated solution. The FEA will be performed using the element type and number of elements that gave the most accurate results, compared to the results given from the classical analysis. The Finite Element Method (FEM) is a numerical approximation method. It is a method of investigating the behaviour of complex structures by breaking them down into smaller, simpler pieces.

#### Experimental stress analysis (Photoelasticity Method):-

The analytical and numerical(computer simulation with finite elemental modelling) determination of stresses in the field of practical engineering design often becomes so complicated that an accurate knowledge of the stresses can only be obtained by experimental means Photoelastic stress analysis is widely used for determining stress under such circumstances. The physical theory involved includes the double refraction of polarized light passing through translucent material which is under stress. Light is plane polarized by altering the waves emitted from a source so that waves are produced which vibrate only in one direction normal to the direction of wave propagation. Experiments have
demonstrated that if this uni-directional beam is passed through a transparent crystal, such as quartz or tourmaline, the beam will be divided into two mutually perpendicular components, phenomenon termed double refraction. Experiments have also shown that transparent materials become doubly refractive under the action of stresses. We thus see that the initial unidirectional beam emerges as two mutually perpendicular beams, and that since their velocities were not the same within the stressed material, they are out of phase when they emerge. If these two beams are now brought back into the same plane of vibration, an interference pattern will be formed due to the difference of phase. If the image is projected upon a screen, a pattern of colour bands will be produced. The most convenient means of obtaining plane polarized light is through the use of polarized discs. One disc is used to plane polarize the light from the source, which is doubly refracted in passing through the specimen and analysed by means of a second polarized disc.

![Fig.I Schematic diagram of Polariscope](image)

### III. RESULTS

**Test specimens:**

![Fig.II Test specimens](image)
Fig. III Fringe patterns obtained by photoelasticity

FEM mesh specimen:
Fig. IV FEM mesh specimens

Table I Dimensions of test specimens

<table>
<thead>
<tr>
<th>Specimens</th>
<th>a (mm)</th>
<th>b (mm)</th>
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<tbody>
<tr>
<td>(a)</td>
<td>5</td>
<td>3.535</td>
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<tr>
<td>(b)</td>
<td>10</td>
<td>7.07</td>
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<tr>
<td>(c)</td>
<td>15</td>
<td>10.607</td>
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<tr>
<td>(d)</td>
<td>5</td>
<td>3.535</td>
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<tr>
<td>(e)</td>
<td>10</td>
<td>7.07</td>
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<tr>
<td>(f)</td>
<td>15</td>
<td>10.607</td>
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IV. Graphs

Fig. V stress distributions for single-edge-notched test specimens
V. CONCLUSION

The FEM has been successfully incorporated with the time-averaged photoelasticity to investigate the whole-field state of stress of both the SEN and DEN test specimens under incidence of the ultrasonic wave. Excellent match between the photoelastic and FEM results is to calculate accurately the stress components of the test specimen. The stress distribution in front of the v-notch tip was then determined and compared with the experimentally obtained photoelastic fringe pattern to evaluate the suitability of the design of the v-notch. The stress at the v-notch tip was higher for the DEN than the SEN specimen; it may be still favourable of adopting SEN design due to its simpler manufacturing process and lower cost. Photoelasticity is subject that can be studied at vastly different levels. It is a field in to develop techniques that allow broadest exploitation of this valuable tool of stress and strain analysis.

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