Study on the Influence of Notch for Sheet Material’s Stress and Deformation

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Abstract. Stress concentration, a hard problem in the mechanical analysis, which can be absolutely different due to the different shapes of force component, and so do the laws. The characteristic of deformation in the imminent range and the relationship between the property of material’s deformation with its tough level have been shown in the article, with the use of advanced 3D measuring method, based on the influence of notch in different shapes with a tension.

1. Introduction

Stress concentration is a kind of phenomenon that the stress in the topos-area for a solid body increases significantly, most of which appear in the sharp corners, holes, notches, grooves, and rigid constraints as well as neighborhood. The condition of stress concentration may lead to a fracture for the fragile material and produce a fatigue crack on the fragile and plastic materials[1,2]. In the stress concentration region, the maximal value of stress (peak stress) is related to some factors, such as the geometry of the object and the mode of loading. The stress value increased in a region would be damped dramatically as the distance between the peak stress point with the region increase[3,4].

The stress concentration is not only related to the shape and structure of the object, but it is also associated with the material selected and another factor, that is, external application environment (such as temperature) which can not be ignored in the , in addition, the change of stress may also appear in the machining process, such as the two-time tempering quenching crack caused by the improper temper, the WEDM process of micro crack and mechanical design may also inevitably lead to the stress concentration in a region[5,6].

2. Experimental Process

Two cameras should be calibrated firstly before the tension experiment; otherwise, it may result in the error of the deformation information acquired in the experiment.

In this paper, three kinds of specimens with various notches have been designed, whose materials are all 304 stainless steel plate, and the Fig.1 (a) (b) (c) have shown the size charts of the three specimens.

The experiment was carried out at room temperature with an electronic testing machine of SANS series for its loading system. Two ends of notch specimen were clamped vertically, and the holder for testing machine was fixed on the chuck with a 2mm/min uniform loading. There are three kinds of loading modes for the testing machine, namely, the uniform deformation loading, the uniform loading and the constant displacement loading. The 2mm/min constant displacement loading had been selected...
in this experiment to ensure the camera acquisition image was synchronized with the test machine loading as a result of the condition that the camera acquisition image was in accordance with the time series. After the material had been held out on the grips firmly, an adjustment (both of the focal length for two camera lens are 25cm with a pixel size for 1624 x 1236 pixels) on the position had been done to ensure that the two CCD cameras were able to acquire clear images. Also, the signal inputs of the two CCD cameras were connected with the signal generator of the control box to ensure that the two CCD cameras could synchronously acquire the deformation image of the notch material specimen. The signal frequency of the signal input was 2Hz, that is, both of the two CCD cameras collected an image every 0.5s, and the two images collected were corresponding to a deformation state for the notch material. To avoid the illumination on the surface of the specimen became uneven during the experiment, two LED lights had been used in the image acquisition system to illuminate the surface of the specimen.

![Image](image_url)

**Figure 1.** Geometrical dimensions of sheet specimens

![Image](image_url)

**Figure 2.** Image of acquisition system

The image acquisition system has been shown in Fig.2.

The images of the half-round specimen before or after the deformation by the CCD camera have been shown in the Fig.3 (a) the image before the deformation; (b) the image after the deformation.
The image manifesting the condition before the deformation is the state image that has not been stretched yet. The image revealing the deformation is the state image of the specimen after stretching for a period of time.

**Figure 3.** (a) Image taken by the CCD camera before the deformation of the semicircular plate

**Figure 3.** (b) Image taken by the CCD camera after the deformation of the semicircular plate

**Figure 4.** Three-Dimensional Displacement Field of Semi-circular Notch Plate

The CCD camera used in the experiment acquired the images in the process of stretching, and stored the images collected into the computer with the control box [7, 8, 9]. And the XJTUDIC deformation measuring system software analyzed the images acquired in the experiment, selecting a speckle regions.
(26*50) in the deformation images and matching the images before or after the deformation. The use of 3D Digital Speckle Correlation Method (DSCM) mentioned in the Chapter 2 may do the calculation, recognizing the corresponding points collected by the cameras and reconstruct the 3D images for the deformation of material’s surface and the surface profiles in the Fig.4. The Fig.4 seen below is the semicircular notch sheet in the 3D deformation displacement images at the time of 126s.

Wherever Times is specified, Times Roman or Times New Roman may be used. If neither is available on your word processor, please use the font closest in appearance to Times. Avoid using bit-mapped fonts if possible. True-Type 1 or Open Type fonts are preferred. Please embed symbol fonts, as well, for math, etc.

3. Analysis for the Experimental Results

As can be seen in the image of Fig.5 (a) (b) (c), the displacement distribution of the three different notch specimens are almost the same at the stretching time of 42s with the same color indicating the same displacement. A clear and complete arc curve has been shown in the cut position but things will not appear in the general complete plate during the stretching process, and the existence of the displacement leads to the uneven variation in the displacement. Some errors may appear in the 3D displacement distribution image as a result of condition that the undemanding operation in the process of clamping revealing in the arc curve in Fig.5 (a) and (c). The standard distribution has been shown in the Fig.5 (a). The existence of some holes in the 3D displacement distribution image in Fig.5(a) notch radius of 1mm material and Fig.5(b) notch radius of 3mm material is resulted in unsuccessful match for the speckle image before and after the deformation caused by the faulty spray. However, the existence of errors has no influence on the analysis.

In the Fig.5 (a) (b) (c), after an observation on the yellow circular arc curve separately, it shows that the circular arc curve has clearly reflected the deformation characteristics of the material in the stretching process which provides a valuable reference for the study of the tensile deformation of notched material.

According to the mathematical knowledge, the radius of curvature for the characteristic arc can be obtained if the values of the three points on the arc are given. Therefore, take the three points from the arc in the three-dimensional displacement distribution diagram for the cut material specimen, which can be seen in the Fig.6. And then, calculate it. During the tensile process, the overall time used in the experiment were 265s, 357s, 478s for the specimen with a cutting angle radius of 1mm, 3mm and 5mm. A teeny separating time will inevitably lead to too much datum, here, after considering the length of article, calculated with a 20-second interval, and the corresponding feature curvature radii have been shown in the table below. The units for the radii of the curvature are millimeter, and R1, R2, R3 reveal the radii of 1mm, 3mm, 5mm notch material respectively.

![Figure 5](image_url)

**Figure 5.** (a) The three-dimensional displacement distribution of the plate with the cut radius of 1mm at 42s
Figure 5. (b) The three-dimensional displacement distribution of the plate with the notch radius of 3mm at 42s

Figure 5. (c) The three-dimensional displacement distribution of the plate with the notch radius of 5mm at 42s

Figure 6. The complete arc curve
### Table 1. Radius of curvature of arc

| T/s | R1/mm | R2/mm | R3/mm | T/S | R1/mm | R2/mm | R3/mm |
|-----|-------|-------|-------|-----|-------|-------|-------|
| 40  | 19.3859 | 19.6742 | 19.9648 | 140 | 13.6749 | 14.8759 | 15.7832 |
| 60  | 18.3853 | 18.6638 | 18.9438 | 160 | 12.4872 | 13.5439 | 14.5637 |
| 80  | 16.4539 | 17.8754 | 18.0542 | 180 | 11.5839 | 12.7648 | 13.5634 |
| 100 | 15.6534 | 16.5839 | 17.4570 | 200 | 10.5738 | 11.4832 | 12.5693 |
| 120 | 14.8736 | 15.3845 | 16.4351 | 220 | 9.6754  | 10.5673 | 11.2487 |

4. Conclusion

It can be seen from the result that the sharper cutting angle is, the less homogeneous stress distribution will be, with a smaller radius for the circular arc curvature. Obviously, the deformation law acquired in the experiment accords with the mechanical properties. According to the 3D displacement distribution image and the calculation, the arc radius which provides a basis on the future research of mechanics can be used as an important parameter to describe the effect of the notch sharpness on the stress and deformation.

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