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Influence of asymmetrical cuts in measuring residual stresses using contour method

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Experimental methods to determine residual stresses are mainly divided into destructive and non-destructive categories. Contour method is a destructive technique that offers a two dimensional map of normal component of residual stresses. The conventional contour method creates a map of residual stress component by cutting the specimen in half and measuring deformed surfaces. Having limitation in cut position does not allow determining residual stresses in various geometries due to discrepancies between the results of unequal cut pieces.

In the current study, contour method was examined when asymmetrical cuts were applied. The residual stresses were measured along an asymmetric line in quenched blocks. The discrepancies in asymmetrical cuts were solved using the same principles employed in the conventional contour method. Different levels of residual stresses were used. Asymmetrical contour method employed the same principle as the conventional one. However, a different interpretation of data was proposed. Numerical findings confirmed the experimental results.

1. Introduction

Residual stresses remain in a specimen in the absence of external forces. However, the equilibrium equations still need to be satisfied. Therefore, the resultant forces and momentums caused by residual stresses are zero. Many considerable failures in engineering components occur due to residual stresses. To determine the integrity of an engineering structure, it is important to evaluate the effects of residual stresses. Residual stresses also have influence on mechanical behavior of materials [1] such as stress corrosion and fatigue life [2], and can cause distortion [3]. Therefore, residual stresses determination can be an important factor in the design of engineering parts and in the estimation of their service life [4]. Tensile residual stresses can limit the fatigue life and cause stress corrosion and crack propagation in materials. However, compressive residual stresses have advantageous effects by preventing crack growth. Thus, the ability to accurately measuring residual stresses improves the understanding of the structural integrity.

There are many different experimental methods to measure residual stresses in engineering components. Details of many of these techniques are available in Ref. [5]. The contour method is a so called destructive technique to measure residual stresses, developed by Prime in 2000 [6]. It is a destructive technique as the component is cut in half and completely destroyed while measuring the residual stresses. Contour method is based on measuring deformation caused by removing a section of component and using Bueckner's superposition principle [7]. The advantages of this method in comparison with neutron diffraction and deep hole drilling technique have been detailed in Ref. [8] and unlike neutron diffraction, it's relatively insensitive to small changes in material chemical composition [9]. One of the unique advantages of this method is to calculate a two dimensional map of normal residual stress component. This method can also measure the stresses deep inside the work pieces [10]. Furthermore, the multiple cuts in contour method can lead to determination of normal stress component on both cut planes [11] or to the complete residual stress tensor [12]. The contour method has already been applied and verified to measure residual stress introduced by various manufacturing processes such as Laser peening [13,14], welding [15,16], friction welding [17] and fusion welding [18]. Residual stresses from quenching have also been measured using contour method and been compared to the finite element analyses [19,20]. Furthermore, the contour method has been employed to measure residual stresses when quenching was combined with

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stretching or cold compression [21,22]. A comprehensive review on the contour method has already been carried out by Prime and DeWald [23].

A limitation of the conventional contour method is that it can only measure one component of the residual stress tensor [8]. Also, similar to other mechanical strain relief techniques [24,25] this method is sensitive to plasticity which influences on measuring stresses that are close to the yield strength of the material [26,27]. The method has also been combined with other techniques such as neutron diffraction [28] hole drilling and X-ray diffraction to measure multiple components of the stress tensor [29].

In the present work, a study was conducted to explore the influence of the cut position. Quenching was chosen as a source to create residual stresses. Although quenching can change the phase in steel, a stainless steel was chosen to prevent phase transformation while quenching. Then, the contour method was

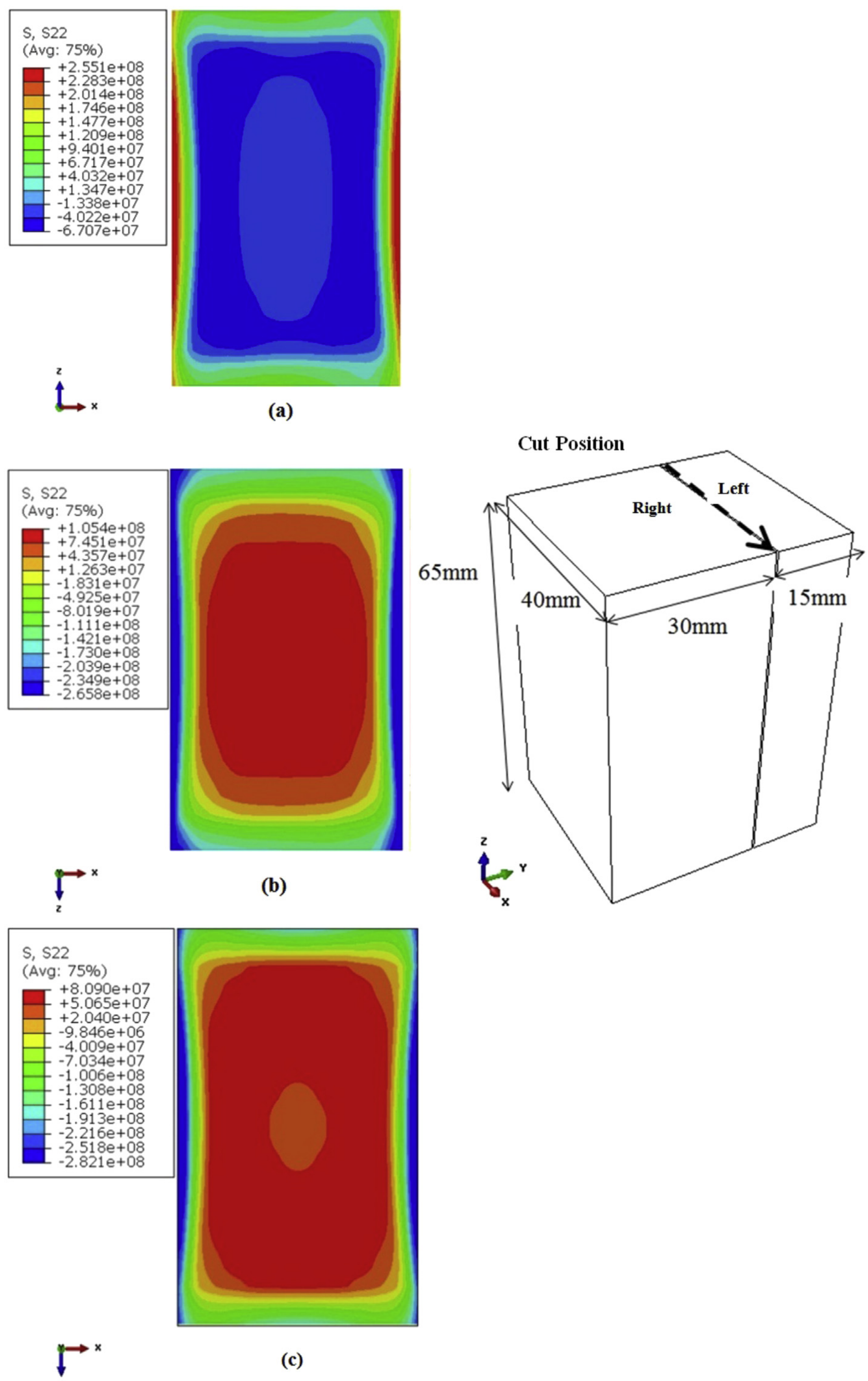

Fig. 1. The contours of normal stress components in an asymmetrical plane for 300 °C. The cut is on XZ plane and 15 mm from Y edge:(a): normal stress of thin section cut(L) after applying contour method, (b): normal stress of thick section cut(R) after applying contour method, (c): normal stress after quench in cut plane.