EFFECT OF MATERIAL REMOVAL ON RESIDUAL STRESS DISTRIBUTION

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ABSTRACT

Residual stress can generate in structural parts during fabrication due to non-uniform mechanical deformation and thermal expansion/contraction. These stresses are modified during subsequent machining process and can create distortion in parts. Here finite element model is created to estimate the residual stress generation during quenching process. Modeling of hole drilling is done to estimate the modification of residual stresses in machining process. Class B railway wheel steel is considered for analysis. Diameter of hole seems to be reduced after drilling process.

Keyword Residual stresses, Finite element modelling**.**

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1. INTRODUCTION

Residual stresses are the stresses that exist in a body when it is free from external forces. They are the consequences of heat treatment, deformation processes, machining, welding/joining or combination of all the above that causes deformation or change the properties of materials. Residual stresses are developed when a body undergoes non-uniform temperature distribution such as in the case of casting, welding and quenching. Residual stress may induce premature failure through cracking, reduce fatigue strength, and induce stress corrosion. During machining process, these stresses are redistributed and can make distortion in parts. Components dimensions can go out of tolerance and be rejected. This situation can be avoided by modeling the process in finite element analysis to understand the residual stress evolution and modification of the same in machining process. Therefore, the investigation and understanding of these residual stress modifications is very important.

Different studies have been conducted to predict the residual stress in manufactured parts. Residual stress generation during thermal spraying was estimated by X-ray diffraction method [1]. Cheng *et al*. reported generation of compressive residual stress in post weld treatment is beneficial for improving fatigue strength of welded structures[2]. Residual stresses generated in railway wheel during manufacturing process is estimated by Brunel *et al.*[3].

Attempts are made to measure the residual stresses generated in components. Rendler and Vigness [4] used hole drilling strain gauge method to measure residual stresses. Leggatt *et al*[5] developed deep hole drilling method. The accuracy of the method was investigated using a 100 mm deep plastically deformed ferritic steel rectangular bar. The stresses in the bar were determined by strain gauges. Incremental hole drilling method was used. In this paper, finite element modeling is done to estimate the residual stress generation during quenching process. Modification of residual stress in machining was determined by hole drilling method.

2. FINITE ELEMENT MODELLING

Commercial finite element software ABAQUS 6.14 was used to perform finite element modeling. A block of dimensions170 x 127 x 124 mm^3made using class B railway wheel steel is considered for analysis (see Figure 1). Initially quenching process of block was modeled. Stress free block with uniform temperature of 500^0Cis immersed in water which is kept at 30^0C. Block is kept in water until the temperature drops to room temperature. Heat loss to water is accounted by taking convection heat transfer coefficient of 3066 W/m^2 K. Thermo-physical, elastic and plastic properties are taken to be isotropic. Linear kinematic hardening model is used. Details of material properties are taken from Vakkalagadda *et al*. [6]. Standard explicit coupled temperature-displacement analysis is used

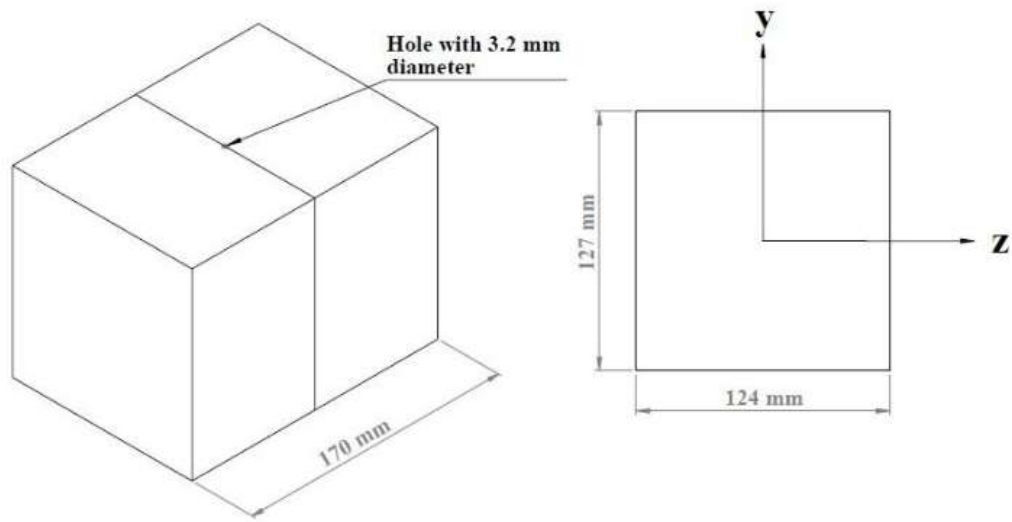


Figure 1: Steel block of given dimension

Modeling of modification of residual stresses during machining is done by drilling a hole of diameter 3.2 mm and 4 mm depth on the surface as shown in Figure 1. Standard explicit static general analysis is used in hole drilling method.

3. RESULTS AND DISCUSSIONS

Figure 2 shows evolution of residual stresses in the block after quenching process. Maximum stress of 340 MPa occurred on all edges of the block. Figure 3 shows the distribution of von-Mises stresses in the block after drilling the hole. After drilling the hole, considerable amount of reduction in von-Mises stresses are observed. But at the area which is nearer to hole edge, peak stress of 425 MPa is observed.

Figure 3 shows the stress distribution in x- direction in the block after quenching process. Maximum compressive stress of about 300 MPa was observed on middle of edges along x-direction. Similar peak stresses can also be observed on middle of edges which are along both y and z direction for the respective normal stresses in these directions.

Figure 4 shows comparison of normal stress component in x- direction and y- direction after quenching and after drilling process. Stress magnitude was plotted along thickness direction which is 6 mm below the surface where the hole is drilled and on the vertical plane of hole center. There is no appreciable variation in stress magnitude is observed after drilling the hole in x- direction. But peak change of compressive stresses was observed at the center line of hole which is about five times the initial value.

Figure 5 shows the comparison of normal stress component in z direction. There is no appreciable change was observed in z-direction. Reduction of hole diameter by 0.02mm is observed

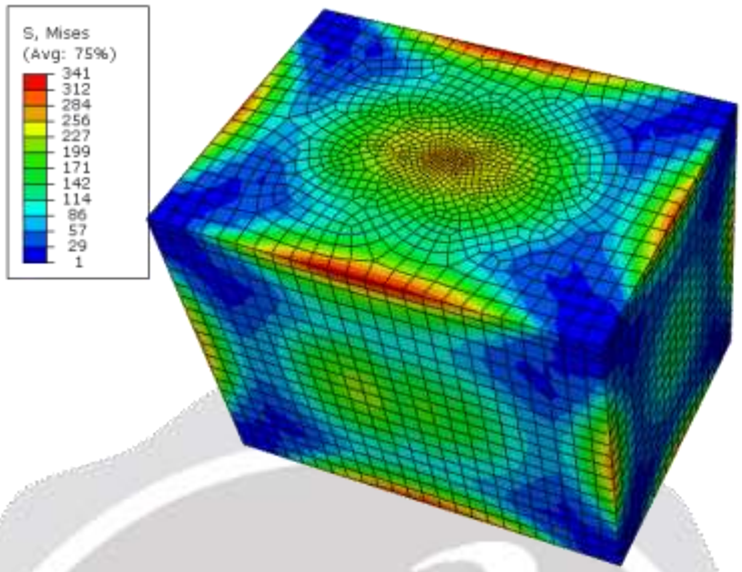


Figure 2: Von-Mises stress distribution after quenching

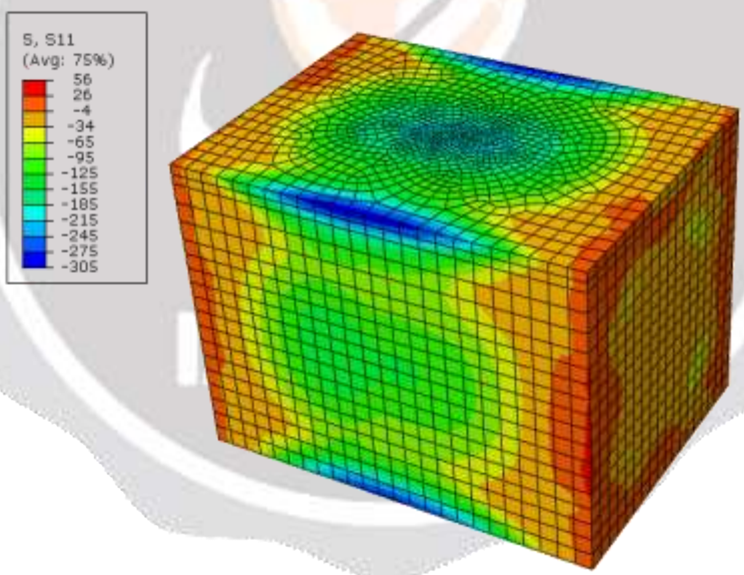
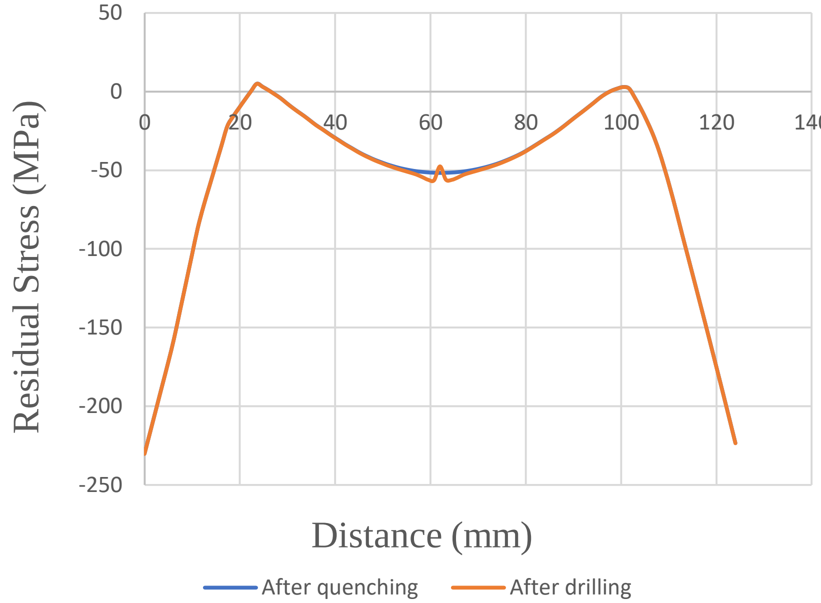
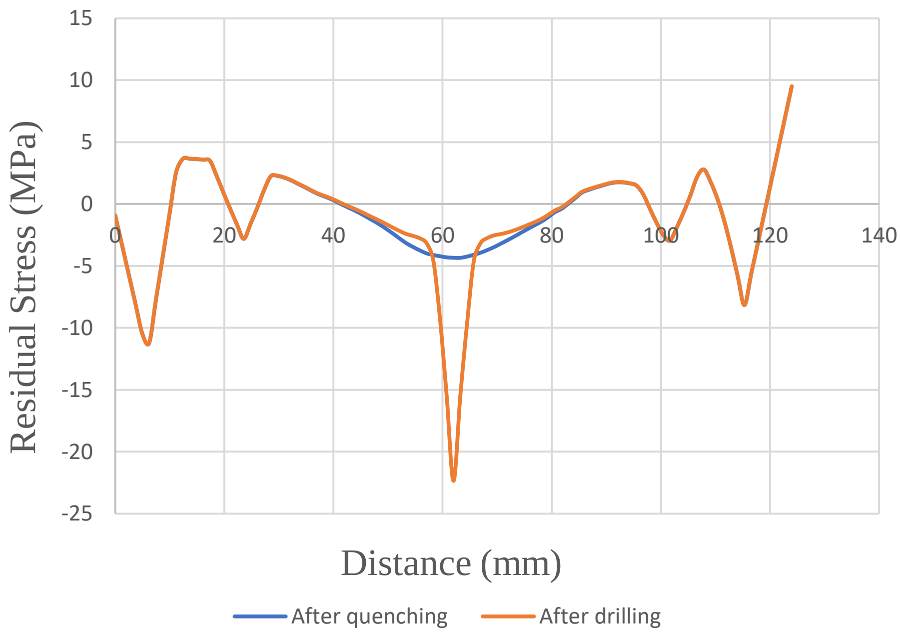


Figure 3: Normal stress along x- direction after quenching process



(a)



(b)

Figure 4: Comparison of (a) x component and (b) y component of residual stress after quenching process and after drilling process

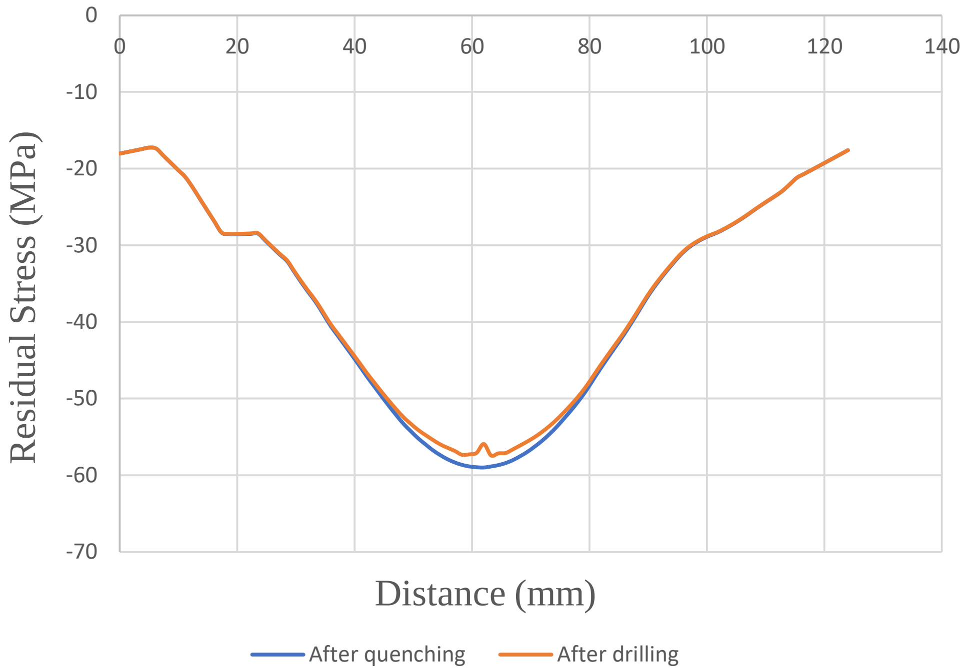


Figure 5: Comparison of z component of residual stress after quenching process and after drilling process

4. CONCLUSIONS

The maximum von-Mises stress is observed on all edges after quenching process. Residual stress magnitude is increased just below the hole after hole drilling along the hole axis. The hole diameter is reduced due to residual stress modification in machining.

6. REFERENCES

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