MODIFICATION OF MANUFACTURING RESIDUAL STRESSES IN RAILWAY WHEEL DUE TO MECHANICAL LOADS

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ABSTRACT

Residual stresses generated during manufacturing process of railway wheel are modified in service from mechanical loads. Mechanical stresses are generated while transmission of carriage weight through rail-wheel contact. Here finite element model is created to estimate the modification of residual stresses which is generated from manufacturing process due to mechanical loads. Considerable reduction in magnitude of compressive residual stress on tread region was observed for wheels with residual stress from manufacturing.

Keyword: - *Residual stress, Railway wheel, Finite element model, Mechanical load*

1. INTRODUCTION

Railway wheel is the most important loaded component in the train. It has to transmit the weight of the coach/wagon to the rail through rail-wheel contact. Besides this, it has to withstand thermal stresses generated during braking for a tread braking system. During manufacturing of railway wheels, beneficial compressive residual stresses are generated on the tread surface of wheel. Railway wheel is manufactured either by casting or forging process. After this wheels are kept in a furnace at 900^0C to relieve any stresses generated during manufacturing process. After taking out the wheel from furnace, rim quenching is performed. Next, tempering process is performed at 500^0C. After taking from tempering furnace, wheel is cooled to room temperature. Estimation of residual stresses during manufacturing process of railway wheels in Indian railways were done using finite element analysis [1]. Compressive hoop stress of 315 MPa was found on tread surface. Conversion of stresses from compressive to tensile is occurred during severe braking. Residual stress generation during mechanical loading because of plastic deformation was analysed using finite element method [2]. Stress free wheel was considered initially and it is found that effect of mechanical loading presents only for a small depth. Stresses induced in manufacturing process were not considered for analysis. This paper considers initial stresses induced during manufacturing process before applying mechanical load.

2. FINITE ELEMENT MODELLING

Commercial finite element software ABAQUS 6.14 was used for the analysis. Two dimensional finite element analyses were performed. Wheel is considered as cylinder with diameter 915 mm which is the diameter of new wheel [2]. Rail is modeled as a rigid cylinder of diameter 100 mm. Tie constraint was used to model the interaction between wheel and axle. Axle is modeled as rigid cylinder. Detailed of geometrical dimensions considered was given in Table 1[2]. Class B railway wheel steel is considered for the analysis. Material properties of the same were reported in [3]. Initially quenching process was modeled to generate residual stress in the wheels as reported [1]. Then the mechanical load is applied using rail cylinder through the point of contact. Interaction between wheel and rail is assumed to be hard normal contact with friction coefficient of 0.1. The analysis is carried out by using two different loads 2740 N/mm and 4566 N/mm [2]. Very fine mesh is created on outer surface of wheel to capture the effect on the surface. The mesh made coarser inside. Wheel is rotated through an angle of 45^0 about its axis to model the rail-wheel contact during running condition.

Table -1: Geometric parameters of wheel-rail system[2]

Parameter	Value given (mm)
Outer radius of the wheel	457.5
Inner radius of the wheel	126
Radius of the axle	126
Radius of the rail	100

3. RESULTS AND DISCUSSIONS

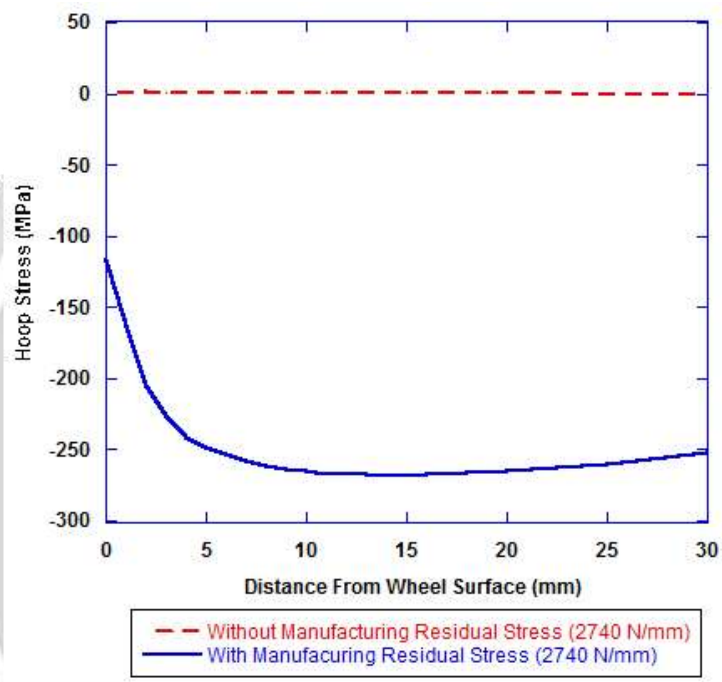

Fig -1: Hoop Stress vs Distance from Wheel Surface at F=2740 N/mm

In Figure 1 shows the hoop stress distribution in wheel after application of mechanical load 2740 N/mm through the roller. Red dotted line represents the stress distribution in a wheel without considering the initial residual stress generated from heat treatement process. The wheel is in a stress free state before application of mechanical load. Blue solid line represents the stress distribution with considering the stress developed from heat treatment process. Compressive residual stress on the surface [1] was present in the wheel before application of residual stresses. The following can be noted from the figure: (i) The magnitude of stress developed from mechanical load was almost zero in the currrent loading conditions for a stress free wheel initially, (ii) stress on the tread region was decreased from 315 MPa to 125 MPa for a wheel having initial residual stresses from manufacturing. Reduction in beneficial compressive stresses in tread region can accelerate the crack propagation on tread surface, and (iii) however, reduction in compressive stress is observed for about 10 mm from tread surface.

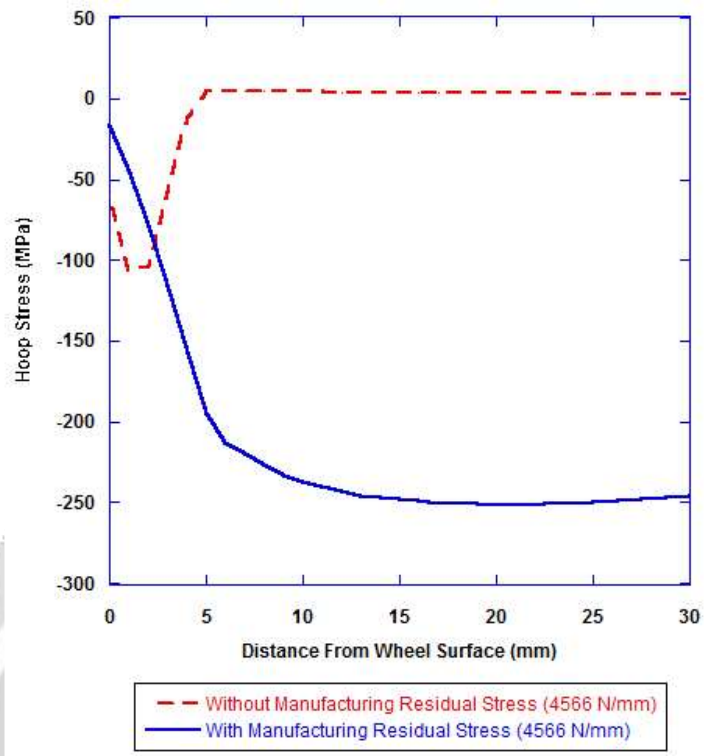

Fig -2: Hoop stress vs Distance from Wheel Surface at F=4566 N/mm

Figure2 represents stress distribution in the wheel with the same condition for an increased mechanical load of 4566 N/mm. The following can be noted from the figure: (i) For the condition with a stress free wheel, hoop stress of 100 MPa is developed on the tread region contrary with the previous condition of 2740 N/mm, (ii) Compressive stress is developed for about 5 mm from tread surface, (iii) Higher reduction in compressive stress from 315 MPa to 25 MPa is observed on tread surface for the wheel with initial residual stress from manufacturing, and (iv) depth of affected region was found to be increased from about 10 mm from previous case to 15 mm.

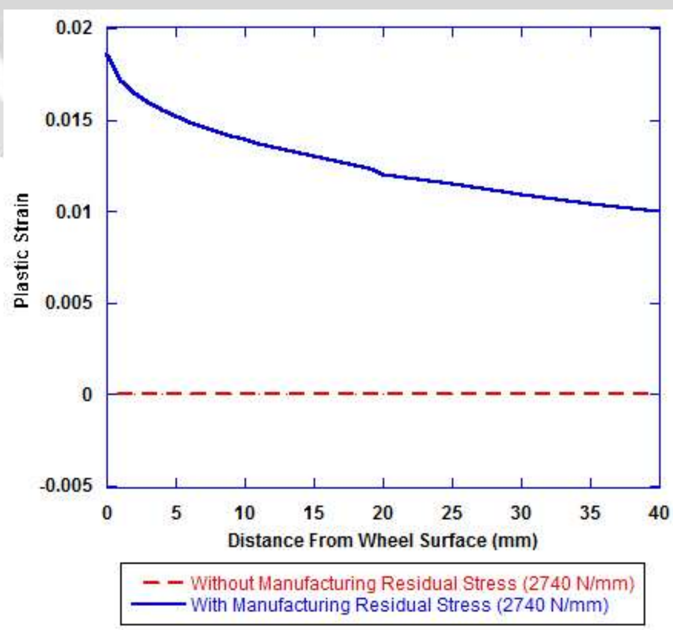

Fig -3: Plastic strain vs distance from wheel surface (at 2740 N/mm)

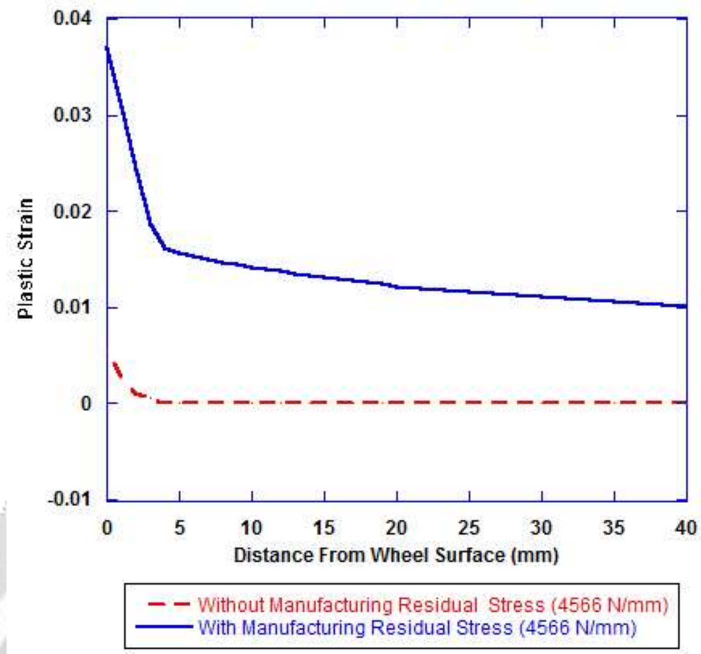

Fig -4: Plastic strain vs distance from wheel surface (at 4566 N/mm)

Figure 3 and 4 represents plastic strain developed for similar conditions for application of load 2740 N/mm and 4566 N/mm respectively. Plastic strain was not developed in stress free wheel for 2740 N/mm load. Plastic strain increases in wheel with initial manufacturing residual stresses after application of mechanical load. Figure 5 shows comparison of plastic strain developed in two different loads. Considerable plastic strain was observed after application of higher loads on tread region.

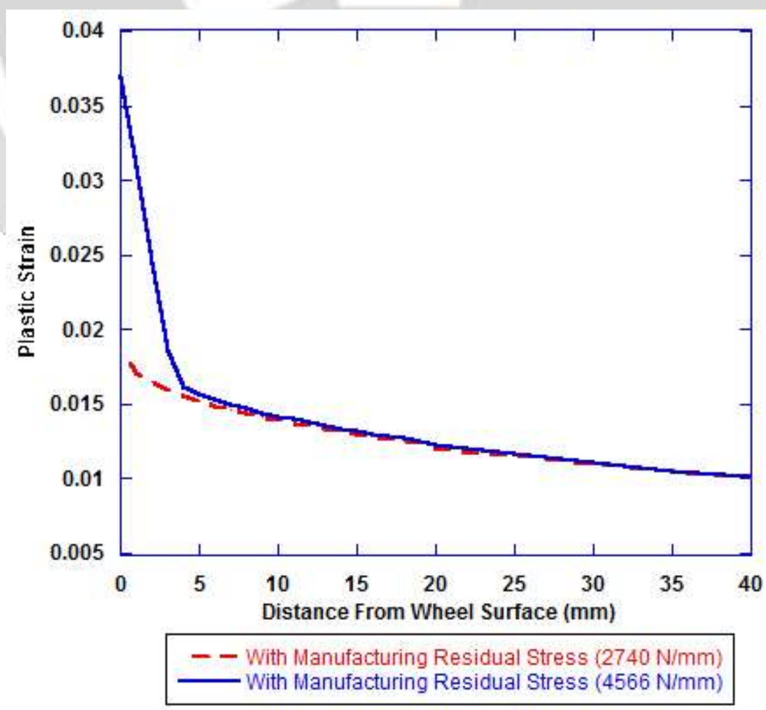

Fig -5: Plastic strain vs distance from wheel surface (at 2740N/mm and 4566 N/mm)

4. CONCLUSION

Reduction in magnitude of compressive residual stresses is observed on tread surface region of railway wheel during application of mechanical load. Higher Reduction in magnitude of compressive stresses occurs as the magnitude of mechanical load increases.

5. REFERENCES

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