EXTENSOMETRIC MEASUREMENTS OF RESIDUAL STRESSES AND ITS COMPARISION TO FINITE ELEMENTS ANALYSIS ON LIGTH ALLOY WHEELS

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Abstract

Many engineering specifications, manufacturing procedures, inspection and quality controls require the evaluation of the residual stress of critical parts of components. The finite elements analysis (FEA) provides a simulational advantage and it is very helpfully in projects aiming manufacturing improvements, thus reducing costs in terms of time and money. This study had as proposal to improve the database of the analysis systems using FEA extending the knowledge of the residual stresses phenomena in wheels using extensometers. To this work were use strain gage to acquire and make available this information available. The residual stress values obtained from the experimental tests by drilling method with rosette type strain gages. The region to test is a critical region (the spokes), showed on FEA simulations. The relevance of the present study and research on residual stresses meets the required effort towards the safety improvements in car's wheel industry.

Keywords: aluminum wheels, residual stress, extensometer, strain gages, hole drilling.

1. Introduction

The study of the residual stress in automotive wheels, using the strain gages experimental testing in comparison to simulation analysis using finite element (FEA), it is the present target [1]. All experiments were undertaken in residual tension auto-static equilibrium, where the resultant internal forces and moments are zero. It is known that the tensile residual stress can be added vectorially to a static load by the principle of superposition (Eq. 1), where σ_n, σ_A and σ_r are resultant stress, external load and residual stress respectively [2].

$$\sigma_n = \sigma_A + \sigma_r \qquad (1)$$

The data acquired from experimental procedures, in general, was compared with each generated simulation and used to improve database of FEA simulation [3]. Although the FEA provides the simulation advantage, it is required experimental procedures to verify and validate the simulation (Fig. 1).

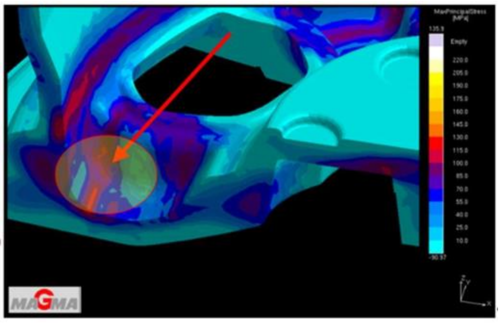

Figure 1: FEA simulation, the arrow points to critical region of residual stress (spoke) for wheel.

Usually it is distinguish three types of stress states, according to their size radii. First: macroscopic, high range stresses acting on a macroscopic region covering a wide number of grains. Second: structural micro-stress, located in a grain and its surroundings. Third: molecular, involving the structure at the atomic level. For each type it is associate one or a combination of methods to get better response from the experiments [4]. The most usual methods are: blind hole, cut ring, cut by section, removing layers, and X-ray and neutron diffraction. In this paper is presented the methods of section cutting and hole drilling and the results compared with FEA simulation. Even the experimental methods, basically have not similarity, the value of residual stress should be the same quantitative order [5].

2. Experimental methods

2.1 Section relief method

The sectioning method is considered over all macroscopic area. In section method proceeds a simple relaxation of residual stress of entire wheel. This method is comprised of three parts (fig. 2):

1) Partition: a portion of material is removed from the body by two parallel cuts.

2) Breakdown: the part removed is divided into two parts, and the inner surface and outer the surface in relation to each other at the cutting plane.

3) Removal of layers: it is done removing a slice of the wheel radix by cutting parallel plane layers.

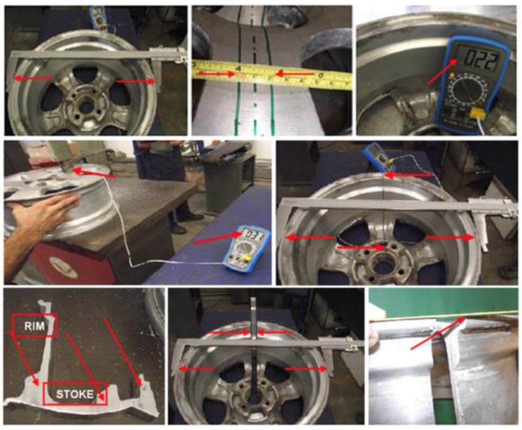

Figure 2 - Section relief method trial.

By removing portion tensioned part of wheel the remainder piece undergoes a tension relaxation deforming the entire wheel (Fig. 3).

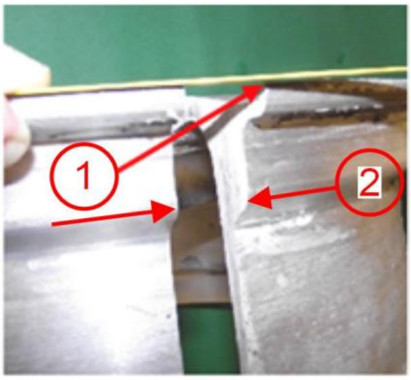

Figure 3 - Sectioned results

The fig. 3 detail 1 show that the entire wheel root across its axial axis and detail 2 show that internal portion of wheel is more close each other than the opposite side. The Section method, in general, is only qualitative showing if the wheel entire mode of residual stress is traction or compresses.

2.2 Hole drilling method

The hole drilling method is widely used to measure average residual stress. In the classical system of blind hole a rosette type strain gauges is used (ASTM E 837) that have a center mark locator for drilling. The method is *in situ* and involves the removal of material under tension by making a blind hole depth, always smaller than the diameter of the drill (0.4 D) in the center of the rosette strain gauge and measuring the deformation occurred in the region adjacent to the hole (Fig. 4).

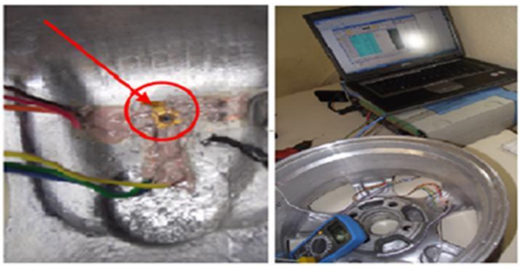

Figure 4 - Hole drilling gages rosette

The method by itself induces a residual stress and needs an initial calibration before starting measurements. An advantage of using the rosette with central hole is a better sampling of the main deformation. On these experimental procedures was combined a cutting section method to reduce the area under the gage rosette (Fig 5).

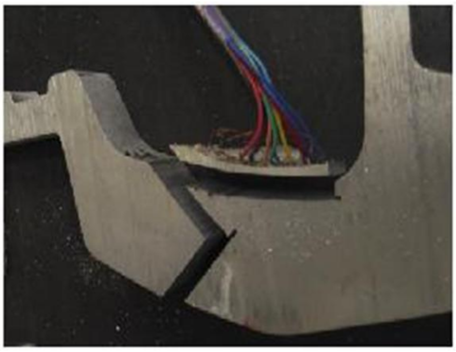

Figure 5 - Minimal section for hole drilling method

3. Results

3.1 Section relief method

The analysis of experimental data from the technique of cutting a section of the wheel, used the diameter differences obtained between measurements - initial and final (before and after removal of a section), of both sides of the wheel (front and bottom) as shown in Table 1. This data was used to calculate the linear deformation occurred in the entire wheel.

Geometry of the cut	Diameter the outside (front) (mm)	Diameter inner side (bottom) (mm)	Maximum temperature during cutting (ºC)
Without cut	387.54	384.30	22
1st. cut	387.51	384.33	37
2nd. cut	387.43	384.50	58
Observed difference (mm)	-0.11	+ 0.20	36

Table 1: Section relief method results

3.1 Hole drilling relief method

The local residual stress results show that was not affected with around relief by cutting. The analyzes shows during 225 s, divided into six distinct elapsed times: (1) 0-45 s calibration setup of the "zero" signal level is a pre-punching process; (2) 45-55 s punch; (3) 55-105 s waiting for the positioning of the drill; (4) 105-130 s on the positioning of the drilling rosette; (5) 130-150 s drilling process; (6) 150-225 s stabilization the surface.

Calculated the values of micro-deformations in each stain gauge direction (Fig. 6).

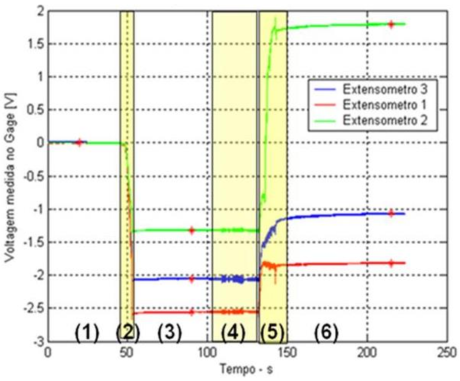

Figure 6: Method of blind hole - graphics analyzes.

4. Conclusion

The analysis of experimental data from hole drilling method indicates a residual stresses behavior seams to be convergent with similarity to those obtained using FEA simulation. The cutting method of entire wheel show compressive residual stress mode. The results from the cutting method were only qualitative. There is a need of conducting further experiments to confirm the trend toward the simulation results data, and to investigate new approaches.

5. References

[1] Assan AE. Finite element analysis first steps. Campinas - Brazil: Ed.; UNICAMP, 2003. (In Portuguese).

[2] Lai, M.O., Oh, J.T., Nee, A.Y.C., Applicatons of Fracture Mechanics In Residual Stress Measurement of Cold Worked Holes, ICF International Conference of Frature, Singapure, Singapure, 1991.

[3] Holffmann K., An introduction to measurements using strain gages. Darmstadt - Germany: Hottinger Baldwin Messtechnick GmbH, 1989.
[4] Beghini M, Bertini I, Santus CA. Procedure for evaluating high residual stresses using the blind hole drilling method, including the effect of plasticity. University of Pisa. Pisa - Italy, p. 301-314. 2009.
[5] Colosio MA, Santos JC, Ferrante RP. Virtual simulation of residual stress in aluminum wheel designs. SAE International Paper n. 2009-01-0417, Detroit - USA, April 2009.