NUMERICAL STUDY OF THE MECHANICAL BEHAVIOUR OF RAILWAY WHEELS CONTAINING TEARING ON THE TREAD.

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ABSTRACT

With the intention of ensuring security and diminishing the costs of service in the railway systems, it is necessary to characterize the mechanical behavior of the zone containing tearing of metal caused by a manufacturing defect which can be at the origin of breaks. The influence of these defects, present in the metal of the wheel was studied by simulating three geometrical forms: circular defect, elliptical defect and any form defect. The constraints and distortions were analyzed in the immediate neighborhood of these defects. The Calculations were performed for a level of load corresponding to the weight of the trailer of the new railcars in Algeria and to the assistant of a code of calculation by finished elements (ANSYS).

Key Words: *damage, railway wheel, numerical modeling, tearing of metal, constraints*

NOMENCLATURE

Symboles :

E modulus of elasticity (Young's modulus) N/mm^2

υ Poisson's ratio

λ, μ are the lamé coefficients

1. INTRODUCTION

I treated an encountered problem at the AMF on the new railway wheels of the new rail cars which are characterized by a metal extraction on the wheels' rotation table. Therefore I changed the geometric model by creating singularity of forms close to those encountered on the rotation table: extraction under circular, elliptical form and under any form of the same dimensions and with different depths at the level of contact wheel- rail. Then we made a static analysis, initially, to observe the resultant mechanical behavior and to compare the outcomes with the flawless ones.

This second technique is, currently, widely used in railways. However, it was noted that damages occur most often in these zones which can have serious consequences on security and comfort during operation.

In this study, i offer a modeling of flake defects. The first defect is modeled by circular and introduction. elliptical forms, and the second is modeled by any forms. This modeling is accomplished by the method of finished elements and with the aid of calculation code (ANSYS V14).

Figure1. The different defects on tread (Photos taken in the railway maintenance workshop (RMW) SMK Constantine .

1. STRUCTURE OF WHEELS AND TERMS OF PARTS

A solid wheel of a railway vehicle (hereinafter “wheel”) consists of three parts, as shown in Fig. 1. They include a hub, where in an axle is inserted, a rim that contacts the rail, and a web that unites the two parts. The outer circumferential surface of the rim, which contacts the rail, is tread, and the projected part is flange.

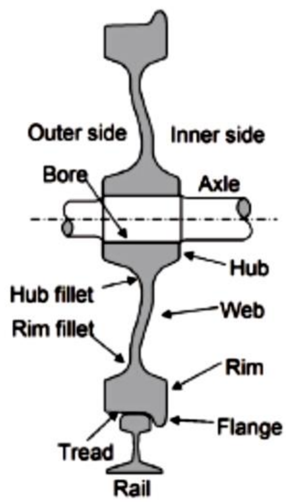

Figure 2. Designation of each part of solid wheel [1]

2. CHARACTERISTICS OF MATERIAL

The steel of wheel is of nuance ER8 with chemical composition and mechanical characteristics as follows:

IN %

	C	Si	Mn	P	S	Cr	Cu	Mo	Ni	V	Cr+Mo+Ni
ER8	**≤0.56**	**≤0.40**	**≤0.80**	**≤0.020**	**≤0.015**	**≤0.30**	**≤0.30**	**≤0.08**	**≤0.30**	**≤0.06**	**≤0.50**

TABLE 1. The Chemical Composition of Steel ER8 [2]

Steel grade	rim			web		υ: Poisson's ratio	E(Young's modulus)
	ReH(N/mm2) (1)	Rm (N/mm2)	A5 %	Decrease Of Rm ≥(N/mm2) (2)	A5 %		
ER8	**≥ 540**	**860/980**	**≥ 13**	**≥ 120**	**≥ 16**	**0.3**	**2.1e5 (N/mm^2)**

(1)If the elastic limit related cannot be distinguished, the conventional limit to Rp0.2 must be determined.
(2) Decrease Tensile strength compared that rim on the same wheel

TABLE 2. The mechanical characteristics of steel ER8 [3]

. **3**. BEHAVIOR LAW

Submitted to a constraint, the material deforms linearly compared to this constraint provided the deformation generated is low. When the stress is removed, the material returns to its standard state reversibly. This observed behavior for all materials is said elastic. In static, the state of stress on the wheel is defined by the following expressions:

3.1. Relationship between deformation and displacement

$$\begin{cases} \varepsilon_x = \frac{\partial u}{\partial x} \\ \varepsilon_y = \frac{\partial v}{\partial y} \\ \varepsilon_z = \frac{\partial w}{\partial Z} \\ \gamma_{xy} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \\ \gamma_{xz} = \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} \\ \gamma_{yz} = \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \end{cases}$$

3.2. Relationship between deformation and constraint:

$$\begin{cases} \varepsilon_x = \frac{1}{E}\left[\sigma_X - \upsilon(\sigma_y + \sigma_z)\right] \\ \varepsilon_y = \frac{1}{E}\left[\sigma_y - \upsilon(\sigma_x + \sigma_z)\right] \\ \varepsilon_z = \frac{1}{E}\left[\sigma_z - \upsilon(\sigma_x + \sigma_y)\right] \end{cases}$$

$$\begin{cases} \sigma_x = \frac{E}{1+\upsilon}\left[\frac{1-\upsilon}{1-2\upsilon}\varepsilon_x + \frac{\upsilon}{1-2\upsilon}(\varepsilon_y + \varepsilon_z)\right] \\ \sigma_y = \frac{E}{1+\upsilon}\left[\frac{1-\upsilon}{1-2\upsilon}\varepsilon_y + \frac{\upsilon}{1-2\upsilon}(\varepsilon_x + \varepsilon_z)\right] \\ \sigma_z = \frac{E}{1+\upsilon}\left[\frac{1-\upsilon}{1-2\upsilon}\varepsilon_z + \frac{\upsilon}{1-2\upsilon}(\varepsilon_x + \varepsilon_y)\right] \end{cases}$$

3.3 The Von Mises stress

$$\sigma_{vm}^2 = \sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y z + 3(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{xz}^2)$$

With:

$E = \frac{\mu(3\lambda+2\mu)}{\lambda+\mu}$ and $\upsilon = \frac{\lambda}{2(\lambda+\mu)}$

4. MODELING DEFECTS

a- CIRCULAR DEFECT

The section of defect is circular of diameter D=16 mm, located in a depth varying 2, 5, 8, 11 and 14 mm, which is subjected to the maximum pressure of Hertz Po=890 MPA (which corresponds to the empty weight by wheel wish is 9.5 tones with 850 of diameter).

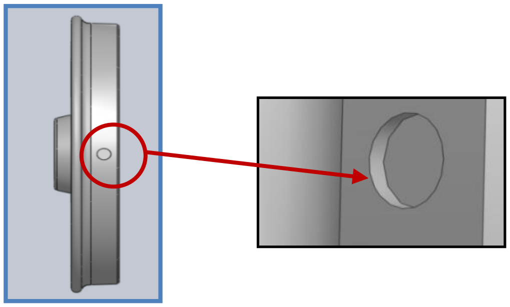

Figure 3. Circular defect

b- DEFECT OF ELLIPTICAL FORM

The section of defect is in elliptical form (a=16; b=4 mm) and the applied load (Po=890 MPA). As for circular defect, we varied the depth of defect from 2 to 14 mm.

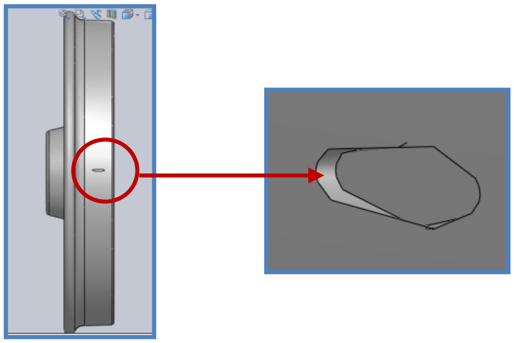

Figure 4. Elliptical defect

c- DEFECT OF ANY FORM

We modeled another defect having any form. The applied load corresponds is the same, and the section of defect S3=201 mm^2 equivalent to the sections of other defects. Scaling the depth h varying from 2 to 14 mm.

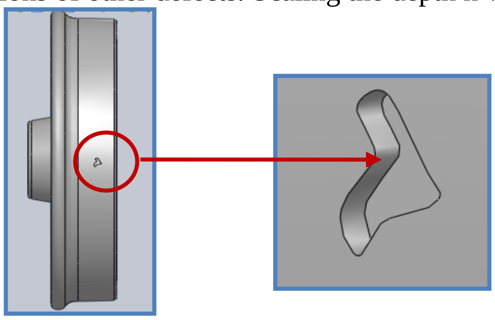

Figure 5. Any form defect

5. SIMULATION BY THE FINISHED ELEMENTS METHOD

We therefore simulated the mechanical behavior of the wheel by considering different shapes linked to defects mentioned above. These defects are located on the tread in depths varying between 2, 5, 8, 11 and 14mm. The load is applied in form of pressure in the straight case.

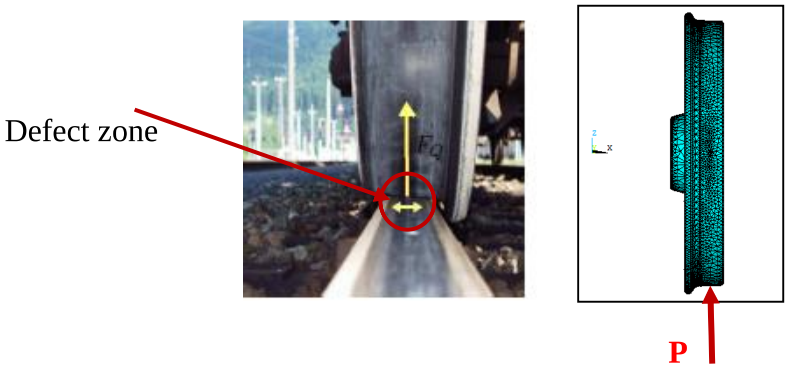

Figure 6. The load in the straight case (in the contact zone) [3]

5.1 MESH SIZE AND LOAD:

Calculations are performed with the hypothesis of a wheel without rubbing, for a state of distortions there 3D. The chosen elements are Solid 185 of code ANSYS 14 [4] and the reaction of the static load as shows it the figure 7.

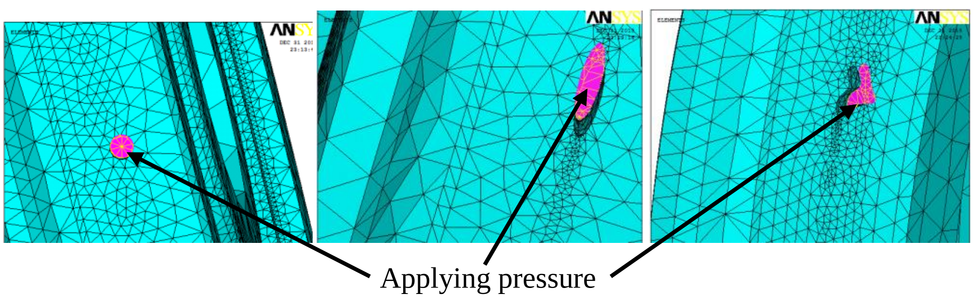

Figure 7. The mesh models

5.2 CONDITION IN BORDERS

In this simulation, we fixed the wheel on the hub assumed rigid which leads us to assume a zero displacements at the boring level (Ux = Uy = Uz=0).

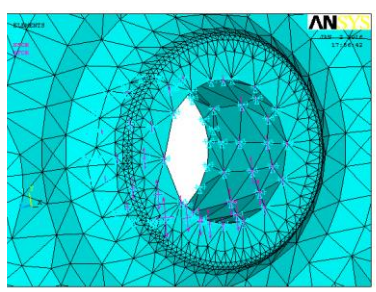

Figure 8. Condition in border (wheel fixed on the hub)

6. RESULTS AND DISCUSSION

Among got results, we represented in the figure 9 the distribution of the pressure of Von Mises and the total Von Mises strain. Through this result we can see that the Von Mises stress and the total Von Mises strain are highest in the vicinity of the defect. This is valid for all the geometric shapes of defects considered.
To highlight the influence of the form of defect, we for the same section respectively pressure and distortion according to the depth. We compared the influence of the defects of circular, elliptical and any forms of the same section (S=201 mm2) by making vary the depth from 2 to 14 mm, in case of a maximum pressure po=890 MPa.

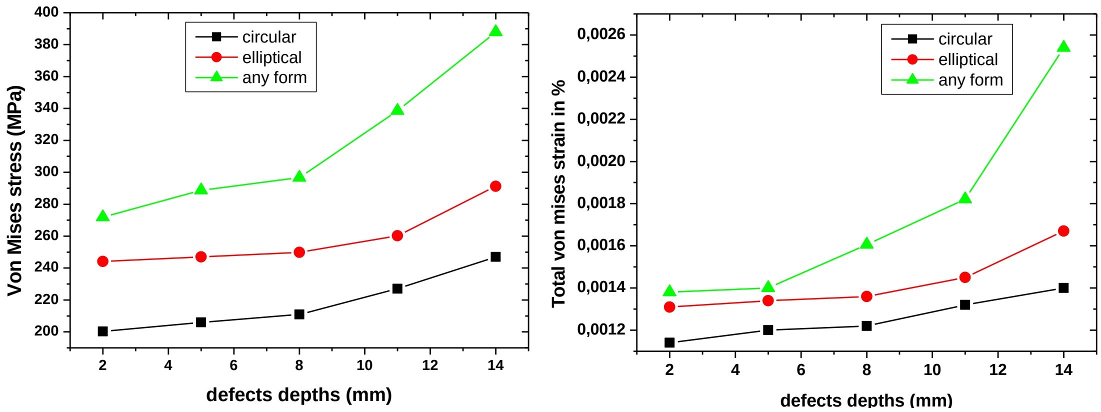

Figure 9. Varying the Von Mises Stress and the total Von Mises Strain versus depth of defects

7. CONCLUSION

According the results of the stress and total strain of Von Mises, obtained by numerical simulation we found after analyzing these results the event of default of a tearing metal in any form is more dangerous than the default in the elliptical shape followed by the circular defect.
The Von Mises stress and total strain are very important when is close to the contact surface. On the other hand; these parameters fade quickly when the default is located more and more away from the contact surface. It appears that the external actions are enhanced only in the vicinity of the defect at the contact zone. Finally the presence of metal tearing failure lying on the surface of the wheels causes the reduction of hours of life.

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[5] Help ANSYS APDL V14 Software.