PROSIDING ABSTRAK

SEMINAR NASIONAL TAHUNAN TEKNIK MESIN X
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OPTIMALISASI PERAN TEKNIK MESIN DALAM MENINGKATKAN KETAHANAN ENERGI

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PROSIDING

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KATA PENGANTAR

Dengan mengucap syukur alhamdulillah ke hadirat Allah Yang Esa yang tiada tuhan selain-Nya, kami selaku Panitia Seminar Nasional Tahunan Teknik Mesin X Tahun 2011 Jurusan Mesin Fakultas Teknik Universitas Brawijaya Malang dapat menyelesaikan prosiding abstrak ini.

Cinta Kasih-Nya yang tak terhingga mendorong kami untuk semangat dalam kegiatan belajar mengajar yang tak pernah putus sampai masuk liang lahat, khususnya dalam hal ini ilmu-Nya yang kita tekuni bersama yaitu rekayasa keteknikan.

Prosiding ini diharapkan mampu menampung para peneliti, praktisi, pemerintah dan mahasiswa untuk mengkomunikasikan hasil-hasil penelitiannya. Prosiding ini juga merupakan sebuah wujud tanggung jawab bidang teknik mesin dalam menyumbangkan pemikiran, ide dan hasil penelitian sehingga mampu diaplikasikan ke masyarakat dan guna mendukung ketahanan energy di Indonesia.

Bertolak dari hal tersebut maka Jurusan Mesin Fakultas Teknik Universitas Brawijaya Malang menggelar *event* akademik Seminar Nasional Tahunan Teknik Mesin X Tahun 2011 yang bertajuk:

"Optimalisasi Peran Teknik Mesin dalam Meningkatkan Ketahanan Energi"

Diharapkan dengan adanya seminar nasional ini, para akademisi pemerintah peneliti dan atau praktisi dapat menambah wawasan mereka serta menerapkan pengetahuannya tersebut dalam dunia *engineering* untuk mengoptimalkan ketahanan energi nasional. Selanjutnya akan terbina suasana akademis yang nantinya dapat dikembangkan menjadi wujud kongkrit di masyarakat pada umunya.

Semoga Allah Yang Maha Pengampun meridhoi jerih payah kita semua. Amien.

Malang, 1 Nopember 2011

PANITIA SNTTM X

DAFTAR ISI

BIDANG KONTRUKSI

Numerical Simulation of Contact Stresses of Rail-Road Interface

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Abstract

Train accident is one of transportation accidents that frequently happen in Indonesia. From engineering point of view, the train accident category which concerned is derailment as a cause of failure function of rail or wheel. During its operation, rail-wheel system could be failure due to contact, known as rolling contact fatigue, and stick-slip behaviour between rail and wheel. Failures usually occurs as wear and initial crack that propagate through rail or wheel. This paper reports result of a nonlinear numerical simulation of contact stresses of rail-wheel interface. Investigation was carried out in the region where derailment happened and fracture modes was documented. Rail and wheel profile was measured before and after failure. Failure modes is then simulated numerically using finite element method, particularly contact stresses at rail-wheel interface. The results show that maximum combined (von Mises) stress occur at a distance of 4mm from the interface toward bottom of the rail and 5.5 mm from the interface toward the centre of the wheel. Whereas the maximum shear stress occurs exactly at the interface of the rail-wheel.

Keywords: *numerical simulation, contact stresses, finite element method, rail-wheel interface*

1. INTRODUCTION (10 pt, bold)

Train transportation is a mass transportation moda used in many developed country. The main anvantage of train transportation is its power to carry massive load for goods as well as for passengers. In Indonesia, however, train transportation is very marginal and can only be found in Java and Sumatera island. In Sumatera itself, there are three train sub-network which apart each other: north of Sumatera, west of Sumatera, and south of Sumatera.

Based on a document of PT. Kereta Api Indonesia in 2005, infrastructure of train rail in Indonesia had increased by about 0.16% during the periode of 2000-2005. This is a result of increasing the number of non-prime (branch) infrastructure by about 10.57%. The increasing of infrastructure of rail during the five years periode is a result of renewing process by PT. Kereta Api Indonesia. Train transportation will be continually developed in the future, both for long distance (Trans Sumatera) as well as for local transportation, such as south of sumatera [Presentation in Faculty of Engineering University of Lampung on the 13 march 2009, by Ir. Anshori Djausal, expert staf of Lampung Governor].

The main problem in train transportation in Indonesia is train accident. In general, there are five categories of train accident in Indonesia [1], i.e., crash of train with train, crash of train with other vehicle in highway, derailment, floods or landslide, and other accident such as commit suicide in rail. The first two categories mentioned above usually result from human error, while derailment is caused by failure of rail/road, such as wearing of rail, crack of rail, small difference in wheel diameter, imperfection in rail connenction, failure of elastic fastening, etc. During the periode of 2000 – 2009, derailment type accident dominated train accident in Indonesia [2]. In 2007, KNKT investigated eight cases of derailment of nine cases [3]. This indicated that a more comprehensive research on structural failure of rail/whell is needed.

Wearing and crack at rail is caused by contact stresses at the rail/wheel interface when a train move on the rail. A key factor to be able to predict wearing accurately is by investigating the distribution of contact stresses and stick-slip behaviour. The distribution of contact stresses at rail/wheell interface is very complex and involved nonlinearity with changing status. Experimental analysis for contact stresses is very difficult and expensive, because strain gage will be fault under contact stresses. To overcome this problem, numerical simulation with finite element method can be the best choise.

The first study of contact of two bodies began at the end of 19th century. It is a Germany researcher, Heinrich Hertz (in 1896), who first published a paper detailed about contact between two cylinders. He showed that when two cylinders in contact under a load *F*, the cylinders will deform with contact area in form of ellips with major axis in line with line connected the centre of two cylinders and minor axis in line with tangent at contact point. Herzt developed equation for stress state along the major axis of the ellip of contact area. The Hertz's equations were developed with assumtion that contact area free from shear stress. The Hertz's formula is still used today when study contact stress. The theory is valid for elactic materials.

Many researchers then calculated contact stresses at the interface of two spherical or two cylinders with contact area in form of circular or rectangular respectively. With this form of contact, the dimension of contact area can be determined analitically by solving a simple equation. For a more complex of contact area, such as rail/wheel interface, contact area is in form of ellips because the curvatures of the bodies in contact are different and the plane of contact area are perpendiculars. For a case of elliptic contact, stress equation cannot be solved analitically, but numerically.

de Santos et al [4] carried out semi-analytical analysis to determine the half-length of axis of elliptic contact area using elliptic integral. Stress tensor at rail/wheel in the vicinity of contact area was obtained in form of double integral and then solved using numerical method. Goryacheva, et al [5] developed a model to analyse wearing and fatigue failure of rail/wheel system based on contact and fracture mechanics approach. The model developed include solution for rail/wheel contact, and calculation of profile change due to wearing process of rail as a function of failure accumulation at rail and wheel. Liu, et al [6] developed a failure model due to high cycle multiaxial fatigue to predict the orientation of initial crack plane and fatigue life of rail/wheel. They also developed 3D model element to analyse rail/wheel contact. Stress response obtained from numerical simulation was used to predict fatigue life of rail/wheel. Liu, et al [7] carried out a study of crack fatigue propagation at the rim wheel of train by modeling 3D finite element for rail/wheel contact. Povov, at al [8] carried out study of the influence of material properties and loading on coefficient of friction of rail/wheel system. Their study showed that friction force directly proportional to normal pressure, as expected. Talamini, et al [9] carried out numerical investigation of sliding effect on surface failure of wheel of train. Finite element model using ABAQUS program package was used to see spalling due to friction heating at the rail/wheel interface.

During its operation, in addition to mechanical load in form of train weight and movement force, rail/wheel also subjected to thermal load that happened at the moment of decceleration braking. Almost all the kinetic and potensial energy is converted into heat in reguler braking system. Some of heat propagated into rim wheel and results in temperature gradient in radial direction.

The presence of residual stress at wheel during manufacturing process adds to complexities of stress behaviour. There are three problems at wheel in relation to residual stress [4]: spalling, sudden fracture, and shelling. Spalling is caused by changing in material microstructures at small part of wheel in contact (tread). Sudden fracture is caused by contact stresses. Changes in stress pattern (originally compression) could cause sudden fracture when a train moving. Shelling is also caused by contact stress. This could happen when small crack at surface propogates in the direction of maximum shear stress.

This paper reports results of numerical simulation of contact stress of rail/wheel interface. By knowing stress state, improvement in rail and wheel design of train could be recommended to reduce rates of wearing and avoid derailment.

2. FINITE ELEMENT MODELING

A wheel of train is usually mounted rigidly on a steel axle. Because of heavy load of shaft and small contact area at the rail/wheel interface, stress at contact area is very high. To obtain an accurate contact behaviour, 3D element is used in finite element modeling and with this element, stress response at contact area can be calculated accurately. Geometric and material nonlinearity were included in analysis.

Before building 3D model, 2D model is builded first, starting from defining keypoints, followed by lines, and then areas. Wheel of train was created by dragging the areas along a circle. Rail model was simply obtained by dragging an area of rail cross-section along a line in z-axis direction. Figure 1 shows the geometry of a pair of rail/wheel in contact. Diameter of wheel was obtained from measurement in PT Kereta Api

Indonesia Subdivre III.2 Tanjung Karang, it was 774 mm.

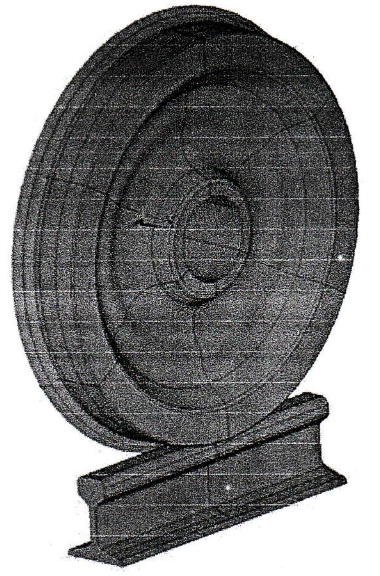

Fig.1 A pair of rail/wheel in contact

Material properties for rail and wheel is assumed the same, i.e., carbon steel of Young's modulus and Poisson's ratio of 207GPa dan 0.3 respectively. In this analysis, it was assumed that material behaves linearly. Only these two properties needed in contact analysis.

In this modeling, SOLID45 element type of ANSYS [10] is used for both rail and wheel. The element has three degrees of freedom, i.e., translation in the x, y, and z direction. For contact type of *surface-to-surfac,* TARGET170 and CONTA174 are used. Contact element TARGET170 is used for rail and modelled as segmented target which consists of one target surface and eight nodes. TARGET170 has six degrees of freedom, i.e., translation in the x, y, and z direction, as well as temperature, voltage, and magnetic. For contact element at wheel, CONTA174 element is used. This element has eight nodes with three degrees of freedom for every node, i.e., translation in the x, y, and z direction. Finite elements for wheel (tetrahedron) were generated using freemesh, while finite elements for rail (hexahedral) were generated using sweepmesh.

Boundary conditions of the model is zero displacement for all nodes at both ends of the rail to simulate the length of span of a rail between two supports. Symmetry boundary condition in plane XY for rail was taken into account as shown in Figure 2.

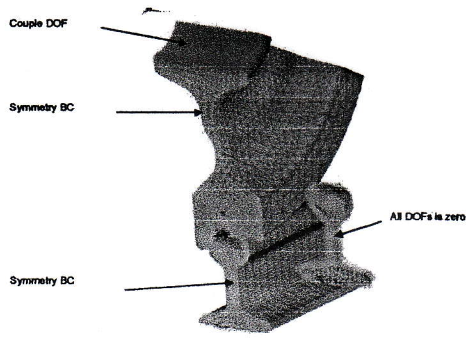

Fig.2 Boundary conditions for rail and wheel in contact

To avoid stress concentration due to singularity at the point of applied loading, the load was so applied that it was distributed at shaft of wheel. This was done by using ANSYS command "couple" so that the region where load applied does not produce stress. Load applied was force downward of 50kN.

3. RESULTS AND DISCUSSION

Figure 3 shows stress (von Mises) contour plot at rail/wheel interface. It can be seen from figure 3 that maximum stress occurs in the vicinity of contact surface. Stress (von Mises) distribution is shown clearly in Figure 4, which reveals that maximum stress does not occur at the interface but at a distant from interface. It can be seen that maximum stress occurs at a distant of 4 mm toward bottom of the rail and 5.5 mm toward the centre of the wheel. The maximum stress values are 299.34 MPa at rail and 155.04 MPa at wheel. It can be seen that maximum stress at rail almost two times of the maximum stress at wheel.

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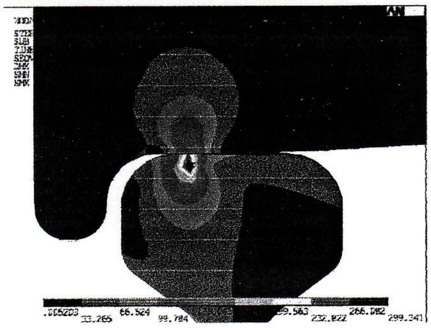

Fig.3 Stress (von Mises) contour plot at rail and wheel in contact

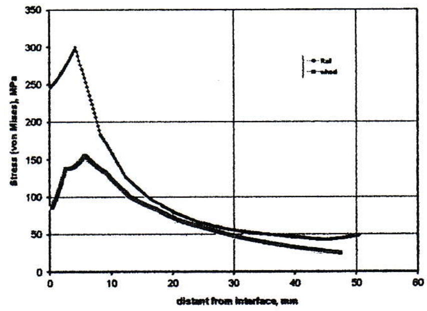

Fig.4 Stress (von Mises) distribution for rail and wheel in contact.

Figure 5 shows shear stress contour plot at a pair of rail/wheel in contact. Distribution of shear stress is shown in Figure 6. It can be seen that maximum shear stress occurs at the interface and tend to decline as away from the interface. Maximum shear stress at the interface is 70.054 MPa for rail dan 66.455 MPa for wheel.

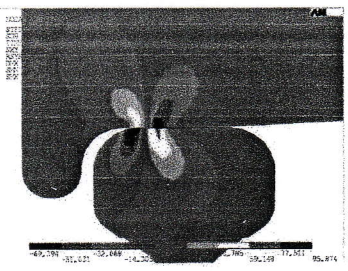

Fig.5 Shear stress contour plot at the rail/wheel interface

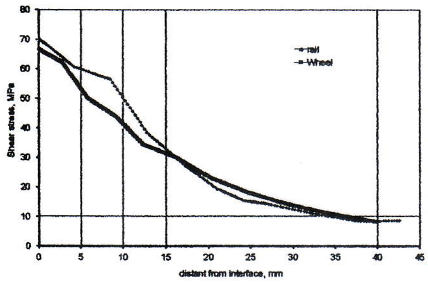

Figure 6 Shear stress distribution measured from interface of rail/wheel in contact

3. CONCLUSION

Based on the numerical simulation of rail/wheel interface just performed, the following conclusions can be drawn:

1. Contact stress is maximum at region near contact surface,
2. The stress became smaller as away from contact surface,
3. Maximum stress (von Mises) is 299.341 MPa and maximum shear stress is 70.054 MPa,
4. von Mises stress is distributed along 0.088 times radius of wheel from contact point toward the centre of the wheel, and 0.315 times height of the rail toward bottom of the rail,
5. shear stress is distributed along 0.074 times radius of wheel from contact point toward the centre of the wheel, and 0.120 times height of the rail toward bottom of the rail.

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