

Finite Element Simulation of Stress Distribution and Thermal Response of Palm Slag Brake Pad Composite

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Paper History

Received: 10-September-2016

Received in revised form: 10-October-2016

Accepted: 7-November-2016

ABSTRACT

This paper is a part of a work aimed at obtaining engineering models of stress distribution and thermal response for the new design geometry shapes of palm slag brake pad composite. 3D finite element simulations have been conducted for brake pad and rotor system using finite element code ANSYS. The stress distribution and temperature response of brake pads for this investigation was significantly influenced by the surface design of brake pads.

KEYWORDS: palm slag; brake pad; geometry shapes.

1.0 INTRODUCTION

Owing to the complexity and high cost of laboratory test dealing with the stress distribution and thermal response of palm slag brake pad composite, it is of interest to investigate the possibility to use finite element analysis in order to reduce the necessary number of experiments. In a previous study, three-dimensional transient temperature field of brake shoe during hoist's emergency braking [1], temperature and thermal stresses in a pad during braking [2], investigation of heat transfer phenomena in a ventilated disk brake rotor with straight radial rounded vanes [3], and more recently the temperature behavior from the new design geometry shape of motorcycle brake pad was analyzed to compare datum design with new design to determine the best design of motorcycle brake pads [4]. Hwang and Wu investigated

the temperature and thermal stress in the ventilated disc-pad brake during single brake by basing their study on multi-body technique and 3D thermo mechanical coupling model [5].

Lakkam et al., studied heat dissipation characteristics of different types of brake discs during their operation [6]. The experimental results in this study were employed as thermal properties inside a computer simulation in order to determine the temperature responses and temperature distribution as well as the deformation of such brake discs.

Akhtar et al., employed finite element (FE) method and has explained the transient thermoelastic phenomena of a dry clutch system [7]. The effect of sliding speed on contact pressure distribution, temperature and heat flux generated along the frictional surfaces was analyzed. The clutch system has been simulated by axisymmetric model using ANSYS software.

This paper will focus on the simulation analysis of stress distribution and thermal response behavior of palm slag brake pad composite during operation when forces and moments generate from braking is applied during the static. The stress distribution and thermal response of brake pad from simulation result can be analyzed. The results will be compared with finite element simulations of the brake pad design in associated paper [4].

2.0 FINITE ELEMENT MODELS

The compressive strength and wear behavior of palm slag composites using various percentage weight of materials content were studied experimentally. Table 1 shows the properties of palm slag brake pad composite [8].

Table 1: Properties of palm slag brake pad composite

Density, ρ	2.69 g/cm ³
Compressive strength, σ_c	76.2 MPa
Wear rate	6.26×10^{-13} m ³ /m
Thermal stability [9,10]	50 – 1000 °C

The finite element model for the brake pads as shown in Figure 1 was created by using Autodesk Inventor Professional 2010. The computer code ANSYS also allows determination and visualization of the stress distribution and temperature response due to the sliding contact between the disc and the pads.

Figure 1 presents the model of brake pads design using ANSYS. We developed five kinds of new design geometry surface as palm slag brake pad models.

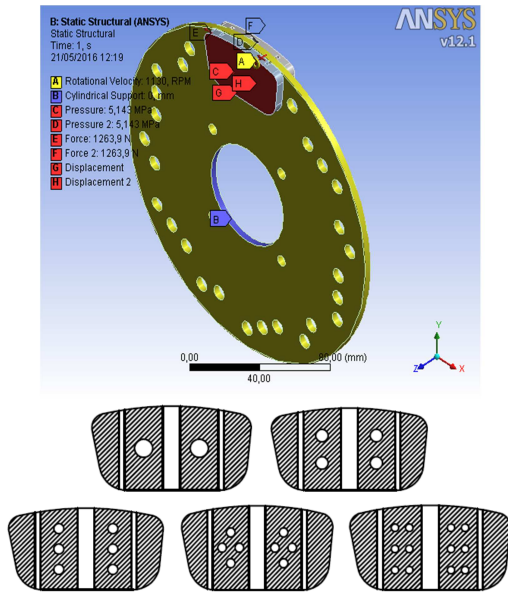


Figure 1: Palm slag brake pad design

Figure 2 shows the complete finite element mesh used to palm slag brake pad composite models.

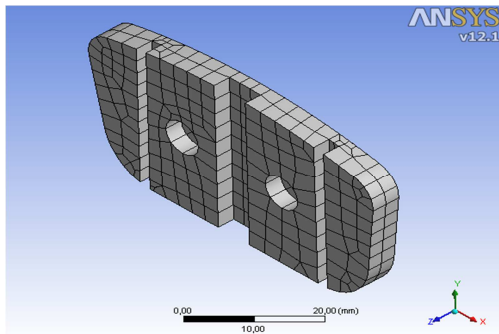


Figure 2: Finite element mesh of palm slag brake pad composite

A series of finite element analysis has been conducted [4] which is an assemblage of discrete pieces called elements, which are connected, together at a finite number of points called nodes. Loading boundary conditions are then applied to these elements and nodes. A network of these elements is known as mesh. The brake pad composites were 1228,81 mm square and 5 mm thick.

Working force to the brake pad is 6319.31 N. The external pressure between the disc and pad is calculated by the force applied to the disc is 5.14 N/mm². The rotational speed of the disc is 118.27 rad/s.

3.0 RESULTS AND DISCUSSION

3.1 Stress distribution

The stress at contact surface consists of normal and tangential components. The normal stress perpendicular to the contact surface result in friction and the change of acceleration is considered in the momentum equation.

The analysis of finite element simulation in palm slag brake pad composite design focuses on determination and estimation of the stress distribution and temperature response during operation when forces and moments generate from braking is applied during the static, which regarded as the critical location of the brake pad design. The design of the brake pad is important to determine the rate of cooling and uniform wear of disc and brake pad and thus affecting braking efficiency.

Figure 3 shows principle stress distribution of palm slag brake pads design. It is observed that the stress response for design 5 exhibits higher values than those for the other design of brake pads section.

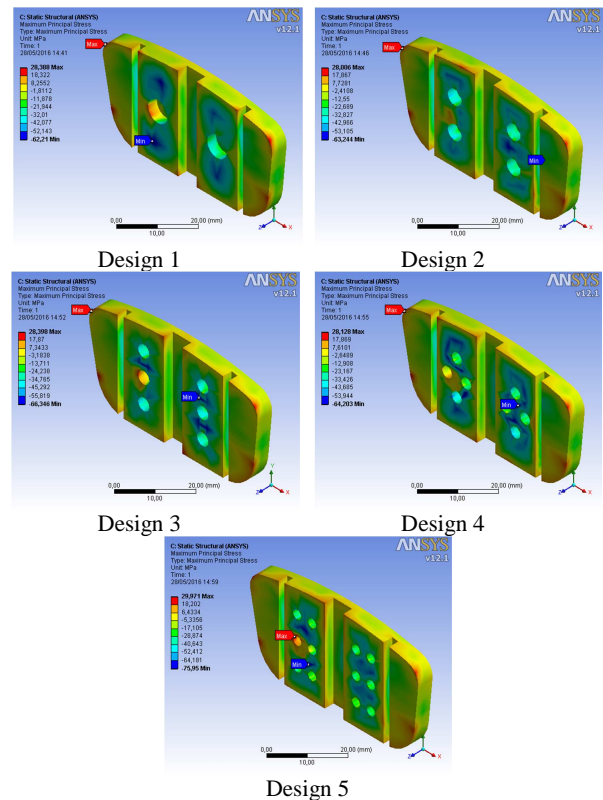


Figure 3: Principle stress distribution of palm slag brake pads design

A comparison of the stress response for all design shows that design 5 is 5.28% higher than that design 1, design 5 is 6.56% higher than that design 2, design 5 is 5.25% higher than that design 3, design 5 is 6.15% higher than that design 4, and design 5 is 7.11% higher than that design Ref. [4]. This indicates the number of holes in the surface of brake pads has significant effect on the stress distribution during operation when force and moment generate from braking is applied.

The computer simulation results of each design in Figure 3 shown that the finite element simulation method can predict the maximum value of the principle stress. It is also observed that the values of stress response for more number and smaller diameter of holes at surface design are much higher than those for the fewer number and larger diameter of holes at surface design.

3.2 Temperature response

Sliding contact member brake discs results in the conversion of kinetic energy into heat at the pad and disc interface. Increase the friction is limited quantity and depends on the coefficient of friction, rubbing the radius of the road, and the forces acting on the pad. Slip process led to a rise in temperature, while the peak is one of the most important factors in the action to occur.

Figure 4 shows temperature distributions of palm slag brake pad design. It is observed that the temperature response for design 3 exhibits higher values than those for the other design of brake pads section.

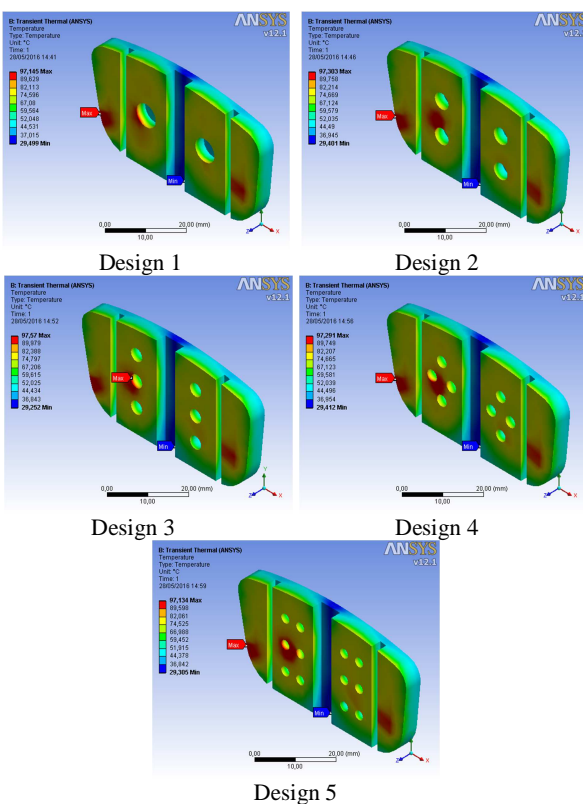


Figure 4: Temperature distribution of palm slag brake pads design

The temperature at the contact surfaces during the quarter emergency brake system intensified by significant heat load caused by the friction force and high velocity of this process [1]. Temperature and thermal constriction resistance as a function of the geometry of the characters and the velocity is determined. Temperature and thermal stresses pad (band) with retarded continuous sliding on the surface of the disk (a half) both during and after the second stop heating studied [2]. If high temperature distributions at disc brake components may cause undesirable effects, leading to brake failure [4].

A comparison of the stress response for all design shows that design 3 is 0.44% higher than that design 1, design 3 is 0.27% higher than that design 2, design 3 is 0.29% higher than that design 4, design 3 is 0.45% higher than that design 5, and design 3 is 1.57% lower than that design Ref. [4]. This indicates the arrangement of holes in the surface of brake pads has significant effect on the temperature distribution behavior during operation under steady state loading conditions. where heat storage effects varying over a period of time can be ignored.

The computer simulation results of each design in Figure 5 shown that the finite element simulation method can predict the maximum value of the temperature response. It is also observed that the values of temperature response for single-row arrangement of holes at surface design are much higher than those for double or rectangular arrangement the holes at surface design.

Figure 5 shows a comparison between stress response of palm slag brake pad design and design Ref. [4].

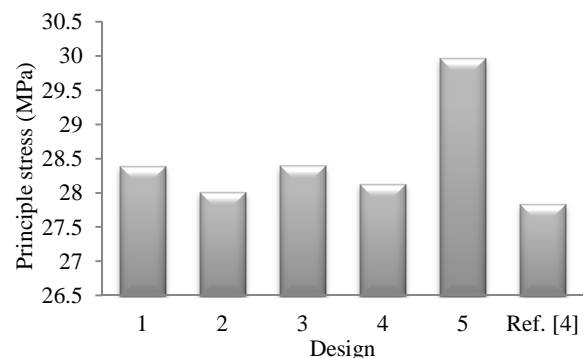


Figure 5: Comparison between stress distribution of palm slag brake pad design and design Ref. [4]

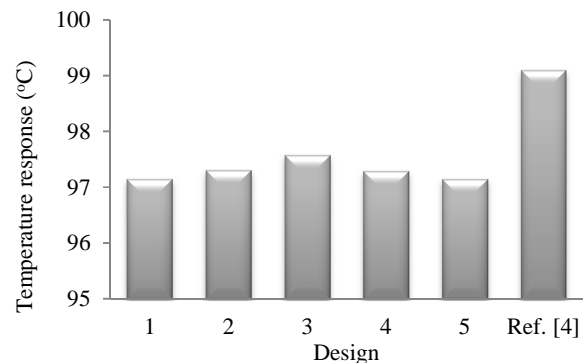


Figure 6: Comparison between temperature response of palm slag brake pad design and design Ref. [4].

The new model of palm slag brake pad is considered can be used effectively as alternative design for motorcycle brake pad. Design 5 is the best from the design Ref. [4] was selected in the graph of stress distribution.

Figure 6 shows a comparison between temperature response of palm slag brake pad design and design Ref. [4]. Design 3 is the best from other design but design 3 exhibits lower values than design Ref. [4]. Finally, in this study design 3 has been selected to the best design in the analysis.

CONCLUSION

In this paper, finite element simulation of stress distribution and thermal response of palm slag brake pad composite is proposed. The finite element was analyzed by means of the sliding contact between the disc and the pads using the finite element code ANSYS. The stress distribution was performed, together with the temperature response of brake pads. The stress distribution and temperature response of brake pads for this investigation was significantly influenced by the surface design of brake pads. The values of stress distribution for more number and smaller diameter of holes at surface design are much higher than those for the fewer number and larger diameter of holes at surface design. The values of temperature response for single-row arrangement of holes at surface design are much higher than those for double or rectangular arrangement the holes at surface design.

ACKNOWLEDGEMENTS

The authors sincerely acknowledge the Directorate General of Higher Education of Indonesia (DIKTI) which supported this research by Hibah Bersaing (Competitive Grant) program in 2016.

REFERENCES

1. Z.-C. Zhu, Y.-X.Peng, Z.-Y.Shia, and G.-A. Chen. 2009. Three-dimensional transient temperature field of brake shoe during hoist's emergency braking. *Applied Thermal Engineering* 29 (5-6) 932-937.
2. A. Yevtushenko, M. Kuciej. Temperature and thermal stresses in a pad/disc during braking. 2010. *Applied Thermal Engineering* 30 (4) 354-359.
3. F. Talati, S. Jalalifar. 2008. Investigation of heat transfer phenomena in a ventilated disk brake rotor with straight radial rounded vanes. *Journal of Applied Sciences* 8 (20) 3583-3592.
4. K. Shahril, M. Khairuddin Hj. Ali Musa, M. Sabri, M. F. M. A. Majid and M. Husaini A.B. 2014. Analysis of temperature distribution behavior of motorcycle brake pads. *Conference colloquium on education, engineering and technology*.
5. Hwang, P., Wu, X., "Investigation of Temperature and Thermal Stress in Ventilated Disc Brake based on 3D Thermo-mechanical Coupling Model", *Journal of Mechanical Science and Technology*, Vol. 24, 2010, pp. 81-84.
6. Lakkam, S., Suwantaraj, K., Puangcharoenchai, P., Mongkonler-dmanee, S., and Koetniyom, S., "Study of heat transfer on front- and back-vented brake discs", *Songklanakarin Journal Sci. Technol.*, Vol. 35, No. 6, 2013, pp. 671-681.
7. Akhtar, M. M. J., Abdullah, O. I., and Schlattmann, J., "Transient Thermoelastic Analysis of Dry Clutch System", *Machine Design*, Vol. 5, No. 4, 2013, pp. 141-150.
8. Muftil Badri, Dodi Sofyan Arief, Adhy Prayitno. 2015. Compressive strength and wear behavior of palm slag composites using various percentage weight of materials content. *Proceedings of Ocean, Mechanical and Aerospace – science and engineering (November) 1-4*.
9. C. M. Ruzaidi, H. Kamarudin, J. B. Shamsul, A. M. Mustafa Al Bakri, A.R. Rafiza. 2011. Comparative study on thermal, compressive and wear properties of palm slag brake pad composite with other fillers, *Australian J. of basic and appl. Sci.* 5(10), 790-796.
10. C.M. Ruzaidi, H. Kamarudin, J.B. Shamsul, A.M. Mustafa Al Bakri, J. Liyana. 2013. Mechanical Properties and Morphology of Palm Slag, Calcium Carbonate and Dolomite Filler in Brake Pad Composites. *Applied Mechanics and Materials Vols. 313-314 (2013) pp 174-178*.