Applied Mechanics and Materials Vol. 695 (2015) pp 535-538
© (2015) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.695.535
Submitted: 21.07.2014
Revised: 09.09.2014
Accepted: 09.09.2014

Finite Element Analysis on Brake Disc of an Educational All-Terrain-Vehicle

Muhammad Zahir Hassan[1, a], Fudhail Abdul Munir[2,b], Mohd Azli Salim [2,c]

[1]Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal Melaka, Malaysia

[2]Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal Melaka, Malaysia

[a]zahir@utem.edu.my, [b]fudhail@utem.edu.my, [c]azli@utem.edu.my

Keywords: All-terrain-vehicle, Eulerian-Lagrangian approach, Finite element analysis

Abstract. All-terrain vehicle is famously used for various purposes such as in civilian and military. The use of finite element analysis in a preliminary design stage has been demonstrated to be cost and time effective. In this paper, the finite element analysis of a brake disc for All-Terrain-Vehicle (ATV) is demonstrated. Eulerian-Lagrangian method was employed in this work where simple annular ring was used as the disc model. This study is limited to thermal and contact analysis between the disc and brake pad. The results in term of temperature and stresses distribution is obtained and presented. Moreover, the lateral displacement of the disc due to the friction contact is also shown. These results are then used to as a technical guideline in designing brake system for a fully customized ATV

Introduction

All -terrain vehicles (ATV) have been widely used either by civilian or military [1]. In some cases, ATV is even used in agriculture field [2]. This type of vehicle is designed to operate in difficult and complex terrains [3,4]. Generally, ATV is consists of three main parts. These parts are structure or better known as chassis, drive train and suspension [5].

Finite element analysis is one of the essential design tools available for the use of engineers and scientists. Many engineering feasibilities studies are performed using FEA software available in the market like ANSYS and ABAQUS [6-10].

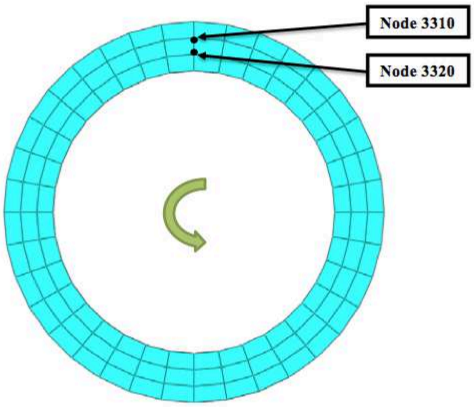
Numerous studies has been conducted in the field of FEA of particularly on automotive braking system. Hassan et al. [11] has successfully demonstrated the fundamental parameters involved in brake squeal phenomenon by using finite element analysis. They managed to develop a fully coupled thermo-mechanical model to study the disc brake squeal phenomena.

This present study is a part of a main project of which an ATV will be designed and fabricated by engineering students in the university. The purpose of the ATV development is to expose the students with hands-on engineering know-how knowledge. The objective of performing the FEA on the brake disc is to obtain meaningful results that can be used as the guidelines in designing a whole set of brake system for the use of the ATV. ABAQUS software is used as the main tools in this analysis [12]. The brake disc is modeled as a simple annular ring, which in contact with a brake pad.

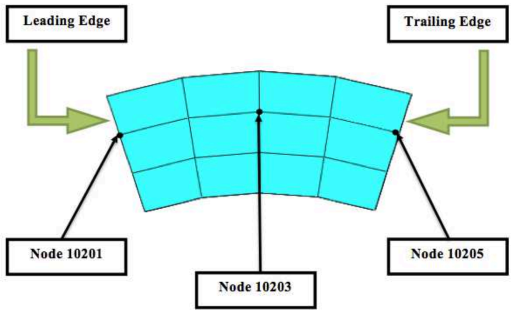
The pad has a 60-degree of arc shape that representing the real dimensions most of automotive brake pad available in the market. This study is however limited to thermal and stress analysis. The results in terms of temperature and stress distribution with respect of the braking period is presented and discussed.

Methodology

Two-dimensional (2-D) model was first developed. Then, the model was extruded to a three dimensional (3-D) model. An annular ring and the brake pad arc model are shown in Fig. 1 representing the brake disc. Two nodes are chosen as the data reference point.



(a) Annular ring model with two nodes



(b) Brake pad model with three selected nodes

Fig. 1 Annular ring and brake pad model

The inner radius of the annular geometry is 68 mm while the outer radius is 115 mm. The thickness is set to be 10 mm. This geometry is the actual dimension of the designed ATV brake system. On the other hand, the brake pad arc is set to be 60 degree while the thickness is 11 mm. Meanwhile, the material properties used in the simulation are shown in Table I.

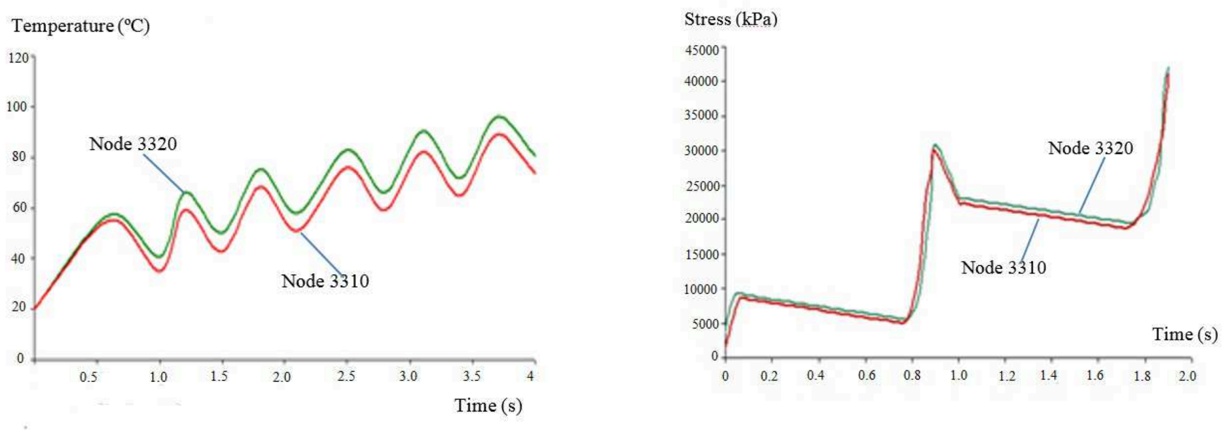
Table I Material properties of the models

Properties	Annular ring	Brake Pad
Density	7050 [kg/m^3]	2620 [kg/m^3]
Poisson's ratio	0.27	0.29
Young Modulus	210 [Gpa]	125 [Gpa]
Thermal Conductivity	533 [W/m.ºC]	2 [W/m.ºC]
Specific heat	103 [J/kg. ºC]	1100 [J/kg. ºC]

A sequentially coupled thermal-mechanical analysis was performed on the annular ring model using Eulerian approach. In the thermal-mechanical analysis, a forced convection or diffusion heat transfer is applied and followed by a steady-state transport analysis.

Results and Discussion

Three types of results that are distribution of temperature and stress, and also the lateral displacement of the annular ring are presented in this section. Those results are plotted againts the braking period (in seconds). The constant parameters are the applied pressure (P= 2 MPa), and coefficient of friction (μ = 0.3). Figure 2(a) shows the temperature distribution on the annular ring surface with respect to the braking period while Fig. (3a) demonstrates the stress distribution on the surface of the disc.



(a) (b)

Fig. 2 Temperature and stress distribution with respect to the braking period

Figure 2(a) suggests that the surface temperature fluctuates over the braking time. As the disc rotates, the temperature increases when the indicated nodes area is in contact with the brake pad. On the other hand, the temperature decreases as soon as the brake disc is out of contact with the brake pad in that particular sectional area. As shown in the figure, the overall average temperature increases after the braking period is over. Figure 2(b) indicates that the pattern of the normal stress distribution is similar with the temperature distribution. The stress becomes maximum at the hottest area due to surface contact between the disc and pad. The other outcome results that are critical in designing the brake system for the ATV are the lateral distortion with respect to the angular rotation. These values are presented in Fig. 3 below. The maximum displacement of the brake disc due to the distortion is predicted to be 0.000450 mm.

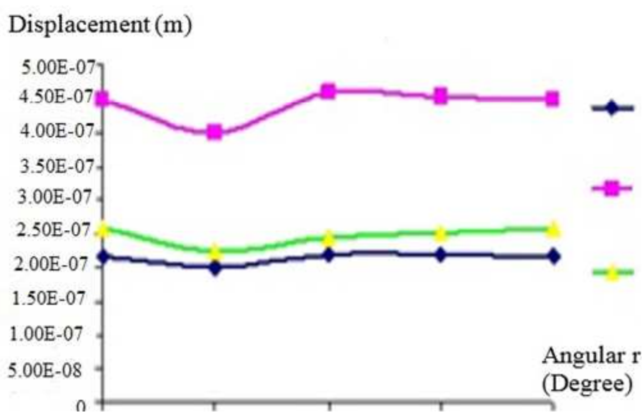


Fig. 3 Lateral distortion around the circumference region of disc brake

Conclusions

In this paper, Finite Element Analysis (FEA) of the brake disc used in the ATV is successfully demonstrated. The Eulerian-Lagrangian approach was employed in the analysis. The effects of the brake disc when it is in contact with the brake pad was simulated and presented in the results. In the results, the highest temperature recorded on the surface of the brake disc during the braking period is 98° C while the highest stress obtained is 45 MPa. On the other hand, the maximum displacement occurs at middle ring of the disc model. All these values will be used as guidelines in designing a customize ATV for educational purpose

Acknowledgement

The authors would like to acknowledge Universiti Teknikal Malaysia Melaka for the financial supports of this work.

References

[1] D.Nagarjuna; J. M. Farooq; .S.N.Saiteja; P. S. S. Teja, Optimization of Chassis of an All Terrain Vehicle, International Journal of Innovative Technology and Exploring Engineering, Vol. 2, n.2 pp. 55-57, 2013.
[2] G. H. Hohl, Military terrain vehicles, Journal of Terramechanics, Vol. 44 n.1 pp. 23-34 ,2007.
[3] S. Milosavljevic, F. Bergman; B. Rehn, A. B. Carman, All-terrain vehicle use in agriculture: Exposure to whole body vibration andmechanical shock, Applied ergonomics, Vol. 41, n. 4, pp. 530-535, 2010.
[4] K. Chaudhari; A. Joshi; R. Kunte; K. Nair, Design And Development Of Roll Cage For An All-Terrain Vehicle, International Journal on Theoretical and Applied Research in Mechanical Engineering, Vol. 2, n. 4, pp. 49-54, 2013.
[5] J. Pijuan; M. Comellas; M. Nogués; J. Roca; X. Potau, Active bogies and chassis levelling for a vehicle operating in rough terrain, Journal of Terramechanics, Vol. 49, n. 3-4, pp. 161-171, 2012.
[6] K. Magaswaran, A.S. Phuman Singh, M.Z. Hassan, An analytical model to identify brake system vibration within the low frequency domain, SAE Technical Papers USA, 2013, Volume 8.
[7] J. Kang, Finite element modelling for the investigation of in-plane modes and damping shims in disc brake squeal. Journal of Sound and Vibration, Vol. 331 pp. 2190–2202, 2012.
[8] A.A. Yevtushenko, A. Adamowicz, P. Grzes, Three-dimensional FE model for the calculation of temperature of a disc brake at temperature-dependent coefficients of friction, International Communications in Heat and Mass Transfer, Vol. 42, pp. 18–24, 2013.
[9] A.A. Yevtushenko, P. Grzes, Axisymmetric FEA of temperature in a pad/disc brake system at temperature-dependent coefficients of friction and wear, International Communications in Heat and Mass Transfer, Vol. 39, pp. 1045–1053, 2012.
[10] F. A. Munir; M. I. M. Azmi; M. A. Salim; M. R. M. Zin; M. Z. Hassan, Preliminary Design of Carbon Composite Facing for Dry Clutch Disc of Mini Agricultural Tractor, International Review of Mechanical Engineering (IREME), Vol. 5, n.4, pp. 577-580, 2011.
[11] M.Z. Hassan, P.C Brooks, D.C. Barton, A predictive tool to evaluate disk brake squeal using a fully coupled thermo-mechanical finite element model, International Journal of Vehicle Design, Vol. 51, n.1-2, pp. 124-142, 2009.
[12] (2004) ABAQUS Version 6.5 Manual. ABAQUS, Karlsson and Sorensen, Inc, Hibbit.