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Coupled thermomechanical computational solutions for stationary and dynamics rocking of all-metal steel belted tyres

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Abstract

All-metal steel belted radial tyres (AMSBRT) for opencast handler super heavy trucks such as Caterpillar, Komatsu, Belaz and others are the basis of productivity and safety of automobile equipment work in mining industry. Supercomputer modelling of thermomechanical tyres states is proposed and main features of computational solutions are discussed. Computational experiments results match with spin test results with acceptable engineering accuracy. So it is possible to predict heat generation in any rubber points and also in metal cord threads during one or more wheel revolution under load.

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*Keywords:*all-metal steel belted tyres; coupled computational solutions; supercomputer SKIF-GPU; LS-DYNA

1. Introduction

Serviceability and efficiency of modern high performance open cast mechanization facilities are determined by resource and quality of superclearance tyres. Inner overheat of AMSBRT is one of the main cause of premature mechanical wear and failure because of tread peeling. Tire complete cost for super heavy truck is compared with the truck cost. So search of new design methods, modeling and optimization tire constructive and technological parameters are very serious and actually science-practical task.

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2. Chapter

Classical book [1] on page 38 emphasized that “ideal situation is to point probabilistic fatigue tire place under certain loading regime, but it is not possible to solve this task in modern time”. But there are many high performance computer systems (supercomputers) which have good scalable universal finite-element solvers; so tire specialists by means of supercomputers can solve quality new design and simulation problems taking into account non-linear behaviour of rubber and rubber-cord systems, general thermodynamic tire rocking and investigation of long-term strength and fatigue elements tire processes.

Main world tire companies successfully used supercomputer tire design and operational development since the end 90 – years last age. Pioneers in this field are Bridgestone, GoodYear and so on. Last time Dunlop [2], Kumho, Yokahama joints this club.

United Institute of Informatics Problems (UIIP) National Academy of Sciences of Belarus has modern Republican Supercomputer Centre. It is a result of successful fulfillment Union Russia-Belarus State science-technical program SCIF (SuperComputer Initiative Fenix). UIIP has advanced laboratories and departments which realized some projects using licenced commercial finite-elements software for engineering constructions and others objects [3].

Since 2011 science-technical process stock and practical experience are transformed on the field of tire industry objects computer and supercomputer modeling [4–7].

Worldwide tire firms use as universal finite-element code ANSYS, ABAQUS, MARC, LS-DYNA and so on as specialized code F-Tire [2]. Laboratory of Technical System Synthesis of the United Institute of Informatics Problems (UIIP NASB) in cooperation with the Department of Petrochemical Synthesis and Polymer Materials Processing of Belarusian State Technological University (BSTU) have developed the supercomputer technology for prognosis modeling of AMSBRT thermodynamic states by means of LS-DYNA 971 MPP code and supercomputer SCIF-GPU with graphical accelerators. It is planned to translate successful AMSBT supercomputer experience on other tire types.

Full scale structure AMSBRT model is on Fig. 1.

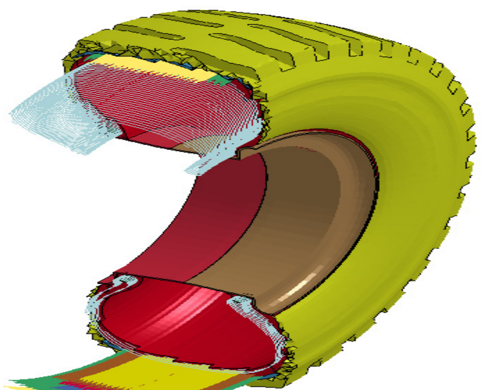


Fig. 1. Structural finite-element AMSBRT model.

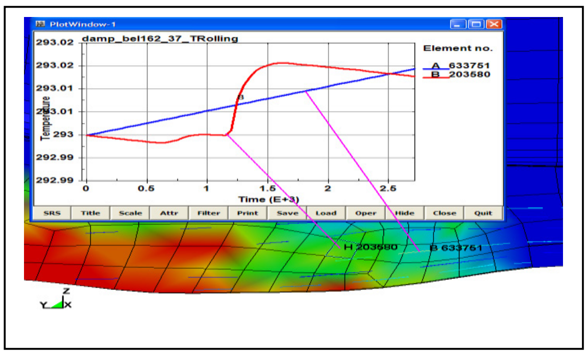


Fig. 2. Result heat generation (element 203580 - breaker, element 633751 - cord).

Structural finite-element AMSBRT model was built taking into account reference [8] (reinforced concrete modeling), own successful experience and DUNLOP using CONSTRAINED_LAGRANGE_IN_SOLID mechanism in LS-DYNA [9]. Assemblage of cords is beam-elements and slave-object in terminology of CONSTRAINED_LAGRANGE_IN_SOLID; protector, tread groove breaker is isotropic master-object. Interactions between slave-object and master-object produce formation of anisotropic rubber-cord properties. Because of this fact it is possible to stationary and dynamically supercomputer rocking of model where heat generation taking place in rubber and steel-cord casing all at the same time (Fig. 2).

Supercomputers experiment series shown that it is possible to change many-stream cord as base wire with equal cross-section with loss-free general tire rigidity.

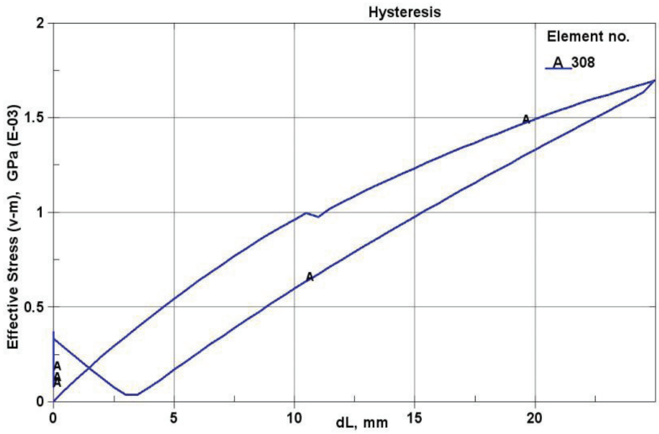
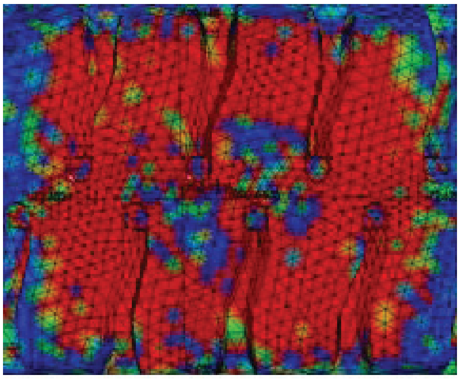


Fig. 3. Hysteresis specimen with MAT_VISCOELASTIC modeling.

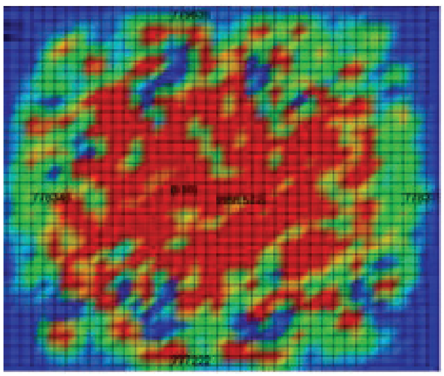
From some LS-DYNA material behaviour rubber models MAT_VISCOELASTIC was selected and its hysteresis properties were experimentally checked (Fig. 3) [6, 7].

The fit of tire on the rim, inflation by internal pressure, operating load application, start off, moving with constant speed and the brake process were under supercomputing modeling both for road model with determinate roadway covering and for spin pit testing.

Computer results were verified by means of comparison with results obtained after static loading stand testing (Fig. 4).



890×788 (мм×мм)



870×720 (мм×мм)

Fig. 4. Dimensions comparison of contact spot: left – computer model; right – real stand.

Supercomputer calculations of static radius, tire width in contact place, form of contact spot and pressure in it have deviations from real test not more ±(10–15) %. These results are suitable for computer aided design and operational tire development.

The fit of tire on the rim, inflation by internal pressure, operating load application, start off, moving with constant speed and the brake process were under supercomputing modeling both for road model with determinate roadway covering and for spin pit testing. Tire specialists has the possibility to make the real process of heat generation and temperature increasing prediction in any rubber layer points and also in metal cord threads during one or more wheel revolution under load.

Fig. 5 and 6 shows differences in heat generation zones under interaction AMSBRT model with road and spin pit respectively.

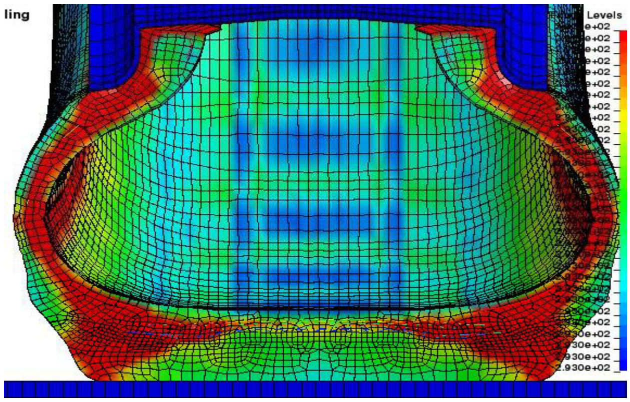


Fig. 5. Heat generation zones under rocking of road.

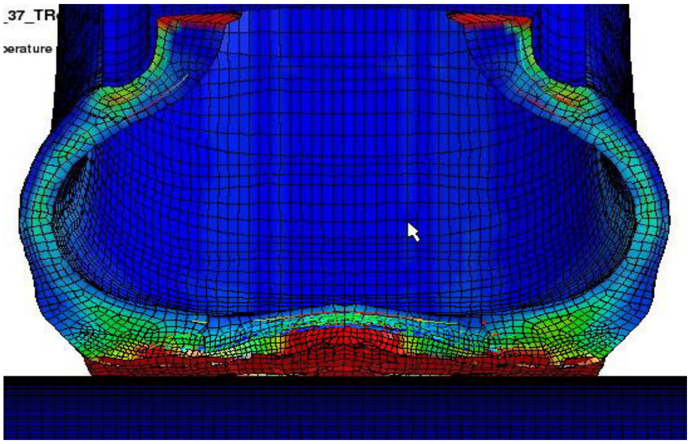


Fig. 6. Heat generation zones under rocking of spin pit.

During one or more wheel revolution under load tire designer can determine temperature increase in any tire and cord points; generally in these points of great temperature growth processes of rubber ageing and protector peeling is taking place.

This paper and positive results in it – some years work on supercomputer SKIF. Coupled thermomechanical computational solutions for stationary and dynamics rocking of all-metal steel belted radial tyres are too difficult to implement on personal computer or graphical stations. AMSBRT model input data with boundary conditions consist of some hundreds Mbites in text files; computational results – more than hundreds Tbites. But on SCIF-GPU AMSBRT coupled tasks are working from some hours to some days depends of task and model complexity. Detail SCIF-GPU technical parameters can find on www.uiip.bas-net.by.

Any Internet-user can have access to computational supercomputer SCIF resources and our original technology. But he (she) should get special grid certificate in UIIP by e-mail. Also there is a special graphical regime under Unicore software where tire specialist works only with graphical information in Ls-PrePost (Fig. 7). During this session all computational results (more than hundreds Tbites) are stayed on SCIF hard disks.

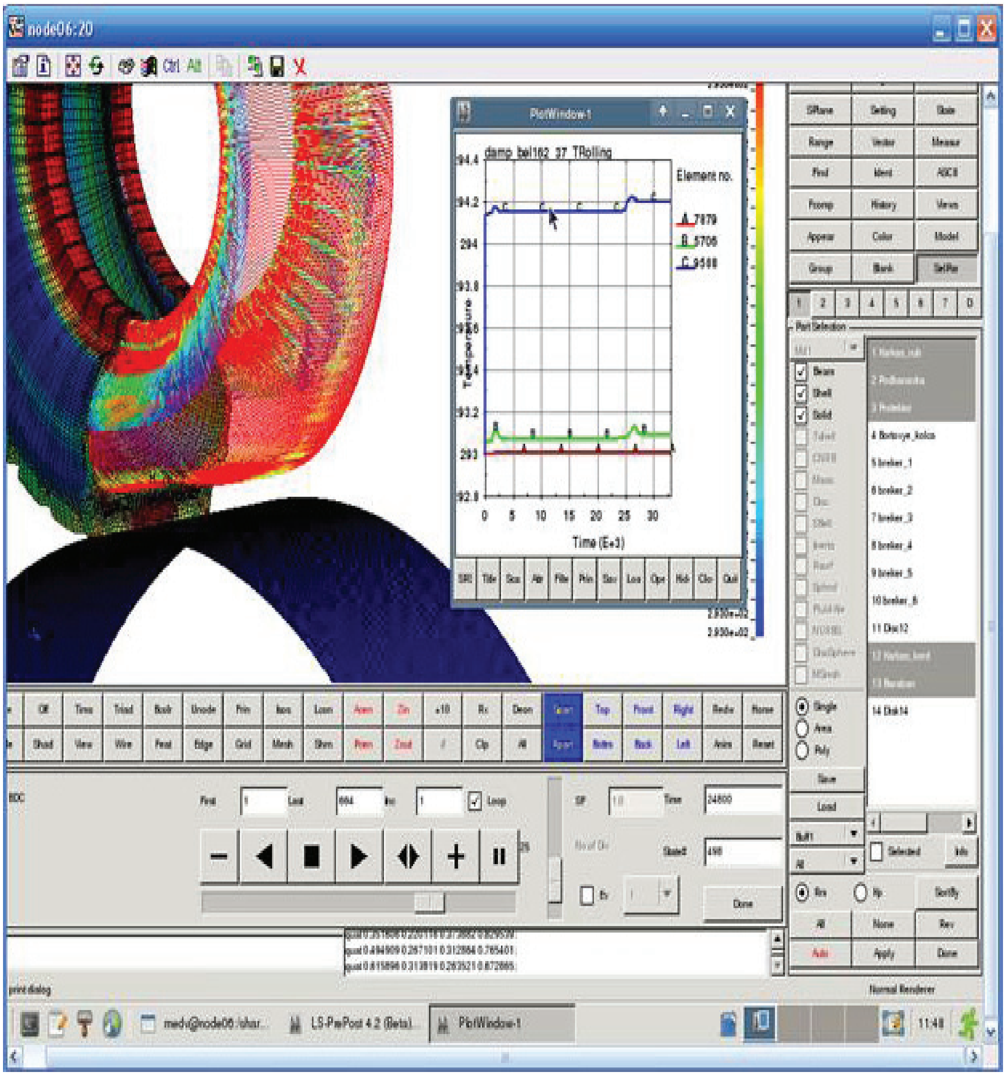


Fig. 7. LS-PrePost in graphical environment Unicore.

Future investigation direction – supercomputer predictive technology for time formation stationary temperature fields during AMSBRT long-term spin pit testing.

UIIP and BSTU made prepared works and are going to use supercomputer technology for students studies in BSTU to teach tire industry specialists.

Authors are ready for fruitful cooperation with enterprises, organizations and specialists about science-technical and practical directions concerned in the paper.

3. Conclusion

1. At the first time the predictive supercomputer technology for modeling of thermodynamics tire behavior was created on post USSR territory.

2. Predictive supercomputer technology and computer facilities were tested on all-metal steel belted radial tyres examples; acceptable engineering accuracy and convergence with spin test results were created.

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