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PREDICTION OF TEXTURE-DEPENDENT EFFECTS ON VEHICLE FUEL CONSUMPTION

Motivation

Due to ever-stricter fuel economy requirements that are taking effect in the EU (95 g/km of CO_2 is targeted to be achieved by 2021) and increased fuel costs,interest in pavement-tyre contact is heightened. Further research is thus badly needed to better qualitatively and quantitatively grasp the texture contributions on tread-stone contact mechanics to advance roadway sustainability by reducing rolling resistance (RR)/pollution/financial expense.

Problem Statement

RR is a cumulative term that embraces three major energy dissipation mechanisms (*tyre macro-distortion*, *micro-distortion* and *pavement macro-distortion*) causing more compression at a leading end than at a trailing end of a contact patch. Stone indentation effects such as visco-elastic/inertia are still poorly understood; a prime intention is consequently to put forward a simplified and computationally efficient numerical technique for assessment of *the micro-distortional* RR taking account of asperity shape/size/packing. Additionally, the research is aimed at developing a purely experimental method to determine *the micro-distortional* RR and in part numerically/visually to validate computational results. Conventional test set-ups are unable to measure this contribution alone. The proposed method could further supplement existing Life-Cycle Assessment packages and enable optimising of pavement reliefs sacrificing skid resistance and drainage functionalities.

Methodology

A novel 3-D numerical approach is developed and comprises macro-scale (whole radial tyre) and micro-scale (tread-asperity interaction) models. The former is applied to investigate *the macro-distortional* RR and provides indentation/release rates to an idealised stone (e.g. hemisphere) at the micro-scale, whereas the latter is used to deduce compressive forces caused by single indenters and subsequently quantify their impacts on RR for a range of loading levels, velocities, surfaces (asphalt and concrete), compounds (stiff and soft). Tread compound is represented in terms of a visco-elastic Maxwell model.

Results and Discussion

Derived contact forces at a tread-stone interface (Figure 1a) appeared of a reasonable distribution and magnitude exhibiting a peak at the end of the indentation phase, followed by a gradual relaxing stress zone with a sudden snap-out at the end of the interaction. The texture-related RR values appeared to be linearly rising as velocity/frequency grows (Figure 1b), explained by a larger

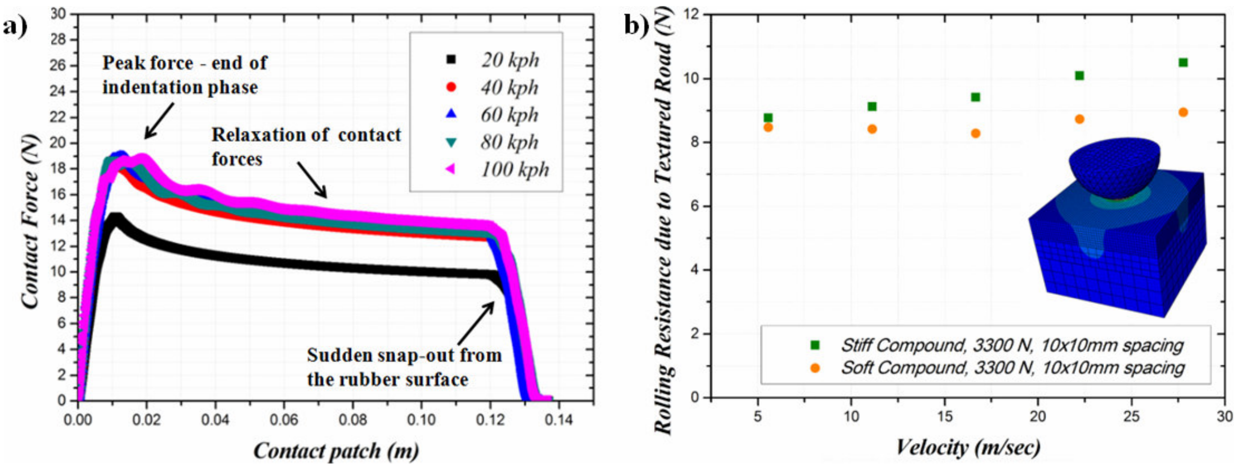

Figure 1 Typical contact force distribution between a hemispherical stone and tread block (a) and texture-dependent RR estimates at 3300 N for a hemisphere of R=5mm (b)

indentation at a lower rate leading to lower contact forces, whilst a higher rate would generate a smaller dent (compound becomes stiffer), but greater contact forces. It has been noticed that this relationship could be strongly dependent on rubber temperature along with other factors (contact area, texture arrangement etc). Figure 1b illustrates that a tyre rolling over a hemispherical surface would have to overcome roughly 9.58N and 8.57N owing entirely to asperities or waste 27.37ml and 24.49ml of fuel per 100km, respectively for stiff and soft compounds, which is equivalent to 68.43g and 61.23g per 100km of CO_2.

Implications

The devised 3-D numerical technique is applicable for texture-related fuel consumption evaluation during service life. Results indicate that stone-based RR can be substantial in magnitude, but conclusions on low/optimal RR texture can only be made if friction/drainage/noise properties are considered.

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References

1. Mansura, D., Thom, N. and Beckedahl, H., ”A novel multi-scale numerical model for prediction of texture-related impacts on Fuel Consumption”, *Journal of Tyre Mechanics*, 2015 (submitted)