Make an impact

NEXTRANS and ICT studies uncover the reality of tire-pavement interaction

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The lifespan of a pavement is directly related to the load and frequency of vehicles that travel over it, and the impact of a specific vehicle is determined by the contact between its tire and the pavement. Therefore, to predict how a pavement will hold up over time, having accurate knowledge about how tires and pavements interact is crucial. This knowledge is valuable to the tire industry, as it develops and modifies designs, and to pavement engineers, as they work to create a quiet, smooth, and safe driving environment.

Research initiated by Professor Imad L. Al-Qadi a decade ago, and continued through support from the Illinois Center for Transportation (ICT) and NEXTRANS, has resulted in a breakthrough in understanding the impact of tire loading on pavements.

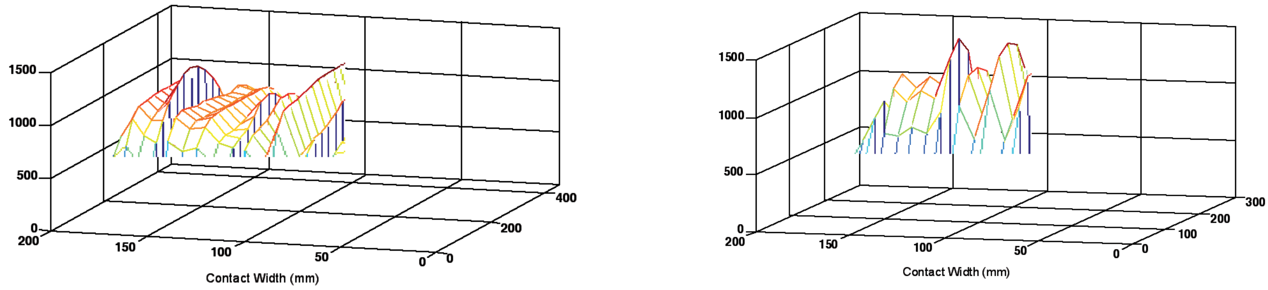
A study sponsored by NEXTRANS that began earlier this year and was led by Prof. Al-Qadi of the University of Illinois at Urbana-Champaign (UIUC) andDr Ilinca Stanciulescu of Rice University with assistance from Hao Wang, a PhD student at UIUC, introduces an innovative modeling approach to simulate the true tire-pavement interaction.

"The outcome will directly impact future tire and pavement interaction understanding and its impact on pavement and tire designs, and allow us to better predict pavement performance and its service life, as well as improve pavement safety," predicts Al-Qadi.

Make contact

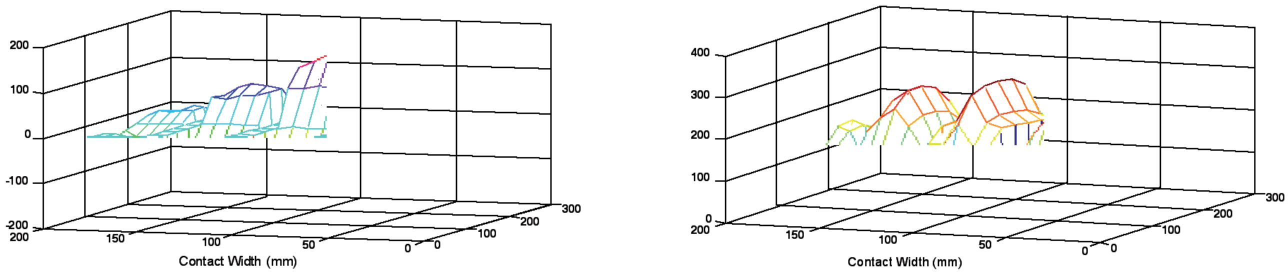
Tire-pavement interaction had previously been highly simplified to assume the contact pressure at the tire-pavement interface as equal to the tire inflation pressure within a circular (or rectangular) contact patch. But because the tire-pavement interaction is essentially a rolling contact, many aspects make it a more complex mechanism than it may first appear. However, the contact is actually nonlinear and exhibits significant deformation. In addition, tire design that incorporates ribs makes the interaction stresses complicated. The incorrect assumptions regarding interaction have resulted in early damage to pavement, as well as safety issues for travelers. Additionally, previous research has lacked adequate formulations for specific scenarios such as a tire sliding on ice and rolling on soft terrain, or other very deformable surfaces.

The improved modeling for rolling tires used in the current studies considers more variables such as composite tire



(a) (b)

Figure 1: Contact pressure at (a) high wheel load and (b) high inflation pressure

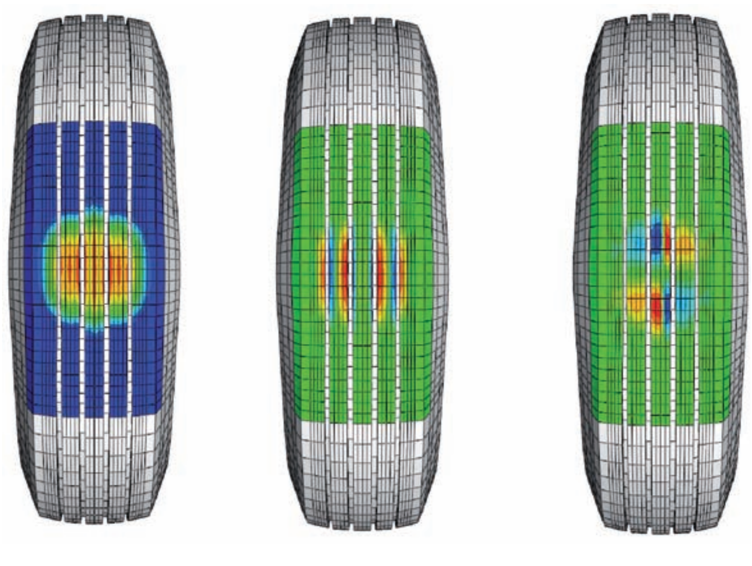


(a) (b)

Figure 2: Frictional forces at (a) static loading and (b) tire braking

structure, pressure-loaded surfaces, and frictional contact in the steady-state rolling process that considers the vehicle sliding velocity, which is the true interaction of tire and pavement. Other factors considered included tire speed, slip ratio, load, tire-inflation pressure, and pavement stiffness. This model of true interaction provides a better mechanism for improving braking and stopping distance, enhancing tire-pavement friction, and above all optimizing the tire-pavement interaction that leads to better pavement performance.

The preliminary results of the research have validated the three-dimensional contact stress fields (vertical, transverse, and longitudinal) as discovered by the experimental measurements (Figure 3). The simulation findings show the comparative interface stress distributions under various loading and rolling conditions. For example, the contact stress fields at the tire-pavement interface exhibit complex behavior at different wheel loads and tire inflation pressures, as well as at different rolling conditions (Figures 1 and 2). The ongoing research considers the dynamic friction law in the simulation to more accurately capture the frictional contact behavior at the tire-pavement interface.



Vertical Transverse Longitudinal

Figure 3: Three-dimensional contact stresses at tire-pavement interface

The future

The outcome of this research will also be valuable for other related studies that are quantifying pavement damage caused by different tire configurations, including wide-base tires. Professor Al-Qadi and his students have conducted cutting-edge research on the impact of wide-base tires on the pavement and environment. These studies have characterized pavement response due to different tire designs, and helped to quantify the expected economic savings from the use of wide-base tires through hauling more goods and lowering the impact on the environment. Compared with conventional dual tires, wide-base tires offer the trucking industry significant economic advantages such as improved fuel efficiency, increased hauling capacity, reduced tire cost and repair, and superior ride and comfort.

However, state DOTs have been concerned about the damage that could be caused to flexible pavements by wide-base tires. Their concerns necessitate that accurate tire-pavement interaction is essential to evaluate the pavement damage caused by wide-base tires.

As a result of all this research, pavement engineers will have the necessary information to build quieter and more durable pavements, and drivers will enjoy a reduced stopping distance and enhanced safety because of appropriate friction. Agencies in charge of pavement maintenance will know the effects of different tire configurations on pavement damage to implement appropriate road charges. ***tire***