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# The induced shock and impact force as affected by the obstacle geometric factors during tire-obstacle collision dynamics

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ABSTRACT

The knowledge on vehicle stability, ride comfort and performance is critically significant on off-road vehicle traversing over irregular terrains. The subject of off-road vehicle analysis from the terrain–tire interaction perspective has always been from complex domains of engineering owing to the elasto-plastic behavior of deformable terrain and nonlinear vehicle dynamics. This paper is dedicated to synthesize the induced shock and impact force as affected by the obstacle geometric factors during tire-obstacle collision dynamics. To this end, various obstacle shapes were included at different depths to determine at which geometric configuration, the greatest and lowest impact forces are induced. Aiming this, the soil bin facility equipped with a single-wheel tester of Urmia University was adopted to carry out the needed experimental tests while the operational condition of the wheel traversing was absolutely controllable (i.e. slip, forward speed, wheel load, etc.). The developed model also was verified by the experimental data and the obtained results showed that the greatest impact force both at the longitudinally and vertically oriented directions were obtained by the triangular shaped obstacle at the greatest height while in contradictory to the expectations, the lowest values were obtained for the trapezoidal obstacle when compared with the Gaussian shaped obstacle. The findings will serve future studies as a functional source to develop improved vehicle designs to interact with differently shaped obstacles and various operational conditions for run-off-road vehicles traversing over irregularities.



## 1. Introduction

The industry of vehicle engineering is associated with diversity of domains from propulsion, vehicle engine, driveline system, power distribution among wheels, suspension system, etc. that drastically can affect the vehicle dynamics, performance, stability and ride comfort. These factors are all central issues for engineers, manufacturers and researchers from various points of view from modeling, analysis and optimization in design, mobility and performance. The components and subcomponents of vehicle system are harmoniously running to affect the three major aspects of ride comfort, handling and performance. The off-road vehicle analysis on rough irregular terrain has called significant attention due to the complex soil characteristic added with the nonlinear vehicle dynamics. If not more significant, at least equally important with the other

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influential vehicle components, the wheels play substantial role in vehicle mobility, handling, maneuvering, stability, performance and ride comfort of vehicles. Tire is the unique element of vehicle being in continuous contact with the surface and is subjected to all the moments and forces applied to the vehicle chassis from the ground [1,2]. There are numerous studies documented in the literature that correspond the kinetics and kinematics of wheel–ground interaction that have been investigated so far such as rolling resistance, traction and tire-obstacle impact force [3–7].

In the theorem of vehicle engineering, an impact is generated by a great force/shock applied over a short time period when wheel collides the obstacle. In this manner, the created force has a greater effect than an ordinary force applied over a longer period of time while it is pivotal on the relative velocity of the tire to the obstacle. Random road profile serves as road obstacles and influences the vehicle performance, handling and ride comfort while forming shocks/impact forces. This type of varying force is also closely concerned with the structural failure of the vehicle body and transport safety. A priori to optimize the vehicle design and describing the limitations of operational condition of the vehicle is to synthesize the physics and mechanics of the phenomenon particularly from the tire-obstacle shock analyzing perspective. The passenger safety, cargo protection, dynamic stress limit and vehicle structural dynamics directly depend on the amount of the impact forces and shock exerted to the wheel. Tire as a part of suspension system that deals with the transmissibility of an off-road vehicle in order to resist the bumps and jerks that randomly occur in an off-road track, takes an important role in negotiating with the impact force and shocks. In the process of route traversing, understanding the impact forces provides also realistic information required to assist in adjusting tire parameters such as tire pressure, wheel load, and slip.

The prediction of transient dynamic behavior of the tire in travelling obstacles under different operating conditions is a significant subject to provide tire designers and researchers with a understanding of aspects of tire behavior in ride comfort assessment and vehicle durability analysis [8]. Given the requisite on through investigation of wheel-obstacle collision dynamics, the following is to cover the relevant studies documented in literature.

An off-road vehicle stability traversing over obstacle has been a matter of concern reflected by the numerous studies [9–15]. Research about tractor stability and dynamics could be experimental, computer simulation or computer simulation and experimentation. The use of experimental methods to investigate tractor stability and dynamics is limited due to the fact that such experiments would be slow, very expensive and perilous and then it will be difficult to have such experiments repeated for numerous operating conditions [9]. In this regard, an explicit finite element analysis for tire-obstacle collision process was carried out by simplifying the vehicle as a single-freedom vibration model. A 3D finite element analysis (FEA) model of 11.00R20 TBR tire rolling on road was established by ABAQUS FEA software to simulate the tire-obstacle collision process while the results showed that the collision process had significant influence on the mechanical properties of the tire [19]. The effect of tire inflation pressure and tire velocity on the force of obstacle climbing were studied while the cleats were inserted in the traversing direction. It was indicated that there is a direct relationship between the forward speed and the induced force while there is a contradictory relationship between the tire pressure and the induced force [10,11].

The stability loss on rough ground is more likely than on smooth ground because the wheels of a tractor follow the bumps and hollows of the rough ground and cause steep local slopes [13]. To examine the effects of different geometries and mass specifications of a tractor operating across irregular sloping grounds on the lateral stability of this machine, a dynamic model was developed. In the proposed model, overturn and skid instabilities were studied and the tractor stability indexes were formulated [15]. However, this study did not cover the aspects of obstacle geometrical configurations on the tractor stability and the created impact forces. There are some other similar studies with the same objectives while not covering the role of different geometric configurations of obstacles in stability and overturning of the off-road vehicles [16–18].

The literature concludes that there is an essential need to understand the effect of obstacle geometric factors on

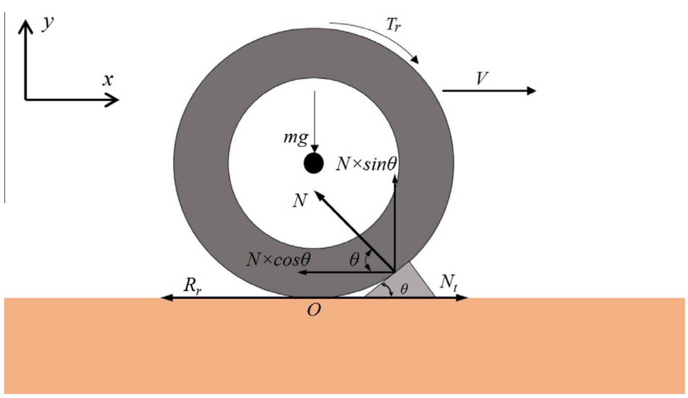


**Fig. 1.** The free-body diagram of the tire-obstacle impact.