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Research Article

Analysis of a dynamic response of an off-road lorry with rigidly and independently suspended wheels

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Abstract: Road freight transport is an important part of a transportation system. It includes transporting goods for short or longer distances. Road freight transport is ensured by lorries. A lorry is a freight car with more significant dimensions and is designed for higher axle load. Depending on the terrain, they are classified as on-road and off-road lorries. Regarding chassis design, off-road lorries usually have a higher ground clearance and damage-resistant tires. The chassis of a lorry consists of a frame, axles and a suspension system. The suspension system plays a key role from the dynamics point of view. Two types of suspension systems are used for lorry chassis. Rigid axles and independently suspended wheels. Despite rigid axles being applied by the most known lorries manufacturers, there is a manufacturer in the middle Europe known mainly through the production of off-road lorries equipped with independently suspended axles. As these concepts represent different ways of mounting wheels on a chassis, it is an opportunity to compare the dynamic response of an off-road lorry equipped with both types of wheel suspension. The main goal of this research is to compare the selected output quantities of an off-road lorry with rigidly and independently suspended wheels. There were chosen output signals of accelerations on a driver seat, a vertical wheel force and a chassis roll angle for a chosen driving maneuver. A multibody model of the lorry was created. The achieved results are presented in the form of graphical outputs.

Keywords: off-road lorry; multibody model; suspension system; dynamics

I. INTRODUCTION

A large number of materials and goods are transported by ground transport. The ground transportation system includes two kinds of transport, i.e., road and rail transport. Every kind of ground transport system has its advantages and disadvantages [1–3]. Rail transport allows tons of material to be moved for very long distances at low wheel/rail rolling resistance together with favorable drag [4–6]. However, road transport offers a door-to-door way of transport. Therefore, just road transport is preferable for shorter distances [7]. Although rail transport with its wagons for intermodal transport is convenient [8–12], vehicle-trailer combinations are used for international transport [13–15]. On the other hand, off-road lorries have an irreplaceable place in middle and heavy off-road terrain. Off-road lorries are road vehicles specially designed for these purposes. They have a strengthened main load-bearing frame, tire with unique tread, more drive axles, higher ground clearance and finally, a wheels' suspension system, which is specially designed to resist rough driving conditions. They include large spring back, often shock with higher amplitudes and unfavorable frequencies [16–19]. Further, the bottom part of an offroad lorry (i.e., a chassis with a suspension system) is exposed to an excessive load, mud and flying stones [20–23].

A wheel suspension system is an essential part of every vehicle and plays a key role in the movement, stability, maneuverability, and controllability of the vehicle [24,25]. Although its design, construction and testing are clearly more complex tasks, the choice between rigidly and independently suspended wheels (or a rigid axle and an independent axle) is the gateway to further progress. Both types have their advantages and disadvantages, and their suitability depends on the specific applications and requirements of the vehicle. Therefore, without existing data, the choice may not be clear at all (which is not only valid for vehicle chassis). This is especially true in the field of heavy vehicles, lorries or passenger – buses [26, 27]. Simulations are beneficial in such indecisive situations. A well-established simulation can, even with great simplicity, imitate the plausible behavior of subjects, even though they do not yet physically exist. Therefore, such simulations are the topic of this work. Although its basis will be relatively simple, in the future, its functionality, complexity, and purposes can be further developed, thus enabling further acquisition of knowledge.

The presented research is focused on investigating the dynamic response of an off-road lorry to chosen operational conditions. The lorry corresponds to a model which is commercially produced by a Czech manufacturer. This vehicle is a universal lorry, which is able to safely drive on a paved road as well as in heavy off-road conditions. It can be equipped with many types of superstructures, from a standard and the most widely used tipper to a concrete mixer, timber lorry, and even for military purposes [28–31]. It can be powered by a combustion engine either by its manufacturer or by another third party manufacturer [32]. The decision about a proper power unit depends on power requirements, maintenance costs, fuel consumption, emission limits, and similar factors [33–36].

The manufacturer offers the lorry with both rigid and independent axles. Therefore, it was chosen for the research purposes. The analyzed lorry is a container carrier with an 8-axle chassis. It is an all-wheel-drive version in which two front axles have steered wheels. An illustration of the solved lorry is depicted in **Fig. 1**.

Figure 1. *An illustration of the solved off-road 8-axle lorry [32]*

The presented research is aimed at analyzing the following three main factors:

- a type of suspension system, i.e., rigidly suspended wheels and independently suspended wheels;
- the test tracks: paved road with curves for the vehicle stability test and unpaved road called as “bad unfortified road” for the comfort test (on a driver seat);
- the loading state of the lorry: an empty state (a lorry curb weight) and a loaded state (a container with a weight of 18,100 kg).

After building all the necessary models, simulations with measurements were launched, the outputs of which are graphs showing the course of the monitored quantities over time. Accelerations at the driver's seat and vertical forces under the wheels were monitored, and finally, a comparison of driving with and without torsional stabilizers was added. Based on these, the driving comfort and safety of the vehicle were then assessed.

II. The vehicle's suspension

A wheel's suspension system of a lorry is a group of parts whose task is to support all other components of the vehicle (a cabin, a superstructure, the transported load, drive and steering elements) and to isolate them from unwanted forces arising when driving over bumps, curves changes of driving speed. Another task of a vehicle’s suspension is vibration damping. Its main components include springs, shock absorbers, supporting and fixing elements and others. The main elements of a suspension system of a vehicle can be considered a group of supporting and fixing elements - wheel suspension on the chassis [37].

1. Rigidly suspended wheels

Rigidly suspended wheels or rigid axles, is a type of suspension in which both wheels are rigidly connected by a single, central body - the axle. When the wheels are steered, they are connected to the axle via steering pins. In the case of drive, a drive shaft is also guided into the wheel, which can also be guided directly through the axle body for its protection. When it is necessary to combine a main load-bearing functionality of an xale together with the drive force transmission both characteristics, the drive shafts must be equipped with constant-velocity joints at the ends. Thanks to them, the wheel can be constantly driven regardless of its movements (rotation of the wheel around a vertical axis, vertical springing in the case of independent suspension).

Rigid axles are the most common type of suspension in the field of lorries thanks to two main advantages. One of them is the fact, that rigid axle has a simple construction. Its basis is a solid, suitably shaped beam, on which other components are attached: wheel hubs, springs, shock absorbers, frame mounts, and possibly also steering and driving elements. Further, in case of a rigid axle, o changes of camber at bounce motion are present, possible self-steering ability in corners due to load transfer arising from the mountings of the leaf springs (if leaf springs are used in a suspension system). Another advantages also arise from the simple design: relatively low production costs, high reliability and high load-bearing capacity. The rigid axle itself can easily be used in practice even for very high loads and is often not a limiting aspect. These are rather the steering elements or the maximum permissible road load.

On the other hand, dependent suspension has two significant disadvantages. The vertical springing of one wheel is transferred to the wheel on the opposite side, which worsens the safety and driving characteristics of the vehicle. More precisely, excessive deformation of the tires occurs when driving over bumps, a reduction in the contact area between the tire and the road, and, in the worst case, the wheel bounces off the road. From the dynamics point of view, a rigid axle has a high unsprung mass. Driving over bumps causes forces or accelerations in the vertical direction, which are borne by the wheels and the parts firmly attached to them. In the case of a dependent suspension, these parts also include the axle, which is a massive steel part that requires much energy to change speed due to its weight. This energy must be transferred by all parts in the chain between the axle and the road, which increases their load and wear. An example of the rigid axle also applied on the solved off-road lorry is shown in **Fig. 2**.

Figure 2. *A rigid axle [32]*

As can be seen in **Fig. 2**, it is a rigid axle with steered wheels. This means that it is mounted as a front axle of the lorry. Further, it can also be seen that the axle includes a differential housing (in the middle part of the axle). This means that it is a drive axle. In the case of the analyzed lorry of the Czech commercial producer of off-road lorries, these rigid axles (**Fig. 2**) are combined with coil springs, telescopic shock absorbers, a hydraulic stop and anti-roll bars.

2. Independently suspended wheels

In this type of suspension, the wheels on one axle are connected to the axle frame via additional arms or semi-axles that allow the wheels to move vertically independently of the axle frame. If steering and axle drive are required, similar solutions can be incorporated into the suspension, such as a rigid axle.

In comparison with the rigid axles, independently suspended wheels have advantages, such as minimization of motion transfer, i.e., before the force from driving over a bump is transferred from one wheel to the other, it must pass through two springs and two shock absorbers. Thanks to this, the mutual influence of the wheels is limited or eliminated, which has a positive effect on the driving characteristics. Further, this type of wheel suspension provides reduced unsprung mass. Unlike a rigid axle, the axle box does not have to exactly copy the vertical accelerations of the wheels and only the damped forces distributed over time that have passed through the shock absorbers and springs are transferred to it. As a result, this means that the wheels can copy unevenness faster and, at the same time, withstand lower forces. An example of this type of suspension system is depicted in **Fig. 3**.

Figure 3. *Independently suspended wheels [32]*

However, independent suspension is relatively rare in the field of lorries, mainly due to the following disadvantages, such as the complexity of the system. There are significantly more parts in the entire axle than in a similar dependent suspension, which results in a higher possibility of failure, space requirements, cost of manufacture and maintenance. Moreover, the load-bearing capacity is usually lower because there are several pins and joints in the independent suspension system, which are vulnerable in terms of long-term operation. Rubber silent blocks are hazardous, and the degradation under constant load causes unwanted clearances between the parts. The cross-sections of all components must also be designed for high loads, which is reflected in their size and weight [11].

Independent suspension can be found more often in buses, where passenger safety and comfort have a higher priority over possible payload ad durability. However, in most cases, it is mounted only on the front axle to achieve a compromise characteristics of of both suspensions.

Despite the described disadvantages of the independently suspended wheels of lorries, the Czech commercial producer of off-road lorries is famous around the world for over 100 years by the chassis design, which includes just the mentioned independently suspended wheel and a backbone chassis frame. The wheels are suspended by means of swinging half-axles bolted together into a single unit. This concept of wheel suspension can be combined with both steel and air springs. Fig. 3 shows an illustration of an axle with independently suspended wheels of the solved off-road lorry.

III. A MATHEMATICAL MODEL OF AXLE OSCILLATION

When comparing the vibration properties of different types of axles, it is necessary to mention some specific properties of a rigid axle, the transverse vibration of which is sometimes also called axle flutter.

1. A description of the oscillation of rigidly suspended wheels

The flutter of rigidly suspended wheels (or a rigid axle) is its rotational movement around the longitudinal axis by an angle φ_1 (Fig. 4). Since in this type of suspension, there is a rigid connection between the right and left wheels, when driving on uneven surfaces, vibrations arise that do not occur on vehicles with independent suspension. In the case of independently suspended wheels (**Fig. 5**), the vertical movement of one wheel, e.g., the right one z_{1P}, is transmitted to the superstructure only by a spring and a damper and then through the spring and damper of the left side to the left wheel.

When the irregularities on the right and left sides are equal, i.e., $h_L = h_P$, the angular movement of the rigid axle will be $\varphi_1 = 0$ and only the axle will heave. If the irregularities are of the same size but in the opposite direction, $h_L = -h_P$, the vertical movement of the axle will not occur ($z_1 = 0$), and the axle will oscillate in the transverse direction (with an angular displacement φ_1). In the general case, i.e., if $h_L \neq h_P$, combined oscillation (heave and transverse oscillation) will occur [39]. The dynamic model of a rigid axle according to the specification (we do not consider the oscillation of the superstructure) is shown in Fig. 4. The parameters marked in **Fig. 4** are

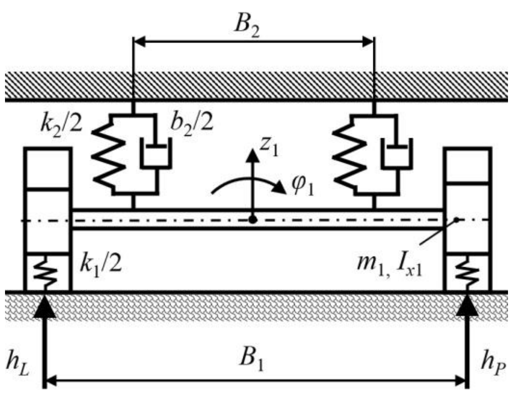

Figure 4. *A dynamic model of a rigid axle for vertical oscillation [38]*

as follows: m_1 is the axle mass, I_{x1} is the moment of inertia of the mass around the longidutinal axis, B_1 is the wheels track, B_2 is the lateral distance of the spring-dampers mounting points, $k_1/2$ is the tyre radial stiffness, $k_2/2$ is the spring stiffness, $b_2/2$ is the damping coefficient.

As generalized coordinates, the vertical deflection z_1 (for heave) and the angle φ_1 (for flutter) were chosen. Thus, the system has two degrees of freedom (generalized coordinates are z_1, φ_1). Two equations of motion are obtained (see Eq.(1)).

$$\begin{gathered} m_1 \cdot \ddot{z}_1 + b_2 \cdot \dot{z}_1 + (k_1 + k_2) \cdot z_1 = k_1 \cdot h_z, \\ I_{x1} \cdot \ddot{\varphi}_1 + 2 \cdot b_{2\varphi} \cdot \dot{\varphi}_1 + \left(k_{1\varphi} + k_{2\varphi}\right) \cdot \varphi_1 \\ = k_{1\varphi} \cdot h_\varphi, \end{gathered} \tag{1}$$

In equations (1), the parameters $b_{2\varphi}$, $k_{2\varphi}$, $k_{1\varphi}$, h_z and h_φ are expressed as in Eq.(2).

$$\begin{gathered} b_{2\varphi} = b_2 \cdot \left(\frac{B_2}{2}\right)^2, \\ k_{2\varphi} = k_2 \cdot \left(\frac{B_2}{2}\right)^2, \quad k_{1\varphi} = k_1 \cdot \left(\frac{B_2}{2}\right)^2, \\ h_z = \frac{h_L + h_P}{2}, \quad h_\varphi = \frac{h_L + h_P}{B_1} \end{gathered} \tag{2}$$

The transfer function of the dynamic force of the rigid axle for vertical oscillation is given in Eq.(3).

$$\left(\frac{F_{dyn\,L,P}(\omega)}{h_z(\omega)}\right)_{\psi=0} = \frac{k_1}{2} \cdot \sqrt{\frac{(k_1 - m_1 \cdot \omega^2)^2 + (k_2 \cdot \omega)^2}{(k_1 + k_2 - m_1 \cdot \omega^2)^2 + (k_2 \cdot \omega)^2}} \tag{3}$$

and for the axle fluttering is given in Eq.(4).

$$\left(\frac{F_{dyn\,L,P}(\omega)}{h_\psi(\omega)}\right)_{z=0} = \frac{k_1}{2} \cdot \frac{t_1}{2} \cdot \sqrt{\frac{\left(k_{2\psi} - I_{x1} \cdot \omega^2\right)^2 + \left(k_{2\psi} \cdot \omega\right)^2}{\left(k_{1\psi} + k_{2\psi} - I_{x1} \cdot \omega^2\right)^2 + \left(k_{2\psi} \cdot \omega\right)^2}}. \tag{4}$$

2. A description of the oscillation of independently suspended wheels

Fig. 5 shows a dynamic model of the oscillation of an independent wheel suspension. The generalized coordinates of the system are the vertical deflections of the unsprung masses of the right and left parts of the axle z_{1L} and z_{1P}. The parameters marked in Fig. 5 are as follows: $m_1/2$ is the unsprug mass of the independent axle, $I_{x1}/2$ is the moment of inertia of the unsprung mass of the independent axle, B_1 is the wheels track, B_2 is the lateral distance of the spring-dampers mounting points, $k_1/2$ is the tyre radial stiffness, $k_2/2$ is the spring stiffness, $b_2/2$ is the damping coefficient.

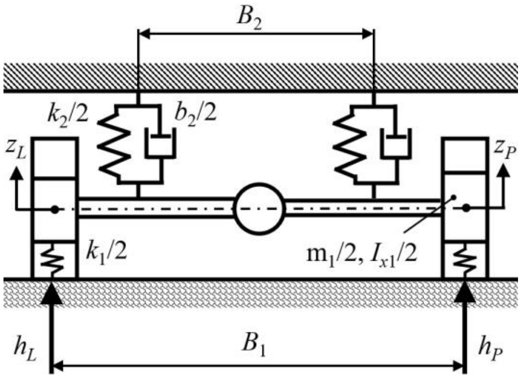

Figure 5. *A dynamic model of independently suspended wheels for vertical oscillation [38]*

The system again has two degrees of freedom (generalized coordinated are z_L and z_P), and its oscillation is described by two independent equations of motion in a form (see Eq.(5)).

$$\frac{m_{1r}}{2}\cdot\ddot{z}_{1L}+\frac{b_{2r}}{2}\cdot\dot{z}_{1L}+\frac{1}{2}\cdot(k_1+k_{2r})\cdot z_{1L}=\frac{k_1}{2}\cdot h_L,$$
$$\frac{m_{1r}}{2}\cdot\ddot{z}_{1P}+\frac{b_{2r}}{2}\cdot\dot{z}_{1P}+\frac{1}{2}\cdot(k_1+k_{2r})\cdot z_{1P}=\frac{k_1}{2}\cdot h_P, \tag{5}$$

where m_{1r} is the reduced mass and b_{2r} and k_{2r} are the values of b_2 and k_2 relative to the wheel plane.

The transfer function of the dynamic force of the independently suspended wheels for vertical oscillation is given in Eq.(6).

$$\frac{F_{dyn\,L,P}(\omega)}{h_z(\omega)}=\frac{k_1}{2}\cdot\sqrt{\frac{(k_{1r}-m_{1r}\cdot\omega^2)^2+(k_{2r}\cdot\omega)^2}{(k_1+k_{2r}-m_{1r}\cdot\omega^2)^2+(k_{2r}\cdot\omega)^2}} \tag{6}$$

IV. A MULTIBODY MODEL OF AN ANALYZED OFF-ROAD LORRY

The presented research is based on simulation computations. The multibody simulation method was applied for the study. A multibody model of the solved lorry was created in the Simpack software package. This software is widely used for the creation and analysis of mechanical system, such as road vehicles, rail vehicles, combustion engines [40–43], and others, in order to investigate the kinematic and dynamic properties of these systems under the defined operational conditions.

Fig. 6 depicts the set-up multibody model of the solved off-road lorry in the Simpack software.

Figure 6. *The created multibody model of the solved off-road lorry*

This model includes rigid bogies, which are interconnected by mechanical and kinematic joints. Further, visco-elastic elements represent springs, dampers, bump stops and others, which allow mutual relative movements between rigid bodies. The tyre-road contact model is important. In this case, the Pacejka tyre-road model [44] was defined. The basic parameters of the lorry are listed in **Table 1**.

Table 1. *Parameters of the analysed lorry*

Parameter	***Value***	***Unit***
Chassis configuration	8 × 8	-
Width	2550	mm
Wheel track	2072	mm
Curb weight	17,700	kg
Payload	18,100	kg
Total weight	35,800	kg
Tyre width	438	mm
Ground clearance	410	mm
Wheel weight	290	kg

As it is mentioned above, two types of roads were modeled. One type is a road with irregularities, which simulates driving on an unpaved road. The track irregularities comes from the ISO 8608 standard [45]. In this standard, there are defined power spectral density (PSD) of the road irregularities for several types of road surfaces. This is possible to define directly in the used MBS software Simpack. An illustration of the PSD is shown in **Fig. 7** [46], where the road qualities are called as follows: A – good cement concrete, B – good asphalt concrete, C – good macadam, D – medium asphalt concrete, E – medium pavement, F – bad pavement, G – bad unfortified road, H – very bad unfortified road. The parameters included in **Fig. 7** are explained as follows: λ – wavelength, $G_d(n)$, $G_d(\Omega)$ – displacement PSD, n – spatial frequency, Ω – angular spatial fruequency.

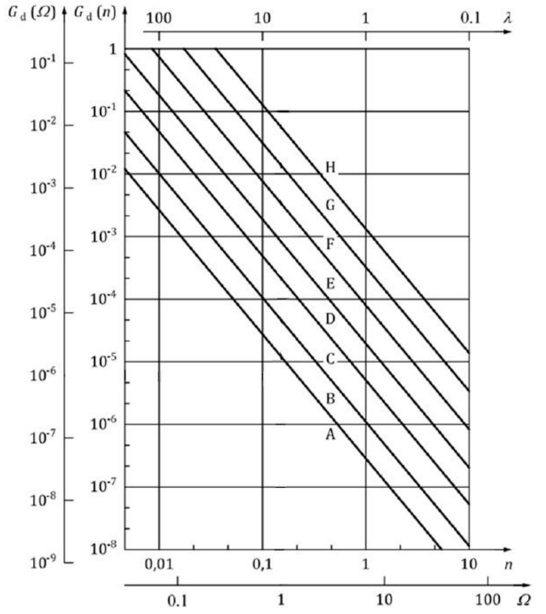

Figure 7. *A classification of a road surface according to the ISO 8608 standard [46]*

This first road includes two straight sections with a length of 100 m. A curve with a radius of 70 m is between these two straight sections. The main purpose of this first type of road was to investigate ride comfort for a driver. The lorry driving speed for ride comfort analyses was v_1 = 36 km/h (10 m/s), and this road is illustrated in **Fig. 8**.

Figure 8. *A top view to the first road profile*

Figure 9. *A top view to the second road profile*

The second type of road was created in order to evaluate the driving stability of the lorry. The road included a curve and subsequent opposite curves. This simulates an evasive maneuver. The curve is created by means of an epitrochoid with a starting radius of 600 m and a finishing radius of 110 m. The evasive maneuver is composed of two curves, left and right. Both have a radius of 60 m and a length of 15. Moreover, the track also includes three straight sections, which serve to stabilize the lorry after passing curves. The lorry driving speed was of v_2 = 72 km/h (20 m/s). This road is depicted in **Fig. 9**.

V. Results and discussion

This section presents the achieved results of the simulation computations performed with the analyzed off-road lorry. The results are presented in the form of graphs, where the output quantities are displayed in time dependence.

1. Evaluation of acceleration for ride comfort

Accelerations in the driver seat are the main quantitative measure of ride comfort. Speeds and displacement of vibrations are not that important, as the human body cannot perceive them directly. However, accelerations are perceived by the whole body through tactile receptors and a unique organ in the inner ear. Too high acceleration frequencies regarding to the general resonance values of the organs of a human body of the range 4 to 6 Hz are perceived as uncomfortable vibrations. In the extreme case, they can lead to damage to muscles and tendons. Moreover, accelerations, which have low frequency and high amplitude, can cause motion sickness in combination with limited visibility [39, 47].

The first test was conducted on both types of suspensions for the empty state on the paved road. The results are shown in **Fig. 10**. There were detected accelerations with relatively high amplitudes. The maximal values were 13.5 m/s^2, and the minimal values were –13.94 m/s^2 for the rigidly suspended wheels. In the case of independently suspended wheels, the maximal values were detected at 10.27 m/s^2 and min. –9.81 m/s^2 for independently suspended wheels) and alternate in short times (approx. with the frequency of 4 Hz).

However, the main goal of this analysis is to compare the waveforms of accelerations. It is evident that the independently suspended wheels lead to smaller acceleration amplitudes than the rigidly suspended wheels. It can also be observed that the rigid axles oscillate somewhat longer after excitation. This is especially evident before the end of the track after the twentieth second.

The waveforms of accelerations for both types of wheel suspension and the loaded state are depicted in **Fig. 11**. A similar trend as in the empty state can be observed. However, amplitudes are, on average, somewhat lower, as is their frequency. This is consistent with the observation that it is more difficult to excite objects with a greater mass to motion. Moreover, the heavier objects have higher inertia. The only exception is the random positive extreme after the eleventh second (15.44 m/s^2), which exceeded the extremes from the unloaded vehicles. The independently suspended wheels again achieved lower or the same amplitudes as the rigidly suspended wheels.

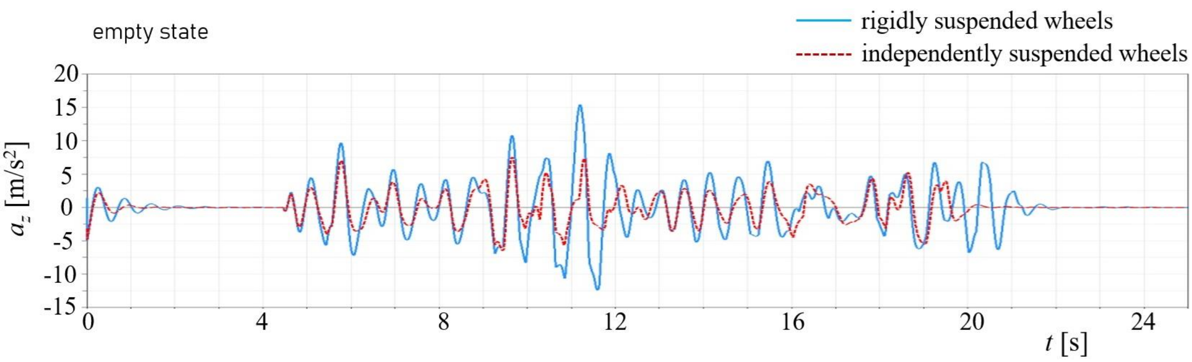

Figure 10. *Vertical accelerations on a drive seat – the empty state*

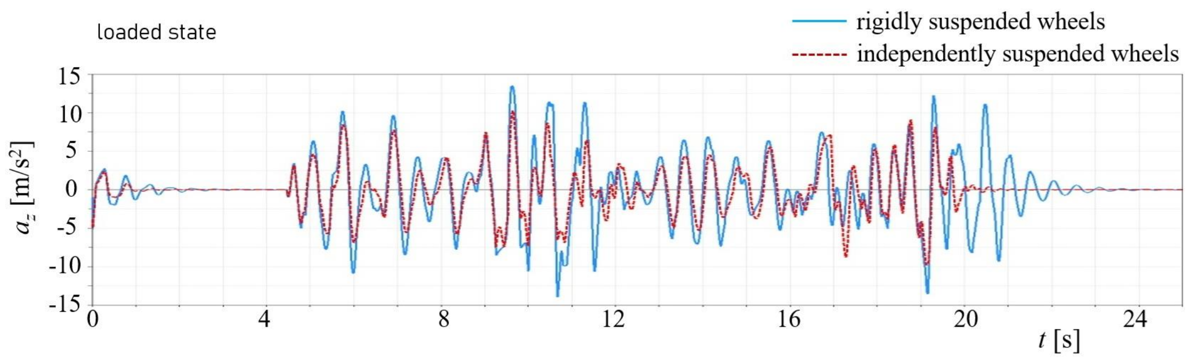

Figure 11. *Vertical accelerations on a drive seat – the loaded state*

2. Evaluation of driving stability

The main criterion for assessment of the driving stability and safety of the analyzed off-road lorry are the values of the vertical forces under the tires because the longitudinal forces in the tire/road contact, i.e., traction and braking forces, directly depend on them. In addition, it is also necessary to check whether the force under in the tire/road contact reaches the zero value. Such a situation represents the tire/road contact. This indicates the driving instability, i.e., a dangerous situation, because the lorry becomes uncontrollable. The tires are simulated in the lorry multibody model by Tire elements, which have the advantage of recording a whole range of quantities, including the necessary vertical forces. These are shown in **Fig. 12** and **Fig. 13**. At the beginning of each of them, there is an oscillation, which is probably caused by the unsteady state of the lorry in the initial position. This problem can be mitigated or eliminated by correcting the initial position. However, a straight section in front of the first curve is sufficient to stabilize the analyzed lorry.

The graphs in **Fig. 12** and **Fig. 13** are for the first axle in the driving direction. These graphs almost accurately describe the expected waveforms of these forces. This means that after the initial oscillation and stabilization of the force, the vehicles entered a left-hand curve. The force in the tire/road contact began to decrease linearly in direct proportion to the curve radius. Subsequently, the vehicles left the curves and leveled off sharply within approx. one second. It is also evidenced by the steep increase in the observed force. Immediately after leaving this curve, the force increased slightly in the case of the empty state of the off-road lorry and then stabilized, which is due to inertia. However, the force increased significantly longer due to the greater inertia of the loaded state of the lorry. This means that after leaving the curve, the vehicle continued to turn in the same direction, but since the force did not increase faster, the tires could no longer transmit more lateral force, and the vehicle could not turn any sharper. It follows that it went into an understeer skid, and from the thirteenth to the fifteenth second, it went significantly off the set path. On the straight section of the road, it stabilized again, taking two seconds longer than the empty state of the lorry.

Both vehicles (i.e., with independent suspension and rigid axles) entered the evasive maneuver with a sharp drop in force. While the force for the empty state of the lorry dropped by approx. 49 kN ± 3%, in the loaded cases, it was as much as 91 kN ± 3%. Since the front wheels were almost completely relieved and, moreover, loaded more than the rear wheels when driving in curves, it can be judged that the lorry was very close to overturning. After driving through the first half of the maneuver, the lorries turned in the opposite direction, which represents a steep wheel acceleration starting around the twentieth second. The forces for the empty lorries

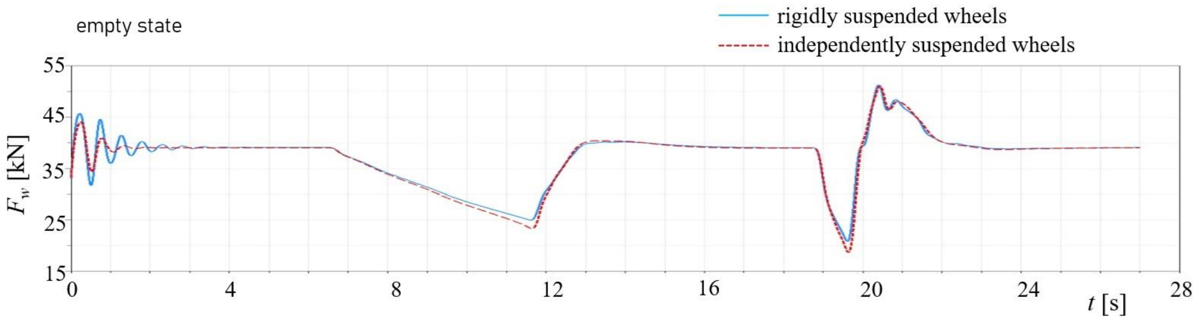

Figure 12. *Wavefrom of the vertical wheel forces for the first axle – the empty state*

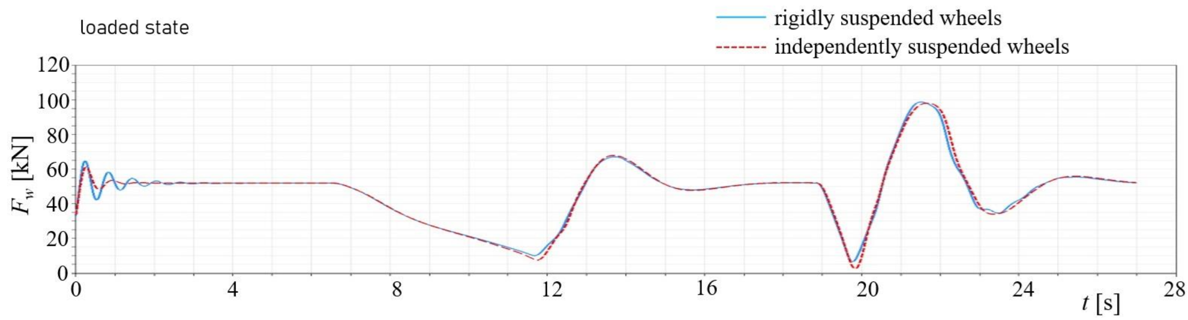

Figure 13. *Wavefrom of the vertical wheel forces for the first axle – the loaded state*

increased sharply in one second without any apparent problems. However, the loaded vehicles needed twice as much time for this change. If the force gradient growth (steepness of the course) is back compared to the first curve, they are very similar. This suggests that the loaded state of the lorry had again entered an understeer skid. This assumption is further supported by the fact that at the twenty-fourth second, the force of the empty states of lorries was close to equilibrium, while in the loaded ones, it was still fluctuating as the vehicle tried to stabilize.

VI. Conclusion

The main goal of the presented research was to create a multibody model of an off-road lorry equipped with rigidly suspended wheels and independently suspended wheels in order to compare the differences between these two concepts of wheel suspension by means of simulation computations. The research was performed using Simpack simulation software. Although the models are simplified, it is possible to assess the estimated driving properties focused on the driver ride comfort and the driving stability.

Based on the design characteristics, it could be expected that the off-road lorry equipped with independently suspended wheels would provide better ride comfort and safety than the off-road lorry with rigidly suspended wheels. The comfort assumption was confirmed on uneven roads, where smaller acceleration extremes were detected for the lorry with the independent suspension at the driver's seat.

From a driving safety point of view, both types of suspension systems have almost identical properties on unpaved roads, and in extreme situations, only slight differences were found. However, both types can be considered equally safe since, in practice, it is very unlikely that a situation will be handled by dependent suspension and not by independent.

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AUTHOR CONTRIBUTIONS

J. Dižo: Methodology, Validation, Investigation, Literature review, Data curation, Multibody modeling, Writing – review and editing, Project Administration.

M. Blatnický: Conceptualization, Methodology, Data curation, Visualisation, Formal analysis, investigation, Writing – original draft preparation.

A. Lovska: Software, Literature review, Formal Analysis, Investigation, Multibody modeling, Data curation, Visualisation, Project administration.

D. Barta: Validation, Investigation, Supervision, Writing – review and editing, Visualisation, Project administration.

Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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