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# The choice of rational stiffness joints parameters of the cabin suspension levers in the vehicle

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**Abstract.** The article is devoted to the choice of rational stiffness parameters of the joints in the suspension levers in the vehicle cabin. The method of formation of cabins dynamic models at their inclusion in spatial dynamic models of vehicles is offered and programmatically realized. In the known methods, the attachment of the cabin to the frame is not taken into account or simulated using linear springs with parallel inclusion of linear dampers or without them. The proposed method deals with the geometric features of the lever guide apparatus, the location of shock absorbers and elastic elements, the presence of a stabilizer in the cabin suspension. In addition, the elastic-damping properties of the mounting parts of the cabin suspension elements are considered. This made it possible, even at the design stage, to investigate the effect of the stabilizer's torsional stiffness and the stiffness of the cabin suspension joints on the vibration loading of the cabin and the driver's seat, which are noticeable at frequencies above 7 Hz.

## 1. Introduction

The modern vehicles are equipped with quite complex, multi-link vibroprotective systems of all levels. Therefore, it is of interest to carry out works on the formation of cabins dynamic models when they are included in the spatial dynamic models of vehicles, on designing and improvement of cabin suspensions, taking into account the properties of their real structures.

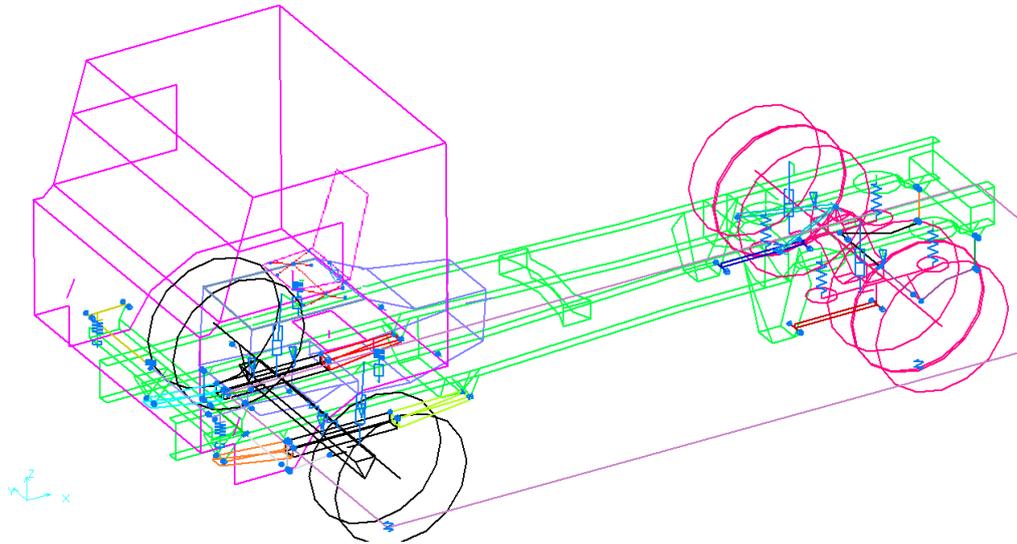
At present, the problem, associated with the rejection of the assumption of the small displacements of bodies, usually used in such calculations, and their implementation on the basis of differential equations of the large displacements of bodies, is relevant [1–7]. This approach implies a precise description in the equations of the angular orientation of bodies and their relative positions. This makes it possible to carry out a refined spectral analysis of the vehicle vibration loading.

As a result, it was possible to choose the rational stiffness joints parameters of the cabin suspension levers.

## 2. The calculation scheme of the vehicle with a refined representation of the cabin suspension elements

The calculation of vibration loading parameters was carried out with the help of a new spatial dynamic model with detailed representation of the front leaf spring and rear air suspensions, and elements of the front and rear cabin suspensions (Figure 1).



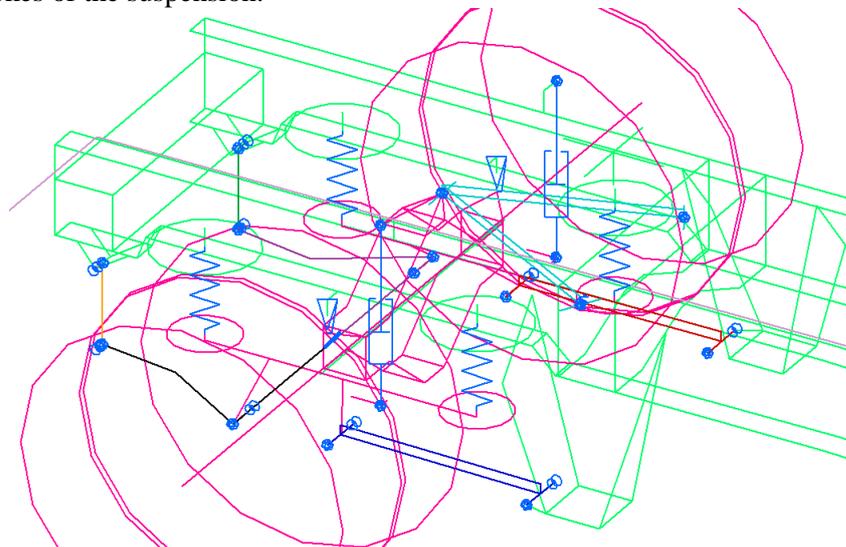


**Figure 1.** The calculation scheme of the vehicle with a refined representation of front and rear vehicle suspensions and cabin suspension elements.

The external forces, acting on the model of the vehicle, are the forces of weight, applied to the centers mass of the model bodies, and the vertical perturbations from the microprofile of the road surface. These perturbations are transmitted through the tires to the suspension elements and further – to the frame and other units. The vibrations from the engine and the transmission in this model are not taken into account. Since only the oscillations, excited by the road microprofile, are analyzed.

Each leaf spring of the front suspension is presented in the form of three bodies, connected by joints. Their characteristics are selected from the condition of equivalence of the leaf spring vertical stiffness, taking into account the forces of interleaf friction.

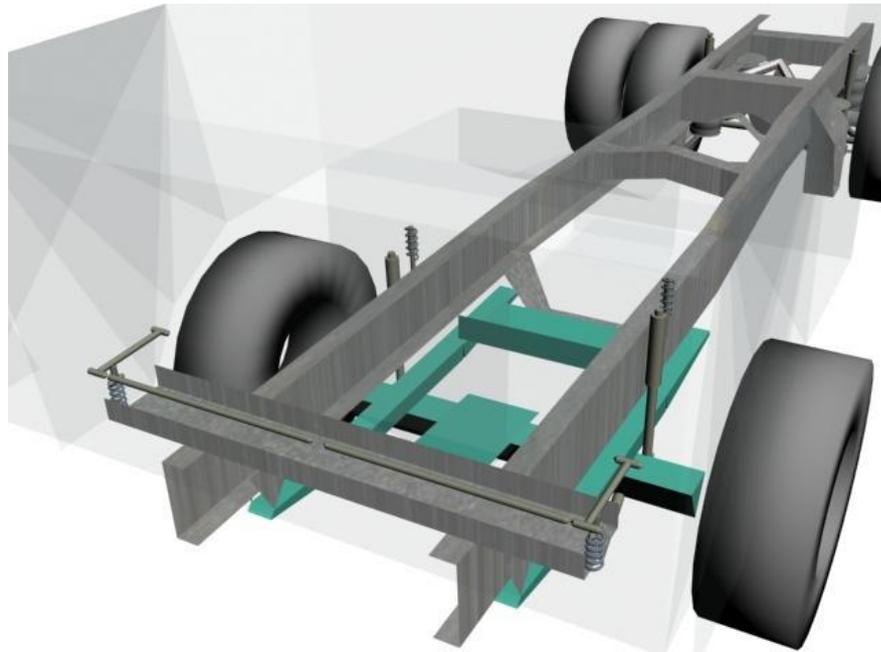
The rear suspension includes the models of the four air tanks, each of which has a non-linear characteristic of vertical stiffness and serves as an elastic suspension element (Figure 2). The characteristic of each air tank is given by a polytropic curve, depending by the volume of the air tank under static load and the initial pressure in it. They are determined by the static load on the rear axle beam. The compression stroke buffer is included into the model of each air tank. In addition, the model introduced a central buffer, which limits the vertical displacements of the rear axle beam during the compression strokes of the suspension.



**Figure 2.** The calculation scheme of the rear pneumatic suspension.

The function of the rear suspension guide device is performed by a system of levers (Figure 2). The lower longitudinal levers are able to perceive mainly longitudinal forces. The upper levers, mounted V-shaped with respect to the longitudinal axis of symmetry of the vehicle, perceive both longitudinal and lateral loads.

The particular attention was paid to the presentation of the cabin suspensions elements in the vehicle dynamic model (Figure 1, Figure 3).



**Figure 3.** Refined representation of the cabin suspensions elements.

In the role of the guide device of the front cabin suspension are the longitudinal levers. The rear ends of these levers are fixed to the cab brackets by means of joints. The middle parts of the levers are connected elastically with the frame, which ensures that the flexibility of the levers of the cabin suspension guide apparatus is taken into account. The stabilizer, which is a part of the front cabin suspension, is presented in the form of a separate body. It is connected to the front parts of the longitudinal levers with the help of elastic elements, taking into account the torsional and flexural stiffness of the stabilizer.

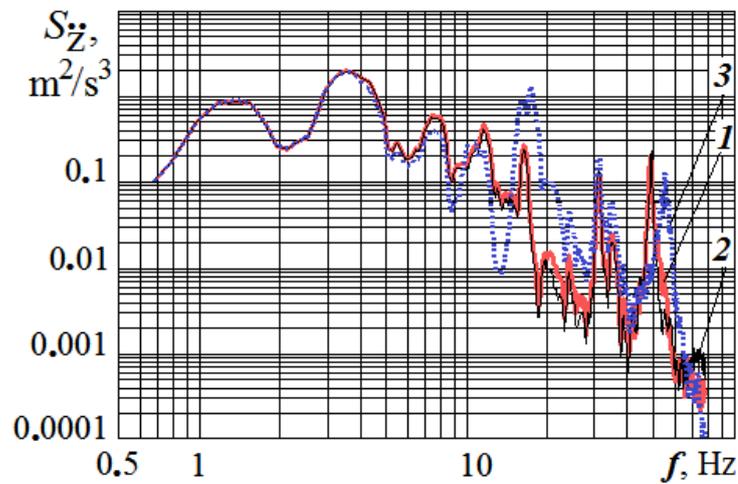
The rear cabin suspension is simulated by two springs with two coaxially mounted shock absorbers, each of which has a piecewise-linear characteristic consisting of four sections.

### 3. Results and Discussion

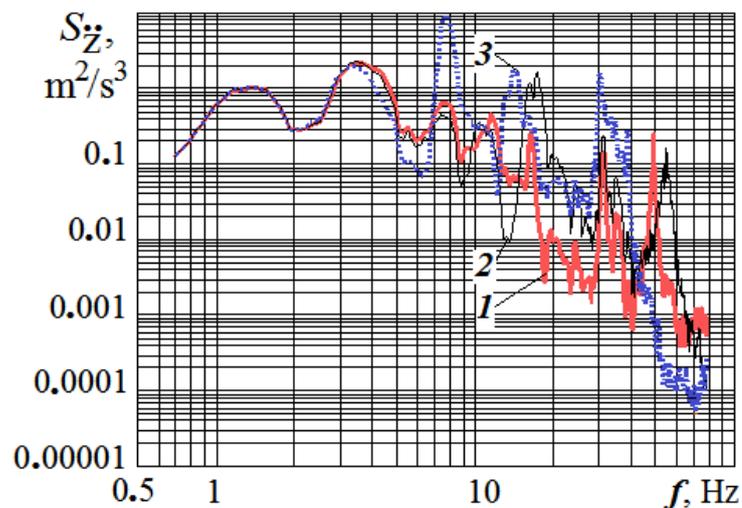
The motion of the vehicle with a constant velocity along the road section with a standard microprofile in the form of an even cobble was simulated. The spectrums of vertical accelerations at several points of the cabin were analyzed. All calculations were performed in the “FRUND” programmatic system [4,5].

By comparing the graphs 1 and 2, we conclude, that the torsional stiffness of the cabin suspension stabilizer does not have a significant effect at high stiffness of the joints (Figure 4). The comparison of graphs 2 and 3 showed, that a tenfold increase in the stiffness of each joint leads a noticeable decrease in high-frequency accelerations in the range of 15–30 Hz and a slight increase in the interval of 7–15 Hz.

For the variant without the stabilizer of cabin suspension, the spectral densities of vertical accelerations on the driver's seat cushion at different joints stiffness of the lever guide apparatus are shown in Figure 5. The highest degree of vibroprotection is achieved, when the joints of increased stiffness are installed (graph 1). In particular, with a tenfold increase in the stiffness of the joints, a significant decrease in vertical accelerations is observed in the ranges of 15–30 Hz and 50–60 Hz (see graphs 1, 2).

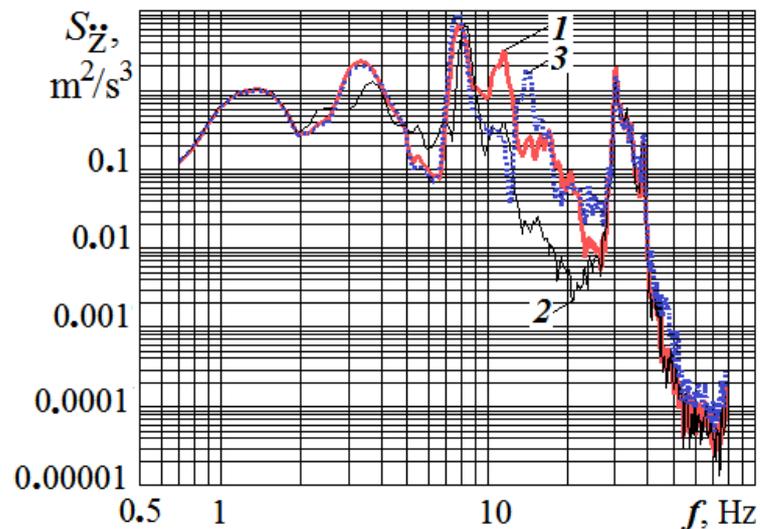


**Figure 4.** Spectrums of vertical accelerations on the driver's seat cushion at high stiffness of the joints of the cabin suspension levers (during the motion of the vehicle along even cobble at a velocity of 60 km/h): 1 – torsional stiffness of the stabilizer of the front cabin suspension is 200 (kN·m)/rad and the stiffness of each joint is 300000 kN/m; there is no stabilizer in the cabin suspension and the stiffness of each joint is: 2 – 300000 kN/m; 3 – 30000 kN/m.



**Figure 5.** Spectrums of vertical accelerations on the driver's seat cushion at the absence of a stabilizer in the cabin suspension (during the motion of the vehicle along even cobble at a velocity of 60 km/h). The stiffness of each joint is: 1 – 300000 kN/m; 2 – 30000 kN/m; 3 – 10000 kN/m.

For a low stiffness of the joints of the cabin suspension levers, the most rational variant is a small torsional stiffness of the cabin suspension stabilizer (Figure 6). An increase in the torsional stiffness of the stabilizer to 200 (kN·m)/rad leads to a slight increase of the interresonance spectral maximum in the range of 2.5–4 Hz and a noticeable increase of spectral density in the range of 9–25 Hz. The absence of the stabilizer resulted not only to a similar increase of the specified interresonance spectral peak, but to a significant increase of spectrum in the region of 13–28 Hz.



**Figure 6.** Spectrums of vertical accelerations on the driver's seat cushion at low stiffness of the joints of the cabin suspension levers (during the motion of the vehicle along even cobble at a velocity of 60 km/h). The stiffness of each joint of the front cabin suspension levers is 10000 kN/m. Torsional stiffness of the stabilizer of the front cabin suspension: 1 – 200 (kN·m)/rad; 2 – 30 (kN·m)/rad; 3 – there is no stabilizer in the cabin suspension.

#### 4. Conclusion

The method of formation of cabins dynamic models with their inclusion in spatial dynamic models of vehicles is offered and programmatically realized. The proposed method takes into account the geometric features of the lever guide apparatus, the location of shock absorbers and elastic elements, the presence of a stabilizer in the cabin suspension. In addition, the elastic-damping properties of the mounting parts of the cabin suspension elements are taken into account. This made it possible, even at the design stage, to investigate the effect of the stabilizer's torsional stiffness and the stiffness of the cabin suspension joints on the vibration loading of the cabin and the driver's seat, which are noticeable at frequencies above 7 Hz.

The torsional stiffness of the cabin suspension stabilizer does not have a significant effect at high stiffness of the joints of the cabin suspension guide levers.

For the variant without the stabilizer of cabin suspension, the highest degree of vibration protection from vertical accelerations on the driver's seat cushion is achieved with increased stiffness of the joints of the cabin suspension levers.

For a low stiffness of the joints of the cabin suspension levers, the most rational variant is the low torsional stiffness of the cabin suspension stabilizer.

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