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INFLUENCE OF MOUNTING AND PRODUCING IMPERFECTIONS ON KINEMATICAL PROPERTIES OF MECHANISM

VLIV VÝROBNÍCH A MONTÁŽNÍCH IMPERFEKCÍ NA KINEMATICKÉ VLASTNOSTI MECHANISMU

Abstract

The paper deals with a kinematic analysis of a truck shifting mechanism and usage of sensitivity analysis. The aim of the work is to optimize the trajectory of a shifting lever hand-grip in order to obtain an acceptable ergonomic trajectory. Mathematical surrogate of the shifting mechanism has been constructed to investigate important mechanism features. Sensitivity analyses have been provided in order to identify the critical dimensions the change of which can cause a distortion of the trajectory shape. The analyses have identified problematic parts and new structure concepts have been based on this knowledge.

Abstrakt

Příspěvek se zabývá kinematickou analýzou mechanismu řazení a využití citlivostní analýzy. Cílem je optimalizovat dráhu řadící páky tak, aby tato dráha bylo co nejpřijatelnější z ergonomického i uživatelského hlediska. Byl vytvořen matematický model kinematiky mechanismu a tento byl podroben důkladné citlivostní analýze, která identifikovala problematické části a rozměry mechanismu. Již nepatrná změna těchto rozměrů způsobovala zborcení tvaru dráhy řadící páky. Na základě analyzovaných výsledků byly též navrženy alternativní konstrukční návrhy.

1 THE SHIFTING MECHANISM

Nowadays, there is a wide offer of trucks, which are designed to operate in the hardest terrain and climatic conditions. Customers decide with respect to price, high reliability and among others also to ergonomic features of a truck controlling. It is important for users that the vehicle manipulation and controlling are in harmony with operator's motions. If we achieve this harmony, the truck exploitation seems to be intuitive and simple to the operator.

The shifting mechanism is also one of the controlling devices, which has to satisfy the ergonomic demands. This mechanism enables the driver to change gear ratios.

The mechanism can be actually based on three principles. We can use electronic components, so the shifting lever becomes a joystick. Unfortunately, electronic devices are in general highly sensitive to vibrations and humidity and their reliability is low too. Or we can transfer gearing impulses from the shifting lever to the gearbox by a wire strand. However, there is a problem with accuracy if the wire is pushed and also soil or sand can intrude between the line and the guiding. So none of the above mentioned concepts can be used. We cannot avoid the using of a classical rigid body mechanism. But these are structurally very complicated and there is also problem with lack of room. It flows to difficult design of the mechanism. We obtain curved lever trajectories, see figure bellow. In case of the real trajectory the driver can hardly find the gearing points and there is also unconcetration and exhaustion due to this inconveniences. Consequently we have to optimize the trajectory of the shifting lever hand-grip in order to obtain an acceptable ergonomic trajectory.

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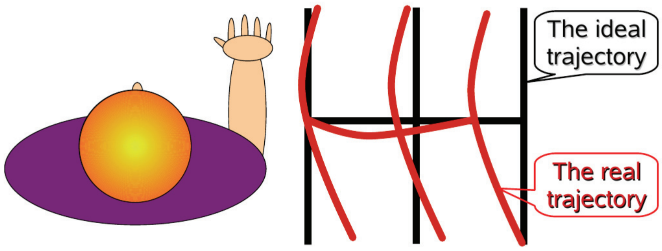

Fig. 1 Real and ideal shape of the shifting lever trajectory

Investigated shifting mechanism is supposed to be used in cars where the driver sits on the right hereinafter called the right-hand shifting mechanism.

2 THE ANALYSIS OF THE RIGHT-HAND MECHANISM

In order to deeply investigate and analyze, any mechanism at first we have to create a kinematic scheme of the particular mechanism (see figure no. 2) and appropriately describe the mechanism dimensions. The best way to describe the dimensions is to measure coordinates of each joint in particular body or global coordinate system.

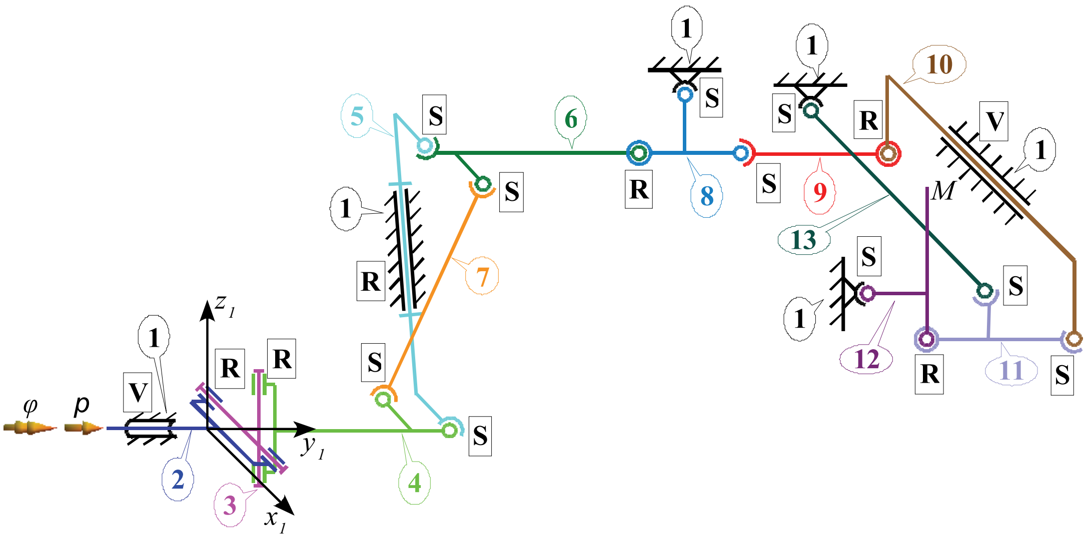

Fig. 2 Kinematic scheme of the right-hand shifting mechanism; joint symbols:
S - spherical; R - rotational; V - cylindrical;

The gearbox is controlled by the fork no. 2 (see scheme above). One can find two marked coordinates of this fork and those are shift (denoted by p) and rotating (denoted by φ) along and about the same axis. Let's call these the mechanism coordinates. Values of the mechanism coordinates and layout of gear ratios is shown in figure no. 3. For instance if a driver choses a second gear ratio the fork has to shift and rotate about certain distance and angle. Let's consider the ideal version of the shifting mechanism; if the shifting lever moves in the car driving direction (respective perpendicular to this direction) the fork shifts (respective rotates). In practice, this two moves are not mutually independent and this independence results in the curved shifting tracks as was sketched in figure no. 1.

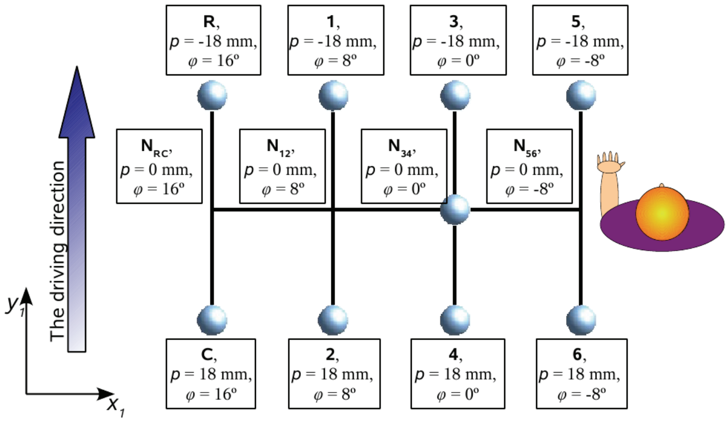

Fig. 3 Layout of the gear ratios

If the kinematic scheme is created and dimensions are described we can determine fundamental mechanism properties. The mechanism is assembled from thirteen parts (including a frame). Number of degrees of freedom is equal four of which two are the mechanism coordinates and two are undefined (undefined rotation of parts no. 7 a 13 about their longitudinal axises). And we can find six kinematic loops in the scheme.

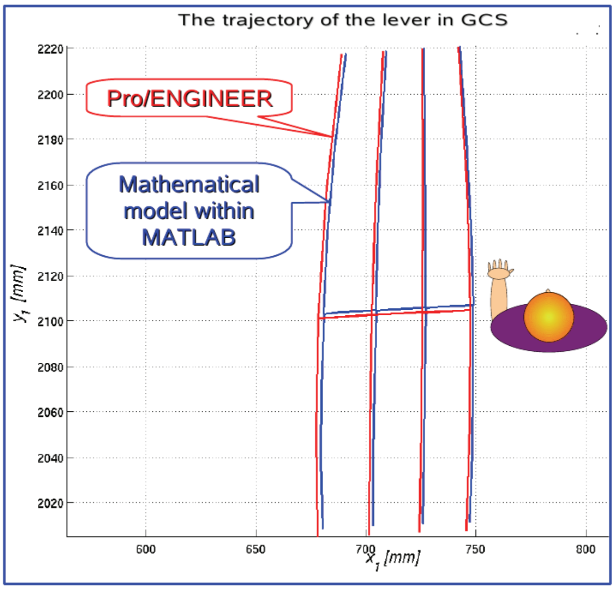

Fig. 4 Shape of the right-hand mechanism shifting tracks

Once we know these basic specifications, we can construct a mathematical surrogate of the mechanism. The construction of the mechanism mathematical surrogate (so called the transmission function) is a long and complicated process, that is why it is not described in the paper in details. The transmission function has been created through the use of the transformation matrix method found in [1]. The function consists of a system of thirty-six (number of loops multiplied by six) nonlinear equations, where thirty-six unknowns represent coordinates of the particular joints (mostly angles of the spherical joints). The system of nonlinear equations has been solved by the Gauss-Newton method. This method turned out to be the most efficiency and the fastest in comparing with Levenberg-Marquardt or „Trust-Region Dogleg“ methods. If the transmission function is solved we can plot the shifting tracks, see figure above. The truck producer found the shifting tracks sufficiently shaped. Unfortunately there was another complication; each produced vehicle differed in the shape so there were ergonomic and force problems during the shifting.

There are two ways to solve this complication. These are sensitivity analyses to identify critical dimensions which have to be kept in certain range or a new structure design of the mechanism.

3 SENSITIVITY ANALYSES

The aim of sensitivity analysis is to define so called the critical mechanism dimensions. One can recognize them if any slight change of these dimensions invokes considerable distortion of the shifting tracks shape. So the producer can establish the set of producing and mounting tolerances of the critical dimensions in order to avoid the distortion of the tracks.

Thirteen mechanism dimensions (which is difficult to hold accurate during the producing and mounting) have been examined; for instance a shift of the cabin in various directions. Also graphs of sensitivity have been created. Finally three dimensions turned out to be crucial (slope of the cylindrical joint axis and the shift of the cabin in the driving direction), see scheme bellow.

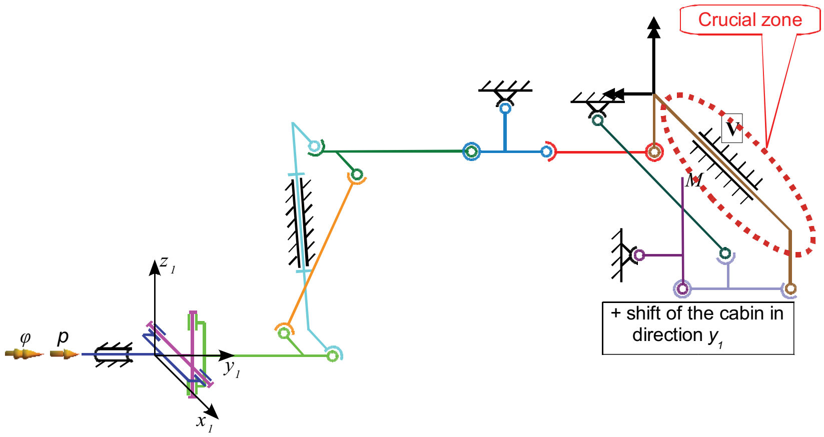

Fig. 5 The critical mechanism dimensions

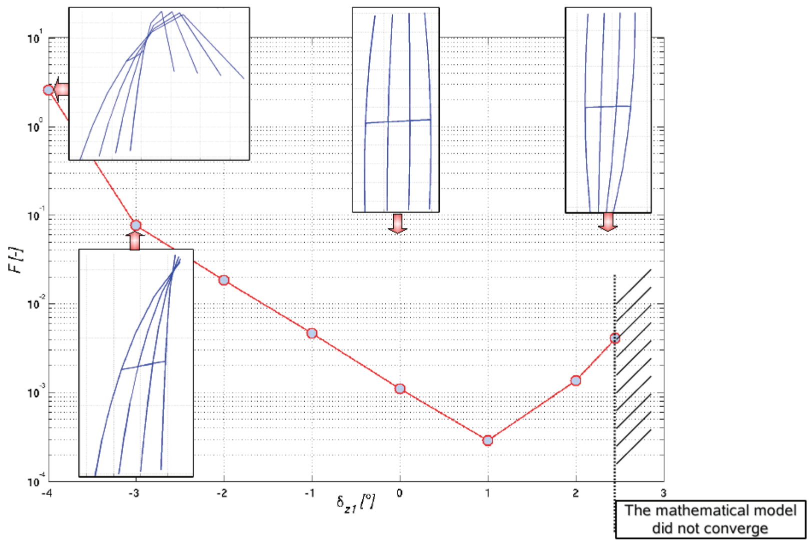

Fig. 6 The sensitivity analysis graph

The sensitivity graph of the most crucial dimension (slope of the cylindrical joint axis about the vertical axis) is shown above. One can see that already a slope about three degrees completely distorts the tracks.

4 NEW CONCEPT OF MECHANISM STRUCTURE

Another way how to solve the described problem is to design new structure. The sensitivity analyses have shown that the part no. 10 (constrained by the cylindrical joint) is the problematic one. So the new concept should be focused on the change in the zone of the part no. 10. Three new concepts have been roughed out. Kinematic scheme of the one is shown bellow. One can see the cylindrical joint was replaced by rotational joint and further necessary and simplifying changes have been provided.

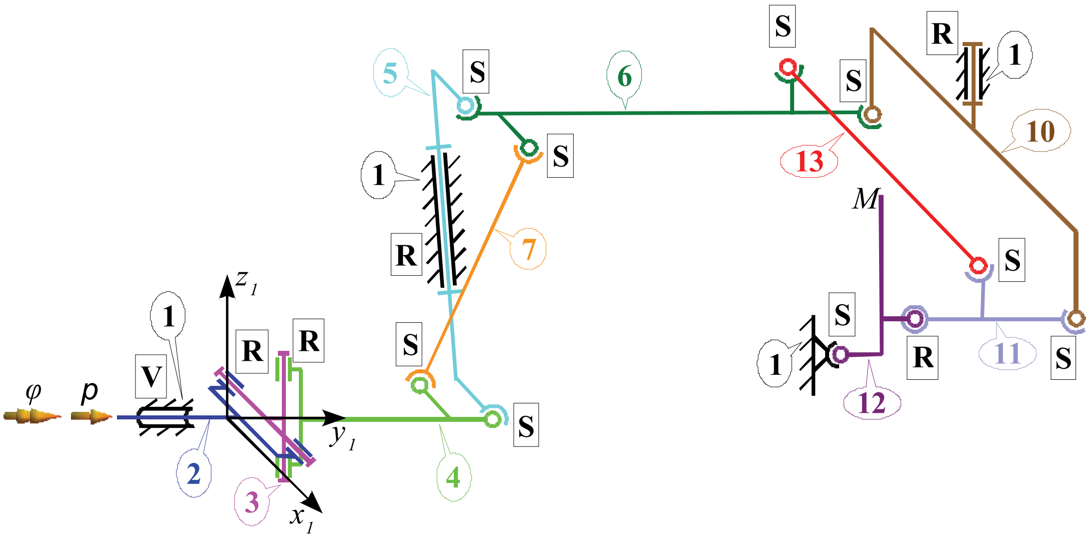

Fig. 7 Kinematical scheme of the new concept of mechanism

The new concept possesses lower sensitivity for manufacturing and mounting imperfections but the producer would have to change many current parts of mechanism. The shifting tracks of this concept are shown in the figure bellow.

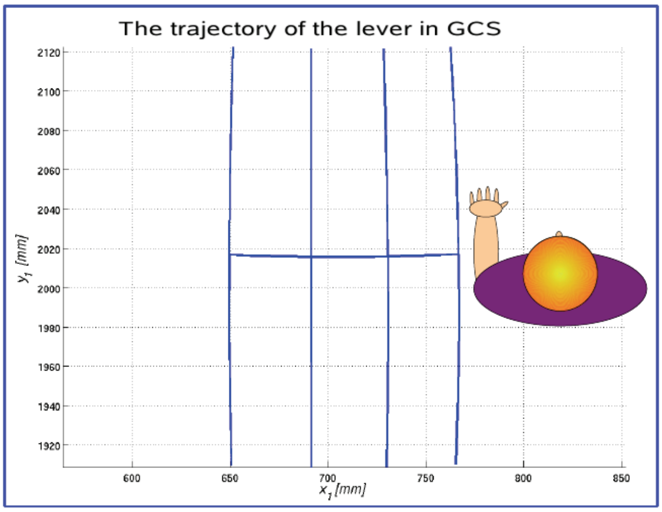

Fig. 8 The shifting tracks shape of the new concept

5 CONCLUSIONS

All of the possible solutions for the described problem were proposed to the producer. Eventually the producer has decided to keep the original mechanism and to work out the system of producing and mounting tolerances to avoid the shifting track distortions.

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