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DECREASING OF DYNAMIC LOADING OF TRACTOR'S POWERTRAIN BY MEANS OF CHANGE OF REACTIVE ELEMENT TORSIONAL STIFFNESS

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Abstract

This article describes original method proposed by authors that provides decreasing of dynamic loading of tractor's powertrain by means of change of reactive element torsional stiffness. In tracked vehicles one of the most loaded elements is final drive unit which loaded by high dynamic modes. In tractor Chetra 6C-315, final drive is epicyclic where stopped element is ring gear. Authors propose using of strictly resilient (5 degrees in forward-backward direction) mount of ring gear instead of stiffening. Design study of installation between hub and gear ring that connects drum and crown gear, of the resilient metal plates pack was performed. This pack is kind of elastic coupling. Resilient packets of coupling sustain loads and smooth over peak dynamic loads and after elastic deformation of these packets rigid coupling between hub and coupling crown is provided at contact surfaces of skewed stops of hub and crown. To analyse efficiency of proposed method of dynamic loadings decreasing of powertrain elements three-dimensional model of powertrain was created in "Universal Mechanism". In addition, solid model of caterpillar mover was created in the same software for analysis of influence on powertrain loadings of complex of kinematic and dynamic factors influencing forming of torque on driving sprockets. This article presents results of modelling of loading processes in powertrains elements with elastic coupling and without it during longitudinal motion at various speeds and in turns with various radii. Results show that elements dynamic loading at high loading dynamic modes in case of installed coupling is decreased by 20-30%.

***Keywords**: dynamic load, power train, dynamic model, torsional vibration, caterpillar tractor*

Volgograd tractor factory is mastering with producing of new agricultural tractor class 6 Chetra 6C-315. On this stage refinement of the construction is performed. One of the ways of construction backfit is study of possibilities for decreasing of dynamic loadings of tractor powertrain. This decreasing provides improvement of tractive-economic and consumer indicators of tractor unit.

Parts of tracked vehicles powertrain sustain loadings with pronounced dynamic character. It is caused by on one-hand irregularities of engine torque and on other hand – irregularity of tractive resistance, changes of speed and direction of vehicle motion, vibrations of frame on suspension, rewind of tracked caterpillar, gears meshing in powertrain, control actions of operator and other factors. It result in material of part sustains additional loadings and accumulates fatigue damages.

To decrease loading of powertrain it is better to use elastic device, which has simple construction, does not require regulation and significantly change construction of whole vehicle. If elastic device is mounted closest to the most loaded part then load of this part and parts connected to it decreases maximal. In tracked vehicles, one of the most loaded elements by modes with high dynamic is final drive unit. This unit is first in powertrain, which sustains dynamic loads from tracked caterpillar rewind, changes of vehicle speed and tractive resistance changes, vibrations of frame on suspension. Therefore, decision was made to install resilient element into final drive unit. In Chetra, 6C-315 tractor's powertrain final drive is epicyclic with stopped ring gear. Ring gear is rigidly connected to frame thus it is base for rotating parts of unit. Therefore, ring gear is reactive element. Design study of installation between hub and gear ring that connects drum and crown gear of resilient metal plates pack was performed. This pack is kind of elastic coupling (Fig. 1a, b). Resilient packets of coupling sustain and smooth over peak dynamic loads and after elastic deformation of these packets rigid coupling between hub and coupling crown is provided at contact surfaces of skewed stops of hub and crown. Elastic characteristic of coupling is presented on Fig. 2. Bumpless contact of skew stops surfaces is provided by sudden increasing of coupling stiffness at the end of working motion.

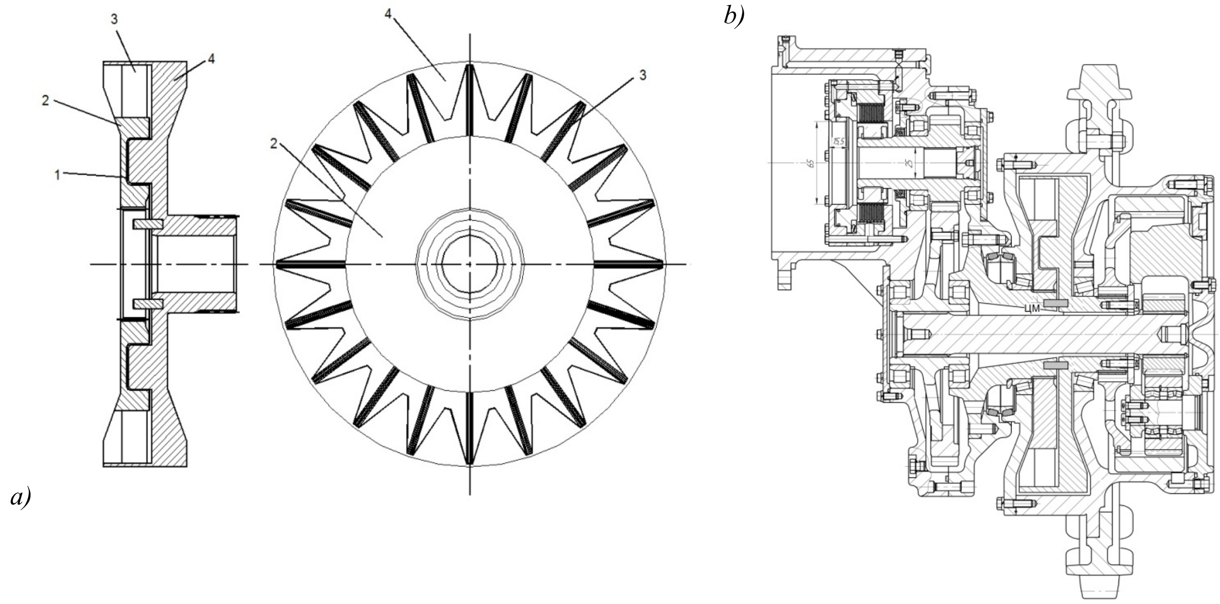


Fig. 1. a – elastic coupling construction; b – final drive unit with installed coupling

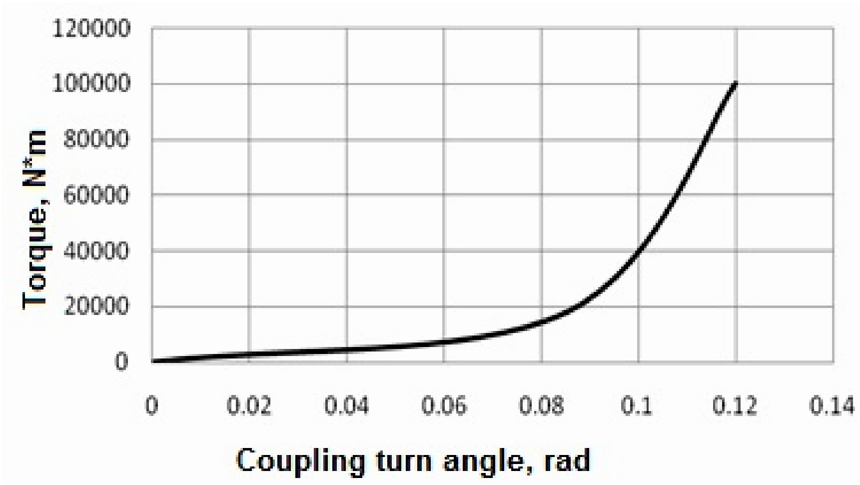


Fig. 2. Coupling elastic characteristic

Coupling consists of half-couplings 4 and 2, which have matched hollows for resilient elements 3 presented as packets of plate springs. These packets are rigidly mounted to half-coupling 2 with one end and inserted to sockets between teeth of half-coupling 4. Coupling construction also includes stoppers 1 which prevents coupling turn on value greater than 5 degrees.

To analyse efficiency of proposed method of dynamic loadings decreasing of powertrain elements three-dimensional model of powertrain was created in “Universal Mechanism” (Fig. 3). This model takes into account reactive forces and moments from case and base elements and from engine. Model provides during the research specifying the character of any engine torque is changing. This character should be determined beforehand from indicator diagrams. Data for 6-cylinder in-line diesel engine Cummins QSM-C330 of Chetra 6C-315 were used in paper.

In addition, solid model of caterpillar mover of Chetra 6C-315 tractor was created in «Universal mechanism» for analysis of influence on powertrain loadings of complex of kinematic and dynamic factors influencing forming of torque on driving sprockets (Fig. 4). In the same software models of tractors with described movers were created and set of computational researches of torque changes on powertrain elements were made. Researches were made for two cases: when elastic coupling installed in reactive element and without coupling. Tractor longitudinal motion with and without hook load and motion in turn with various radii were considered. Bekker model with accounting of sagging was used for describing of soil properties.

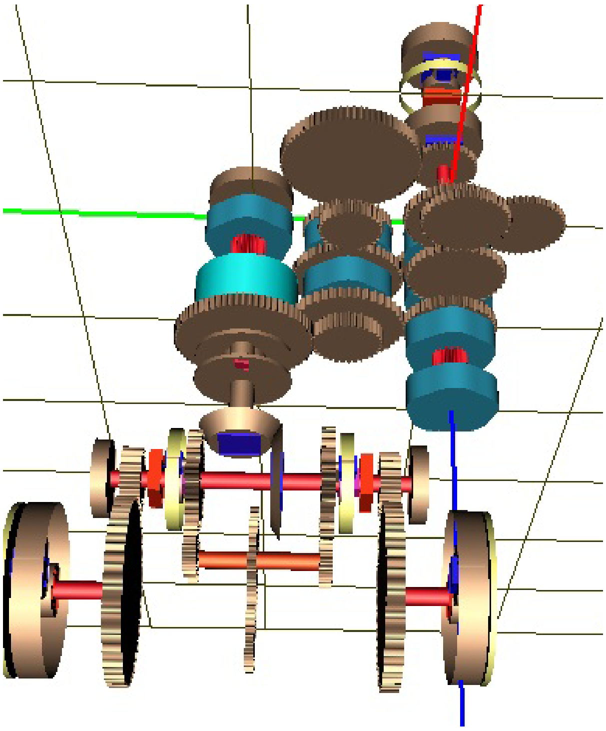


Fig. 3. General view of three-dimensional model of powertrain

Coefficient of load unevenness k_H was used as evaluative parameter, which characterizes degree of areas dynamic loading. k_H is proportional to variation of maximal torque from its average value at the powertrain area:

$$k_{\text{н}} = \frac{M_{\max}}{M_{\text{cp}}}.$$

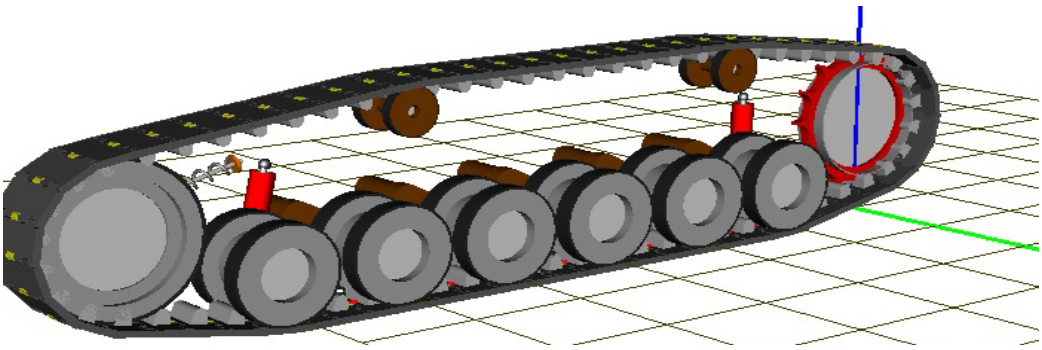


Fig. 4. General view of modelled caterpillar mover

Modes of longitudinal tractor motion with speeds 0.56, 1.1, 1.67, 2.22, 2.78 and 3.33 m/s were considered. On the figures below, numbers of sections are plotted on the abscissa: 1-6 is engine – crankshaft inclusive; 7-11 is gearbox; 12-15 is main gear – final drive inclusive. For example, figure 4 represents graph of change of coefficient k_H at motion speed 0.56 m/s: standard powertrain is in black line; powertrain with elastic device installed in reactive element is in red line. Installation of elastic device provides decreasing of dynamic loading on all sections by range from 16% to 38%. The greatest decreasing equals to about 20% is observed on sections 7-14 that is in gearbox and in rear axle up to final drive. Researches show that during longitudinal motion with hook load, there is similar pattern but loadings decreasing are observed here on sections located up to main gear.

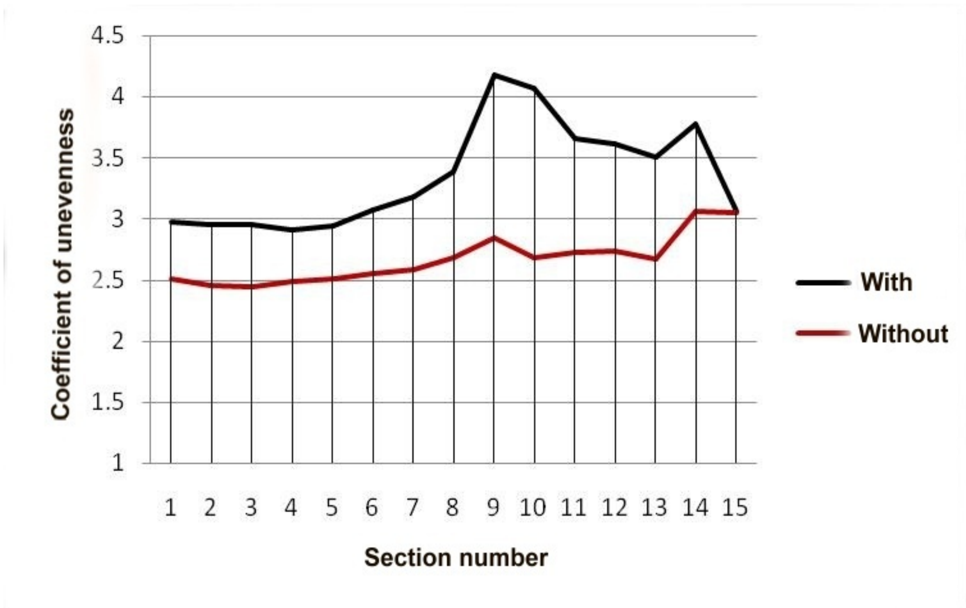


Fig. 5. Change of coefficient k_H on areas at longitudinal motion without hook load

Change of k_H on left and ride sides of powertrain with and without installed elastic device at two speed modes in steady cornering without hook load is presented on Fig. 5. Analysis shows that in turn coefficients of load unevenness of left and right sides are unequal and differ by 1.3-1.5 times. For example on Fig. 6 maximal torques variation on sides is presented for two modes. Torques are only unequal on sections connected to accelerating and decelerating caterpillars. Their difference is from 1% up to 45% at various speeds and turn radii. At turn with hook load, qualitative change of sections loadings is not observed. Loading unevenness decreases from 0% up to 25% on all sections.

a) *b)*

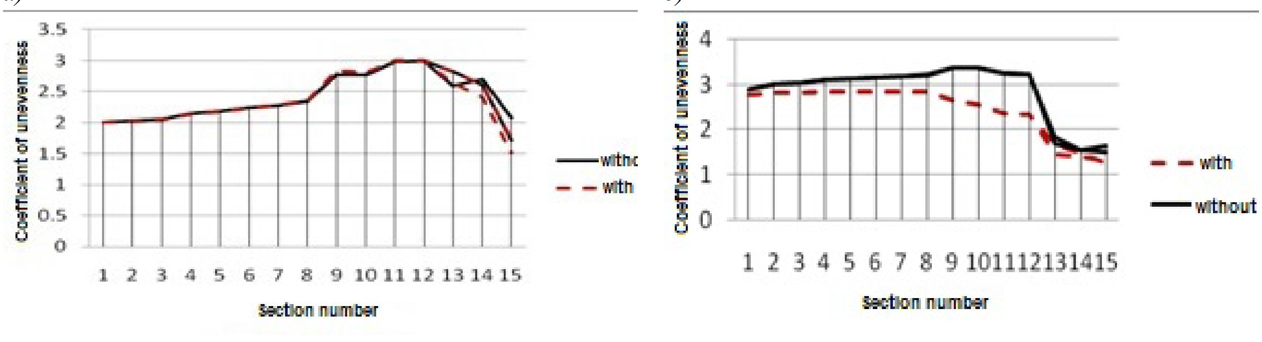


Fig. 6. Change of k_H on areas at steady turn: a-speed is 0.56 m/s, turn radii is 5 m; b – speed is 1.67 m/s, turn radii is 5 m

a) b)

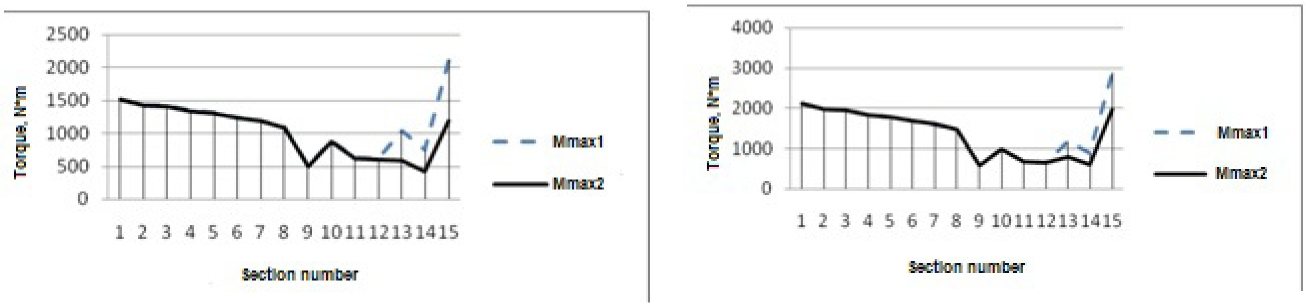
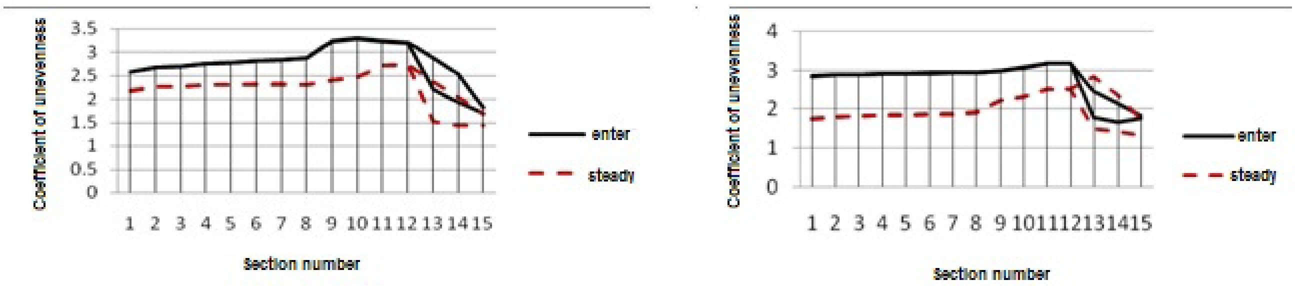


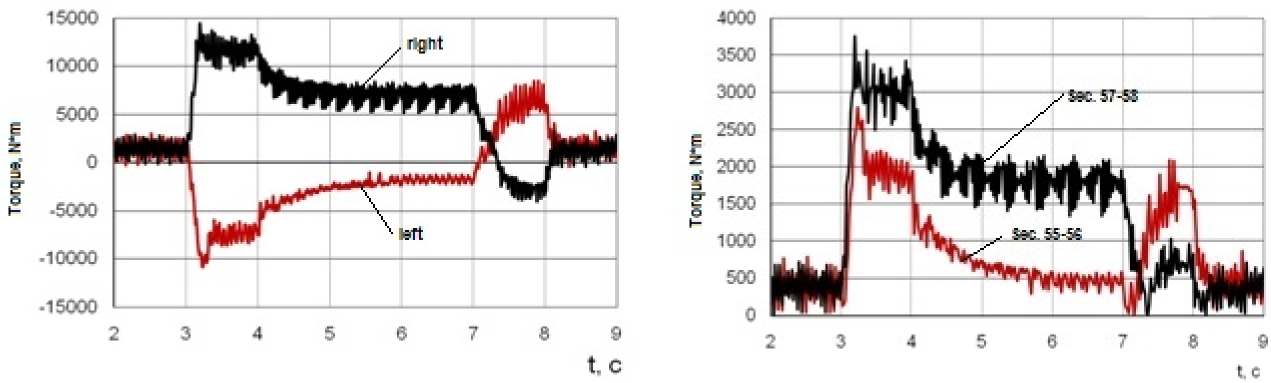
Fig. 7. Change of k_H on areas at steady turn: a-speed is 1.1 m/s, turn radii is 10 m; b – speed is 2.22 m/s, turn radii is 7 m

The highest loading unevenness is usually observed at start and end phase of turn – at turn entry and at turn exit. For example, on Fig. 7 comparison of change of k_H on sections in steady turn and at turn entry at two speed stages is presented. k_H decreases by 20-35% on most of sections.



a b

Fig. 8. Change of k_H on sections at enter in turn: a-speed is 1.1 m/s, turn radii is 3 m; b – speed is 0.56 m/s, turn radii is 2m

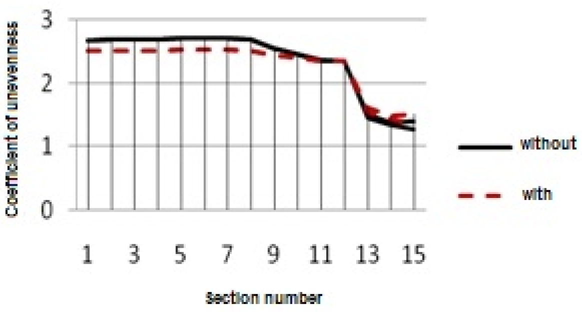


a b

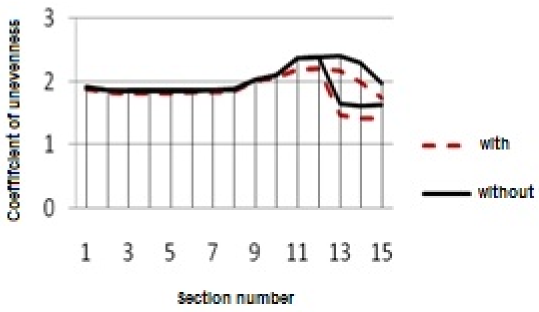
Fig. 9. Change of torque at enter in turn and at exit from turn at speed 2.78 m/s and turn radii 2 m: a – on driving sprokets; b – on sections connected to acceleration and decceleration caterpillars

Sections of numerical oscillograms of torque change on driving sprockets of acceleration and deceleration caterpillars are presented on Fig. 9. Analysis of this oscillograms shows that at turn entry (from 3rd to 4th seconds of motion) maximal torque 3.5 times greater than average torque and at exit from turn (7th -8th seconds) maximal torque 2.5 times greater than average. Analysis of torque change process from 3rd up to 7th seconds on sections lying nearby driving sprockets shows that on sections connected to acceleration caterpillar at turn entry maximal torque 9 times greater than average and at turn exit maximal torque 2.5 times greater than average.

Change of k_H on sections at two speed modes at turn exit with and without coupling is presented on fig. 10. Installation of coupling provides decreasing torque on many sections by 5-6%.



a



b

Fig. 10. Change of K_H on sections at exit from turn: a – speed is 2.78 m/s, turn radii is 2m; b – speed is 0.56 m/s, turn radii is 2 m

Conclusions

1. Original way of decreasing of dynamic loading of caterpillar tractor's powertrain by means of reactive element's torsional stiffness change is proposed.
2. In order to perform of computational analysis of dynamic loading of tractor's powertrain parts at various motion modes mathematical model was created in "Universal mechanism". This model is based on three-dimensional and dynamic representation of elements of caterpillar chassis and powertrain.
3. Based on computational modelling it was determined that:

− at longitudinal motion with and without hook load average decreasing of ratio of maximal torque to average torque is 20% on sections of powertrain,
− in steady cornering with and without hook load at various speeds and various turn radii ratio of maximal torque to average torque decrease by up to 25% on some sections,
− at modes with highest dynamic loading such as turn entry and turn exit ratio of maximal torque to average decreases by 20-35% on most of sections.

Thus, efficiency of proposed method of decreasing of caterpillar tractor powertrain dynamic loading by means of change of torsional stiffness of reactive element was proved based on modelling.

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