Optimum parameters determination of the gripping and cutting device vibration suspension

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Abstract. The article presents the optimum parameters determination results of the gripping and cutting device vibration suspension in the process of holding the tree in a vertical position. Two kinematic schemes of the vibration suspension were considered, and their equilibrium equations for static calculation were compiled. To determine the optimum parameters of the vibration suspension the geometric parameters of its structural elements were selected at which the torque on the drive shaft was minimum. The changes in the lengths of the rotation arm and suspension arm, the arm fixing distance to the boom were justified as variable parameters. As a result of varying the set parameters graphs of the drive shaft moment change depending on the tree weight were obtained. As a result of the study, it was determined that with an increase in the arm fixing distance to the boom, the torque on the drive increases, and with an increase in the parameters of the rotation arm and the suspension arm, on the contrary, decreases. Therefore it is recommended to increase the arm fixing distance to 201 mm, and the rotation and suspension arms, on the contrary, reduce to 200 and 86 mm, respectively. The results obtained made it possible to determine more optimum parameters of the gripping and cutting device vibration suspension, which can be used in further theoretical and practical research of the gripping and cutting device design with vertically held tree.

1 Introduction

The gripping and cutting device of the logging machine is designed for cutting, holding and directional felling of tree. In some logging technologies, a gripping and cutting device (GCD) holds a tree in an upright position when it is moved by the course of a logging machine [1-5]. The tree retention occurs due to the weight and size of the base tractor or through the stabilization system use that compensates for external disturbing influences [3-7].

The use of the reverse pendulum dynamic stabilization principle on the oscillating suspension was proposed as one of the stabilization system variant for the GCD with a vertically held tree [8-9]. To apply the dynamic stabilization principle the GCD design was

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proposed, which is characterized by the vibration suspension usage [4]. The GCD vibration suspension is a vibration mechanism that creates sufficiently fast vertical vibrations of the GCD with a vertically held tree during operation.

Depending on the held tree parameters the vibration mechanism can experience significant loads, which affect the entire structure reliability and its main parameters choosing.

When the vibration suspension is in operation, the main acting force is created by a rotating drive (for example, a hydraulic motor), which raises and lowers the GCD with a tree through lever mechanism. In this regard the main task of the vibration suspension optimum parameters determination is the selection of geometric design parameters at which the torque on the drive shaft will be minimum.

2 Material and methods

One of the ways to determine the vibration suspension optimum parameters is to analyze the structure using the method of classical theoretical mechanics [10], which can be used to determine the forces acting on the vibration suspension.

Assuming that the maximum static load with a vertically held tree will occur when the GCD boom is located absolutely horizontally. Then the masses of the GCD and the tree will be directed absolutely downward. A right angle of 90 degrees is formed between the boom and the direction of tree gravity. In this case the tree gravity will not decompose into projection components and will create the maximum moment. Figure 1 shows the GCD vibration actuator with an indication of the main elements.

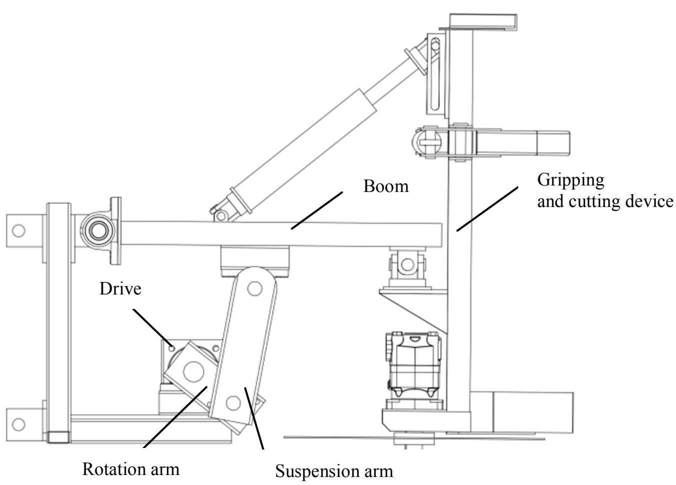

Fig 1. Vibration suspension of the gripping and cutting device.

Since at each moment the position of the lever mechanism has two coordinates relative to the trajectory of rotation around the drive shaft, therefore, consider two kinematic schemes (Figure 2).

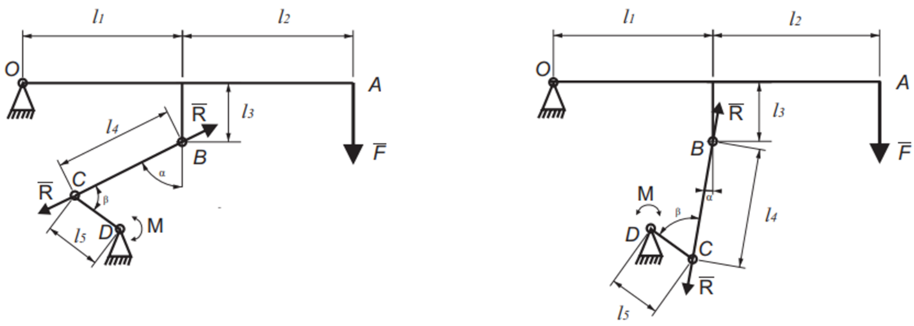

Fig 2. Kinematic scheme and forces acting on the vibration mechanism: a) Scheme 1; b) Scheme 2.

The center of the coordinate system is at point *O*. We discard the supports in the scheme and replace them with reaction forces, leaving only those forces and reactions that affect the finding of torque at point *D*.

We make up the equilibrium equation for the schemes in Figure 2. For both cases, the equilibrium equation will be the same:

$$\sum M_O = 0\ ;\ -F \cdot (l_1 + l_2) + R \cdot \cos\alpha \cdot l_1 + R \cdot \sin\alpha \cdot l_3 = 0 \quad (1)$$

$$R = \frac{F \cdot (l_1 + l_2)}{\cos\alpha \cdot l_1 + \sin\alpha \cdot l_3} \quad (2)$$

Taking into account the value of the force *R* (2), the moment in point *D* will be equal to:

$$M = R \cdot \cos(90° - \beta) \cdot l_5 = \frac{F \cdot (l_1 + l_2)}{\cos\alpha \cdot l_1 + \sin\alpha \cdot l_3} \cdot \cos(90° - \beta) \cdot l_5 \quad (3)$$

3 Results

To determine the optimum design parameters we will set the initial values of the GCD vibration actuator elements parameters (Table 1) taken from the GCD 3D model [4].

Table 1. Initial data for the calculation.

	The GCD mass	l_1	l_2	l_3	l_4	l_5
Unit	kg	m	m	m	m	m
Value	100	0.38	0.4	0.14	0.29	0.125

To identify a more loaded circuit, taking into account the initial data (Table 1) we determine the static moment on the drive shaft (Figure 3) for each of the circuits (Figure 2).

It can be seen from the graph that scheme 1 is the most loaded due to the fact that in scheme 2 the entire load affects the short rotation arm (l_5), but in scheme 1 the load falls on the longer part (l_4 and l_5), as a result of which a greater torque is created.

Fig 3. The values of the static torque on the drive shaft for scheme 1 and scheme 2 under the same conditions.

Assuming that the vibration actuator design can significantly affect the resulting torque parameters, we will identify a change in the static torque on the drive shaft by varying the parameters l_3, l_4 and l_5.

The boom parameters (l_1 and l_2) not used in the variation. Because it is clear from the design that to reduce the torque the length of the GCD boom should be minimum. When changing the length parameters l_3, l_4 and l_5, the angles of their mutual arrangement change, which were taken into account in the subsequent calculation.

As a result of varying the parameters l_3, l_4 and l_5, the following graphs (Figures 4 – 6) for torque changes on the drive shaft depending on the tree weight were obtained.

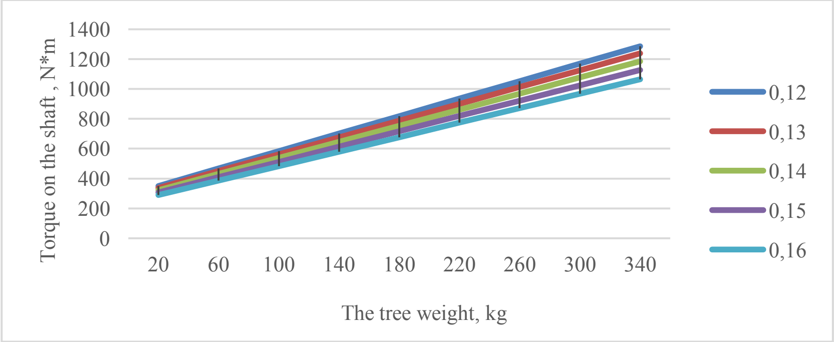

Fig 4. The change of torque on the shaft depending on the tree weight with varying values of l_3 .

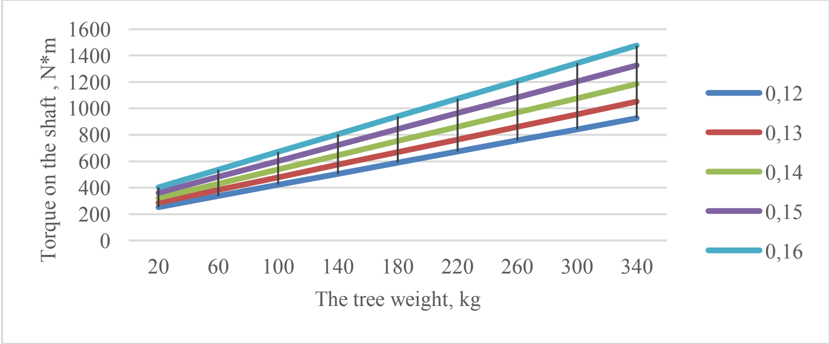

Fig 5. The change of torque on the shaft depending on the tree weight with varying values of l_4.

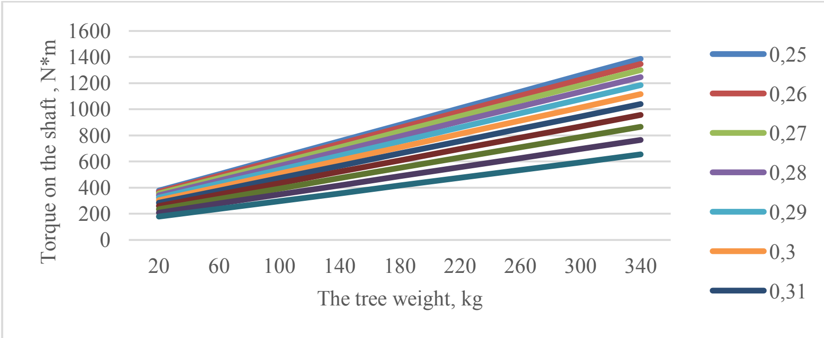

Fig 6. The change of torque on the shaft depending on the tree weight with varying values of l_5.

4 Conclusions

Varying the parameters l_3, l_4 and l_5 shows that with an increase in the parameter l_3, the torque on the drive increases, and with an increase in the parameters l_4 and l_5, on the contrary, decreases. Therefore, it is recommended to increase the arm fixing distance to 201 mm, and the rotation and suspension arms, on the contrary, reduce to 200 and 86 mm respectively.

The results obtained made it possible to determine more optimum parameters of the gripping and cutting device vibration suspension, which can be used in further theoretical and practical research of the gripping and cutting device design with vertically held tree.

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