Simulation of the movement of hedge cutter links in the Simulink application of the Matlab package

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Abstract. Simulation modeling allows researching a mechanism consisting of many links interacting with each other according to complex laws. In order not to write a model for each node of the investigated mechanism, it is advisable to use ready-made blocks of the Simulink application. To simplify the process of creating blocks responsible for the links of the mechanism, we used the Solidworks computer-aided design system. 3d models of each link were designed, kinematic connections between them were established. Thus, the mass characteristics of the links, their geometric parameters, moments of inertia and kinematic pairs were obtained. After exporting the model from the computer-aided design system to Simulink of the Matlab package, a basic block diagram was obtained which was supplemented with disturbing input signals, virtual oscilloscopes for characterizing, mechanical transmission units, etc. Based on the obtained coordinates of the frame links and the rotor knives, dependencies were constructed to determine the kinematics of their movement in three planes, which made it possible to clearly demonstrate the top and rear view of the mechanism under study in the considered time interval. The developed simulation model can be upgraded to study the dynamic characteristics of the mechanism.

1. Introduction

To lighten forest cultures and prevent their overgrowth with unwanted tree and shrub vegetation, it is necessary to use mechanized machines - hedge cutters. These machines are frames with working bodies in the form of rotors with knives. These machines can be analytically described as systems of material points and rigid bodies. A great contribution to the development of the mechanics of systems of material points and solids was made by V G Vilke. In the works of Hui ma, a model of a rotor with blades was studied, taking into account the lateral and torsional deformations of the shaft [1]. The study of the kinematics of rotating links using virtual prototyping is the work of Chen Yong [2]. In [3], a finite element model of a rotor is presented, taking into account the inertia of the shaft rotation. Recently, the Simulink application of the Matlab package has begun to be used more and more actively for modeling technical means. So in the article by Yiheng Lin [4], the trajectory of the path of an agricultural vehicle was obtained using the Simulink-CarSim bundle. In the article A N Sova [5], using Simulink, a generalized simulation model of the movement of a two-link road train was developed and the dynamics of the road train was assessed. The closest to the topic of our research is...
the work of Mei Fang in which, using the MATLAB/Simulink environment, a dynamic analysis of a machine with a rotor on which there is a knife designed for cutting vegetation is performed [6].

In our previous works, we considered the analytical and simulation model of the flexible working body of the brush cutter, made in the computer-aided design system [7] and using the Unity cross-platform development environment [8]. As a result of these works, analytical and simulation dependences of the change in the coordinates of the rotor links on time were obtained. When considering a mechanism consisting of several links ‘rotor – knives’, the use of the above systems allows one to obtain the required result and take into account the disturbing input parameters of interest. In this paper, we will consider a system consisting of a frame, mechanical transmissions and two working bodies. In this case, using the Unity development environment will require a significant amount of programming to describe the operation of all parts of the mechanism. The use of computer-aided design systems allows you to create a model of the mechanism, but to take into account friction forces, set disturbing signals that simulate soil irregularities, fine-tune the model and take readings from it, it is advisable to use the Simulink application of the Matlab package. Using the example of a simulation model of the movement of hedge cutter links, we will consider an approach for modeling technological equipment, which is based on the use of the Simulink application of the Matlab package. The input data for modeling are the design parameters obtained by us in the automated design system (CAD) Solidworks. This approach greatly simplifies the modeling process and links it to the work of the design engineer.

2. Material and methods
As a result of a patent search for the prototype of the structure, we have chosen patent [9]. As a result of the structural analysis of the mechanism, its main links were identified and a kinematic diagram was drawn up (figure 1). Based on the kinematic diagram in the Solidworks CAD environment, we developed 3d models of the mechanism links and connected them into a common assembly (figure 2).

![Figure 1](image1.png)

**Figure 1.** Hedge cutter with articulated working bodies: kinematic diagram (a); photo of working bodies (b).

Based on the assembly of the mechanism from the computer-aided design system, a simulation model was drawn up. The main elements of the simulation model are described below.

To create a reference point at the origin of the world coordinate system (0,0,0), place the Pochva_1 object (connected through port F), which describes an even layer of soil, relative to which the tractor with the hedge cutte is moving. Connect the PlitaMtz82_1 object, which describes the tractor frame, to the soil through the F1 port. Ports F, F1 describe the lugs for connection by means of Revolute6,7 kinematic pairs of two lower links NizTiaga_1,2 through port F4 the upper link VerxTiaga_1 is connected. All three rods are connected through the kinematic pairs Cylindrical1,2 and Revolute9 and ports F2, F3, F5 to the beam - Balka1_1. The shaft for the driving pulley Val_1 is connected to the
beam through port F1, the shaft of the driven pulley, on which the driving bevel gear ValReduct1_1 is located and the shaft ValUgl_1 to which the Shtanga_1 bar is attached by means of kinematic pairs Cylindrical3, Revolute8, which regulates the inclination of the working bodies. The drive pulley shaft is driven by the Angular subsystem, in which the acceleration characteristic and the revolution per minute (RPM) of the tractor power take-off shaft (PTO) are set. Rotation is transmitted from the driving pulley to the driven pulley due to the V-belt transmission Cable Properties1, the diameter of the driving pulley is 250 mm, the driven pulley is 180 mm. From the drive shaft of the bevel gear, we read the angular velocity in rad / s, take the derivative and get the angle of rotation, which we supply to the input of the driven shaft of the bevel gear. The number of teeth of the driving bevel gear is 48, module 4, the number of teeth of the driven wheel is 24, module 4, the gear ratio is 2. From the pulley located on the driven shaft of the bevel gear, we rotate the V-belt transmission CableProperties2 to the central shaft ValSchkiCentr_1 (pulley diameters 180 mm). On the central shaft there is a Shkiv2_180_4 pulley, from which we transfer the rotation to the left and right pulleys through CableProperties3 belt drives. These pulleys drive the shafts ValShkivBok_1,2, on which they are installed, in rotation, which, in turn, rotates the cutting tools RotorNoz2_1.2.

Figure 2. Three-dimensional model of a hedge cutter with an indication of the main links and kinematic pairs.
Figure 3. Visual form of the hedge cutter frame model in the Simulink application of the Matlab package.
Figure 4. The visual form of the hedge cutter working body in the Simulink application of the Matlab package.

The developed simulation model (figures 3-4) makes it possible to obtain the trajectories of movement of any link elements and reactions in kinematic pairs. As an example, the readings of the
overall points of the knife working body and four joints of the lower links of the tractor hitch were obtained.

3. Results and discussion
To simulate the movement of the hedge cutter, set a constant feed rate in the kinematic pair between the soil and the slab along the OY axis, equal to 0.1 m/s. To simulate movement on an uneven surface, let us set the rotation in the kinematic pair between the soil and the slab with an angular velocity of 2 rad/s. We multiply this value by the signal shown in figure 5. After that, having integrated, we obtain the values of the angles of rotation of the plate around its axis OX.

Figure 5. Input signal for calculating the rotation of the plate (PlitaMTZ82_1).

Figure 6. Changing the X, Y, Z coordinates of the NizTiaga_1 hinge during the simulation.

From each point of the links of the working body, as a result of the simulation experiment, we can get the coordinates x, y, z. As an example, figure 6 shows the change in the coordinates of the lower link in the hinge F. The figure shows that the link moves at a constant distance of 0.5 m along the OX axis, from 6 to 14 seconds, the thrust moves down and returns in accordance with the rotation of the plate with a given signal (figure 5) and increases the movement along the OY axis, since the tractor is moving forward.

Figure 7. Changing the X and Y coordinates of the hinges F, F1, F2, F3 of the two lower links of the hitch and two extreme points of the blades of the working body.
Combining the obtained data on the coordinates of the thrust hinges and the extreme points of the blades of the working body, we construct a top view (figure 7) and a rear view (figure 8).

![Figure 8](image)

**Figure 8.** Changing the X and Z coordinates of the joints F, F1, F2, F3 of the two lower linkage links and the two extreme points of the blades of the working body.

It figure 8 follows that the coordinates of the hinges of the lower links, which are at the plate when it is turned, move by an amount of 0.1 m, and the coordinates of the hinges connecting the hinge to the hedge trimmer frame move by an amount of 0.3 m. Two working bodies with knives when turning the frames, as a result of imitation of the unevenness of the soil, move from a height of 0.4 m above the soil level to a height of -0.5 m, i.e. will enter the ground, which is unacceptable. Thus, knowing the operating conditions, it is possible to simulate the movement of the links of the mechanism in advance and, if necessary, change its design.

4. Conclusion

On the basis of the developed simulation model, the trajectories of the hitch rods and two knives on the hedge cutter rotors were calculated. By changing the input geometric and dynamic parameters at the input on the basis of the model, we can carry out a computer experiment, the data of which can be used to optimize the hedge cutter. The trajectories clearly demonstrate the working width of the working bodies, the movement of the hitch frame and the vibrations of these links under disturbing influences that simulate the unevenness of the soil.

In addition to the obtained kinematic parameters of the links described in the article, the trajectories of movement of the remaining links can be taken from the developed model in a similar way. The developed simulation model is also a basic frame and can be upgraded to obtain the dynamic characteristics of the hedge trimmer.

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