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3D Model of the Mechanical Part of a Weed Recognition System in an Agricultural Robot in 3D Experience Environment

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Abstract. **The damage from weeds in the cultivation of agricultural crops is ubiquitous and they adversely affect the yields of agricultural production. The soil conditions of the places where the crops are grown deteriorate. Contribute to the development of diseases and the enemies on them. Apart from this, it is difficult to carry out mechanized processing and harvesting activities. Weeds also worsen the very quality of the harvested produce. That is why the availability of a recognition system to the agricultural robot is essential to reduce the adverse influence. It is part of a system of control and destruction. In this weed recognition system, an essential element is a robotic arm to enable a camera to perform video surveillance.**

The aim of this paper is to modelling only the mechanical anchorage system for weed recognition elements that it does not interfere with the other elements with which it interacts. To be as effective as possible, this system must be as close as possible to the plants and at the same time close to the weed eradication system in agricultural robot.

A three-dimensional model of the weed recognition mechanical parts from system is discussed in the paper. It is designed in a 3D Experience environment, taking into account the parameters necessary for the movement of the system. Strength sizing of the structure and working simulations of the model were made.

Keywords: 3D model, agricultural robot for weed control, mechanical systems, strength sizing, weeds recognition.

I. Introduction

Robots are successfully used in a variety of industries, especially those that are unattractive due to high demands on output, heavy physical labour, and low wages [1, 2]. In such conditions, agricultural robots also work – moisture, strong heat. Agricultural robots have a number of operations, such as sowing, cultivation and harvesting. Work on these complex tasks is greatly facilitated in the use of machine vision and decision-making [3].

In the cultivation of crops, in addition to cultivated plants, weeds also grow in the soil. This creates big problems because the yields of crop plants are reduced, crops are destroyed and prerequisites for the growth of other weed species are created [4]. Weed control is a complex and costly task to begin with. Using an agricultural robot without human intervention requires serious knowledge of these weeds [5]. Weed control by robot will improve conditions in modern agriculture. The elements of the machine vision system should be placed on an equipped manipulator, as close as possible to the plant and to the work equipment [6].

The time for the creation of the weed recognition system would be shortened by using CAD modelling in the creation of the mechanical part of the system [7].

In this paper a three-dimensional model of a mechanical part of the weed recognition system is developed. It is necessary because it is part of the weed eradication system to an agricultural weed control robot. The mechanical part must be stable, carry the recognition elements themselves (the camera), and be part of the weed destruction system, while being close to the plants. It should not be influenced temperature by the heat flux in the destruction of weeds. The three-dimensional model was designed through the use of a CAD product, and some of the elements were strength sized.

II. Materials and methods

The design of a mechanical part of a weed recognition and control system in this paper is reduced to the

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development of a three-dimensional model of the system, where all the peculiarities of the process are taken into account. The recognition system consists of a camera located at a certain focal length from the plants. The camera is part of a machine vision system that directs the robot onto the weeds. The robot crosses the rows with different crops, monitoring for weed recognition. The camera data is compared with a machine-learning database and the tines perform weed removal activities.

The robot that is mounted for the weed recognition and control system is an existing self-propelled wheel with a 4x4 wheel formula. It has a variable transverse base and working height. The robot is implemented under the task of the national scientific program "Intelligent Plant Growing" in Bulgaria. The robot and the designed system are part of a patent proposal submitted to the Patent Office of Bulgaria.

In the present paper, only the mechanical weed recognition system is considered. It is part of a weed control system including an agricultural robot, a system for destroying weeds by heating, an electronic control system for weed recognition based on machine learning, a mission control system, etc.

The presented mechanical system is installed at the bottom of the robot, under its body, to be as close as possible to the plants.

The design of the mechanical part and the preparation of a 3D model is carried out on the CAD product CATIA V5, and the strength sizing was carried out through the 3D Experience development environment in the CAD laboratory of the Agricultural University – Plovdiv, Bulgaria.

III. Results and Discussion

The developed model of the mechanical part of the weed recognition and control system is shown in Fig. 1 and Fig. 2.

Fig. 1 shows the top view of the system. It consists of a 10 plate. The plate is aluminium and is fastened to the agricultural robot under its body through 14 screw M8. The plate is 4 mm thick and 500 x 500 mm in size and is consistent with the robot body gauge.

On the plate is attached the base 2, to which is connected servo motor 1. The base is made of three aluminium parts. Of these, two are vertical and one cylindrical horizontal for attachment to the plate. At one end of one vertical detail there is a separate place for fastening the servo motor. It is a product of the company "FEETECH" - FT 6560 M. The servo motor has the following parameters [8]:

Torque – 5.88 Nm; Operating voltage – 7,4 V;
Mass – 0,2 kg; Speed – 0,15 s/60 degree.

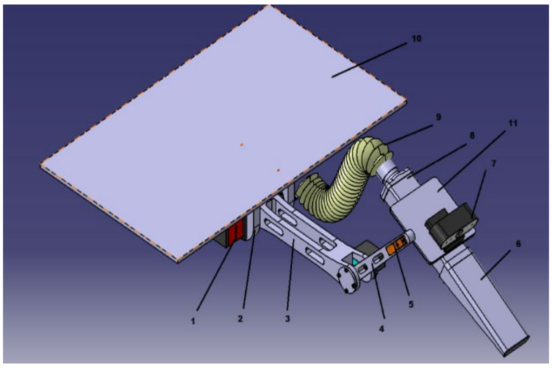

Fig. 1. Top view of the 3D model: 1, 5 – servo motors; 2 – base; 3- long shoulder; 4 – short shoulder; 6 – working tip; 7 – camera; 8 – rear tip; 9 – aluminum sleeve; 10 – plate; 11 – working plate.

The long arm 3 is attached to the servomotor by means of flanges and bearing support (in the other vertical aluminium detail). The flanges give torque to drive the arm. The bearing support is provided by the plate 1 (Fig. 2). It also serves to secure the aluminium sleeve 9. The long arm is made of PLA material by 3D printing [9,10].

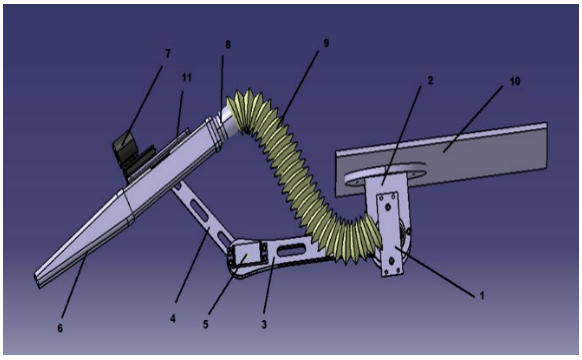

Fig. 2. Side view of the 3D model: 1 – plate; 2 –basis; 3- long shoulder; 4 – short shoulder; 6 – working tip; 7 – camera; 8 – rear tip; 9 – aluminium sleeve; 10 – plate; 11 – working plate.

It serves to position the system in a vertical position. At the other end there is a separate place for attaching servo motor 5 (Fig. 2) MG 996 R. The servo motor has the following parameters [11]:

Torque – 0,92 Nm; Operating voltage – 4,8 - 7,2 V;
Mass – 0,055 kg; Speed – 0,17 s/60 degree.

Through flanges and bearing support, it drives the short arm 4 (Fig.1 and 2) of the system. The short arm serves for additional tilt system and more accurate positioning. It is also made by 3D printing. In the opposite of the flanges end of the arm is a separate bed for another servo motor 5 (Fig. 1). The servomotor is MG 90 S and has the following parameters [12]:

Torque – 0,18 Nm; Operating voltage – 4,8 - 6 V;
Weight – 0.0134 kg; Speed – 0,1 s/60 degree.

The working plate 11 is attached to the servo motor (Fig. 1 and 2). It is aluminium [1] and the machine vision elements of the robot and the working bodies are fastened on it. The working plate measures 100 x 100 mm and has a thickness of 2 mm.

Machine vision is provided by camera 7 (Fig. 1 and 2). The camera is a product of HikVision DS-U02. It allows making frames with a resolution of 1920 × 1080 @ 30/25 fps. This resolution allows to create frames for recognition by machine vision. It has a mass of 0.089 kg and operates in a temperature range of -10 0 -450 C at a humidity of up to 90% [13, 14].

The working parts 6 and 8 are made of stainless steel. They are used for weed control and are not relevant to this article. Fastening is by means of screws, and a thermal insulation pad is placed between them and the working plate. The aluminium sleeve 9 is attached to them.

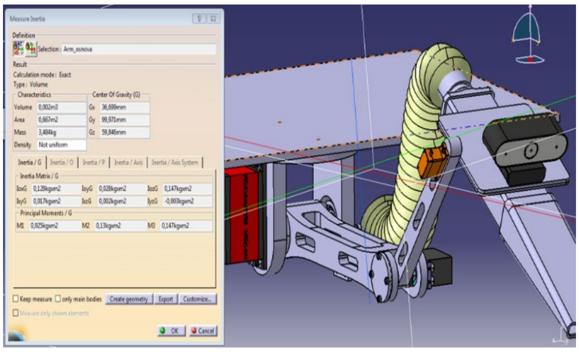

Fig. 3. Mass and moments of inertia of the 3D model.

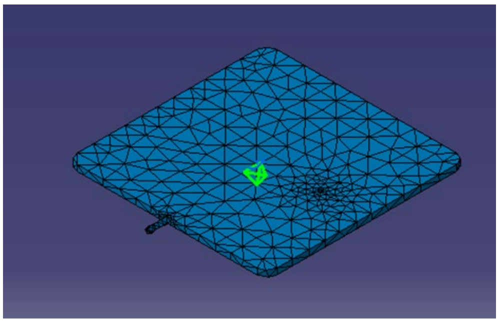

Fig. 4. Mesh for strength sizing of the working plate.

Fig. 3 shows the total mass of the system. It is 3.48 kg. The figure also shows the moments of inertia of the system along the three axes.

After 3D modelling of the system, strength sizing of the threatened parts is provided. These are the working plate, the long and short arm.

Initially, for convenience in the strength sizing of the parts, the work piece with the known parameters is based.

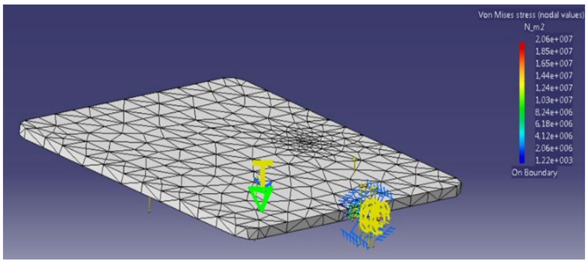

Fig. 5. Results of strength sizing of the working plate.

Fig. 4 shows the network for strength sizing of the working plate. The mesh is 8 mm in dimension, with absolute sagging set of 1,102 mm. As mentioned above, the plate is made of aluminium alloy 5052 [15].

Fig. 5 shows the results of the strength sizing of the working plate. In determining the load, the whole mass (of 0.91N) of all elements in contact with it was taken into account. The thermal load from the working members of 400 K was recorded. This temperature is without taking into account the thermal insulation coating between the plate and the working organ. The torque of 0.18 Nm generated by the servo motor was also recorded. As a result of the strength sizing, the threatened section is located in the axis for joining the servo motor and the maximum recorded load is 20.6 MPa, which is far from the limit values for aluminium alloy 5052 [15].

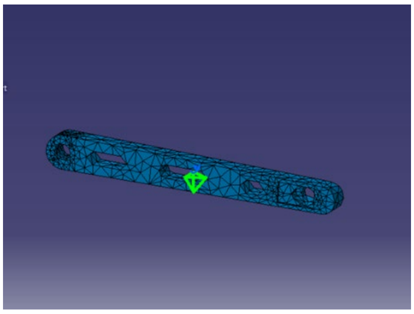

Fig. 6. Short arm strength sizing mesh.

The next detail that is subjected to strength sizing is the short arm. In Fig. 6 is given the general appearance and mesh of the work piece. The mesh used has a dimension of 12 mm, with absolute sagging set of 1,792 mm. To make the short arm was used PLA material printed at a nozzle temperature of 210^{0}C when filling 100 % [9].

In Fig. 7 the data for the stress state analysis of the tested work piece are shown.

Here again all loads from the working plate and servo motor MG 90 S are recorded. In addition, however, the torque from the MG 996 R servo motor also enters the strength sizing. The servo motor drives the arm and the additional equipment to it. The threatened sections are located in the connection ports of the drive flanges from the servo motor. The maximum voltage that is obtained at the load thus set is 2.87 MPa, far from the limit values for the PLA material. In the figure, the software also notes the possible deformations of the material. As expected for this kind of detail this deformation is expressed in the zones of load change.

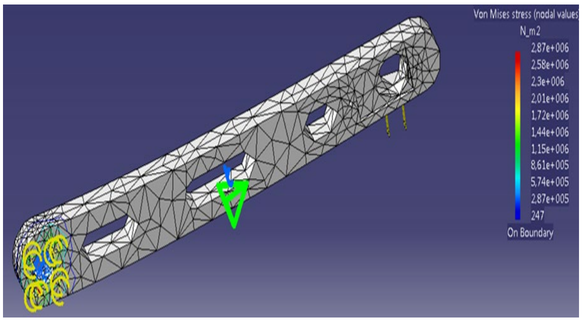

Fig. 7. Short arm strength sizing results.

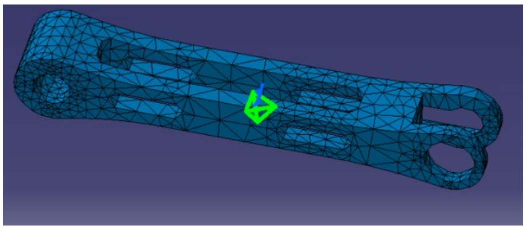

Fig. 8. Long arm strength sizing mesh.

Fig. 8 shows the mesh for the strength sizing of the long arm. The mesh used has a dimension of 16 mm, with absolute sagging set of 2,513 mm. PLA material printed at a nozzle temperature of 210 ^{0}C at 100 % filling is used to make the long arm again [9].

The analysis of the results of the strength analysis (Fig. 9) shows that the maximum load in the long arm is 0.57 MPa. This maximum stress is far from the limit for PLA materials [9]. It reappears in the zones of the connection flanges to the servo motor and support.

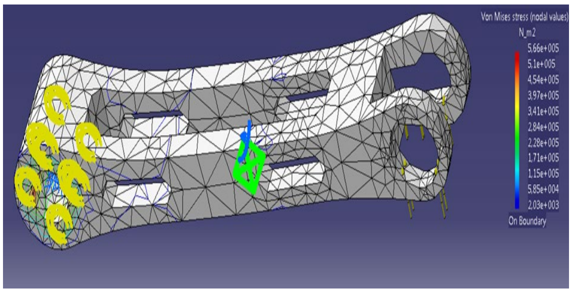

Fig. 9. Long arm strength sizing results.

IV. Conclusions

A 3 D model of the mechanical part of the weed recognition and control system was created. The limiting parameters in the development were an application in a self-propelled agricultural robot. The system has autonomy and can be integrated into other systems. The design of the system was carried out under CATIA V5. The mass of the designed system was reduced to 3.48 kg together with the work pieces.

To check the strength of the structure, three elements of the created 3D model of the mechanical part of the weed recognition and control system were dimensioned through the 3D Experience product.

Strength tests of the elements showed that the elements were properly sized and the structure was not loaded in strength. The maximum stresses generated in parts made of PLA materials are 2.87 MPa and 0.57 MPa, respectively, and in the aluminium work piece 20.6 MPa.

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