DESIGN OF MECHANICAL PRUNER SET USED FOR LOW TRELLIS

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Abstract. A mechanical pruner (similar to a special sprinkler for chemical hop pruning) serves for spring pruning of new hopvine shoots. Later yield depends on the quality of pruning and its right timing, which is why hop pruning is one of the most important agrotechnical operations. Special sprinklers for chemical pruning used abroad are not suitable regarding the effort to minimise the chemical environmental burden. This was the reason which led to a design of a mechanical pruner. The article discusses ways of placing the mechanical pruner on the tractor, and assesses the measured device carrier. It further presents a design of a mechanical pruner set with a gearbox. The conclusion mentions recommendations for a further research.

Keywords: hops, mechanical pruner, low trellis.

Introduction

For low trellis systems the most suitable proves to be the use of a single-disc hop cutter with a flat cutting disc of 600 mm in diameter [1]. The disc is made of abrasion-resistant steel with the cutting edge covered with wolfram-carbide coating 1 mm thick and 20 mm wide. As the disc is coated only on one side, a self-sharpening effect occurs when the disc in the soil is self-sharpened due to a different abrasion-resistancy of the upper and lower part [1]. The flat disc can be further sharpened during pruning by means of a grinder which is mechanically pushed to the cutting disc edge by a rectilinear hydraulic motor. The recommended disc rotation frequency is from 600 up to 750 min^{-1} [1].

Materials and methods

1. *Initial requirements for mechanical pruner*

One of the main requirements is trimming the hop shoots (so called new wood) down to a depth of 50 mm below the terrain level. Thus, the hopvines are cut off their underground root part (rootstock). The cutting mechanism operates in the space under the low trellis bottom anchoring rope which is stretched at the maximum height of 250 mm above the ground. Such distance, however, is not the same for all low trellises due to which this limiting value cannot be relied upon. Generally we may say that the lesser the construction height of the rear transmission with the cutting disc, the more universal the designed mechanical pruner will be. On the anchoring steel cable of 6 mm in diameter there is usually a drop irrigation system hung which must not be damaged by passing of the mechanical pruner. Some low trellises have the drop irrigation placed right on the ground in the axis under the plastic net. With this type of low trellis a mechanical pruner cannot be used. Here it is necessary to apply chemical pruning through a specially adapted sprinkler. Sharpening of the cutting disc when the machine is in operation improves the cutting and above all minimises the idle time caused by disassembling, sharpening, and reassembling of the cutting disc. Without quality sharpening the cut would fray and the rootstock would be more prone to mildew and pest. Automated motion of the mechanical pruner arm makes the operators' labour easier and above all minimises their mistake which might result in damage of the hop field equipment and used machinery. The energetic means must move in low trellis always in the same track rows, i.e., in the axis of hopvine interrows.

2. *Mechanical pruner carrier*

The mechanical pruner motion is one of the key parts of the mechanical pruner design. Hop rootstocks are planted in the hop row axis under the drop irrigation. In the particular axis there are also low trellis supporting poles. The mechanical pruner rotor motion (deflection of the cutting disc from the operating position and its return) is necessary so that the cutting disc edge would not meet the low trellis supporting pole, which would cause a mutual damage.

There are three possible ways of placing the cutting mechanism to be considered. They are:

- Front three-point linkage
- Interaxle tool carrier

- Rear three-point linkage.

The presented design uses a placement of the mechanical pruner on an interaxle tool carrier produced in series. This placement seems to be advantageous compared to the other ones in that the tractor operators can see the pruning device from the cab out of which they manipulate the carrier arm motion directly. An interaxle carrier is a universal device enabling hanging of various working tools. Owing to a close cooperation of the Department of Agricultural Machines, FE of CULS in Prague, with the Hop Research Institute Co., Ltd. in Žatec, an installation and following measurement of kinematic parameters for Wallner interaxle carrier (Fig. 1) was completed. The measurement was carried out on Zetor 5245 tractor.

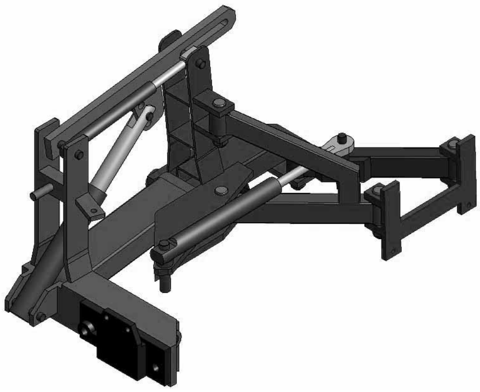

Fig. 1. **Wallner interaxle carrier**

The measurement revealed that while passing through the hop interrows the mechanical pruner rotor deflects sufficiently (coverage of the interaxle carrier is sufficient – Fig. 2), but the deviation of the cutting disc from the cut axis is insufficient (Fig. 3).

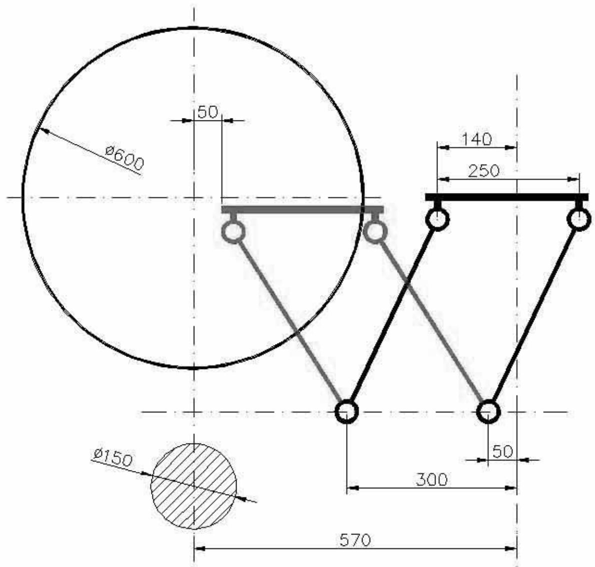

Fig. 2. **Kinematics of Wallner interaxle carrier – cutting disc operating position**

Figure 2 depicts the maximum deviation of the interaxle carrier arm the suspension foot edge of which is 50 mm far from the hop row axis. Due to that no catching of supporting plastic net on the interaxle carrier should occur. In case of deflection it was found out that even at the maximum deviation no safe deviation of the cutting disc occurs which leads to a contact with low trellis pole (see the arrow, Fig. 3). For this reason the Wallner interaxle carrier is unsuitable. The cross-hatched area (Fig. 2 and 3) depicts a low trellis pole. The considered minimum distance of the cutting disc from the supporting pole at a deviation from the pruning axis must not be smaller than 100 mm. Any smaller distance, at an inaccurate passage of energetic means through the hop interrows would result in a damage of the supporting poles.

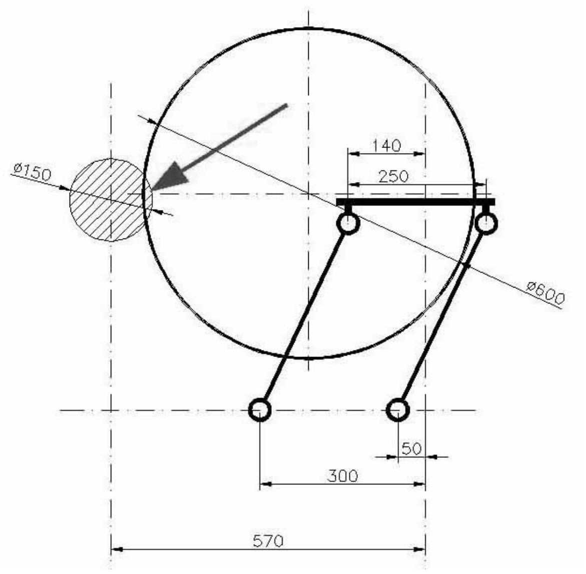

Fig. 3. **Kinematics of Wallner interaxle carrier – maximum deflection of cutting disc**

The measurement proves that the distance of the mechanical pruner rotor axis from the edge of the suspension foot of the interaxle carrier arm (in Fig. 2 this size is marked by 50 mm dimension) should be bigger than 150 mm. If such a safe distance is not kept, there is a danger of contact of the interaxle carrier arm with the low trellis plastic net which would then get caught and damaged. The measurement also showed that the interaxle carrier does not have the necessary kinematic scope for the cutting disc to deflect in a safe distance from the supporting poles of low trellis. For that reason we would have to approach a design of supplementary (secondary) linkage which would put the cutting disc in a safe distance. All the interaxle carrier motion is provided by 3 rectilinear hydraulic motors which already form its part. Due to the necessity of adding a secondary linkage the whole construction of the interaxle carrier becomes unnecessarily complicated.

A design of a whole new interaxle carrier on the basis of the above stated requirements for a mechanical pruner proves to be the most suitable variant.

Besides the type of the used interaxle carrier (another producer is, e.g., Reith Landtechnik), it is necessary to focus on the space under the tractor. When the cutting disc distances, the hydraulic motor block sets in motion (design considers a cutting disc driven by an axial hydraulic piston motor with a slanting block) with the clutch and end transmission in the direction towards the tractor axis. That is why it is necessary to secure enough space for this deflection [2]. The handling space, as we may call it, differs in size with each tractor, therefore, the design puts the emphasis on simplicity and mainly on little spatial demands of the whole mechanical pruner.

The device is designed for Zetor 5245 but due to the usage of the interaxle carrier this design is universal and may be used for other tractors as well. Assembling requires a little adjustment for a specific type of tractor, when the tractor steps (perhaps a metal toolbox too) are removed from the right side of the machine under the cab. This way the handling space for the motion of the hydromotor block during the cutting disc deflection enlarges.

3. *Hydromotor*

When the power parameters (pressure and flow) of the hop pruner hydraulic drive were being measured, the hydraulic oil temperature was kept at 40 ºC. The measuring device was provided by the Hydrotechnik Multi System 5060 company. Due to the absence of the pruner copying wheel, the recess was chosen in the tractor driver's estimation to be approximately 50 mm.

The measuring time was set for 30s with a measuring interval of 500 ms. The measured values were saved on the memory card of the measuring device. After the measurements were finished, the measured data were downloaded into the computer by means of HydroCom program and converted into a form which is possible to proceed in Microsoft Excel.

The measured values are shown in the following graph (Fig. 4).

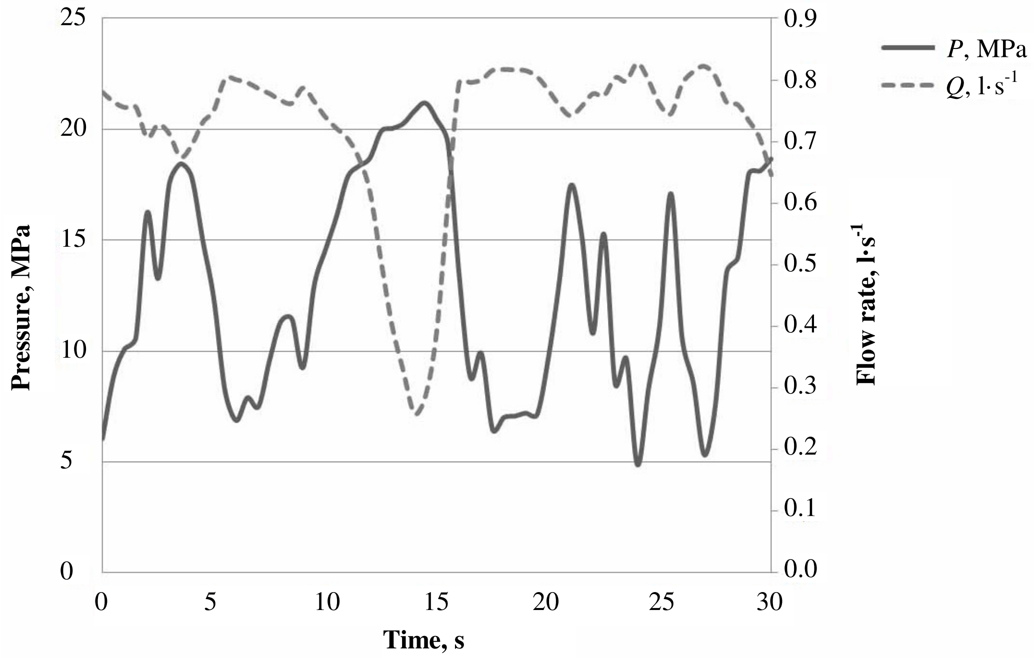

Fig. 4. **Graph of dependency of hydraulic oil pressure and flow on time**

Results and discussion

1. Assessment of hydromotor

The gear pump drive including its control was tested on the premises of the Hop Research Institute Co., Ltd. in Žatec. The measurements revealed values of pressure and flow of the oil in the hydraulic circuit of the pruner. These values show that the hydraulic aggregate has its safety pressure valve set up at a value of 20 MPa. That is why a deeper recess causes a rise in pressure and a decline in oil flowing into the hydromotor. At a partial recess of the disc a decline in the oil pressure occurs and the oil flow rises. The interruption and the decline of the oil flow are seen in the graph (Fig. 4). As a result, the most suitable drive seems to be the devised piston hydromotor with an inclined block which has a higher turning moment than at lower oil pressure.

2. Design of rear transmission with hydromotor

The whole device set is depicted in Fig. 5 where all of the parts of the designed mechanical pruner are connected in a way to keep their coaxiality.

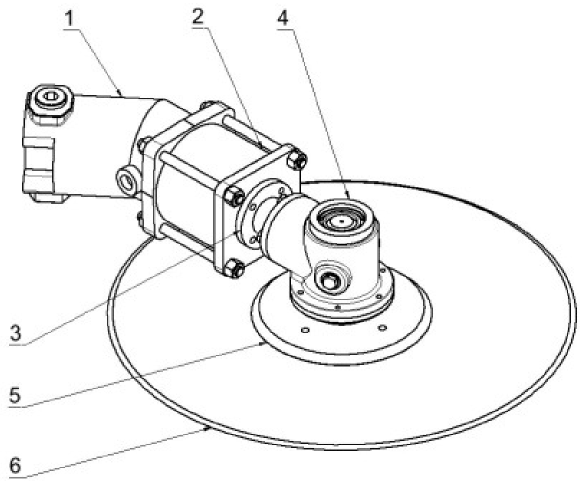

Fig. 5. **Rear transmission with hydromotor:** 1 – axial piston hydromotor; 2 – clutch; 3 – extension; 4 – angular gear; 5 – carrier; 6 – cutting disc

The piston axial hydromotor is connected by thread bars to the clamping plate. Between those there is a clutch with a connecting shaft inserted. The clamping plate is further connected by screws to the angular gear over the extension with collars. The conical wheel is then connected to the carrier with the cutting disc.

Conclusions

The paper presents only a part of the mechanical pruner design. The construction is still in the stage of development. As seen in Fig. 5, the hydromotor block is due to the lack of handling space for free motion under the tractor turned slightly by 90°, i.e., into a horizontal position.

As it emerges from the analysis of the kinematic parameters, the following step is a design and creation of a suitable interaxle carrier. Without a design of a new interaxle carrier it would be necessary to go over to the placing of the mechanical pruner on another tractor part, e.g., rear three-point linkage. However, there would have to be sold an additional display device placed inside the tractor cab, as the operator would otherwise not be able to check the mechanical pruner activity. A variant when machinery does not move in the same track rows is excluded.

Another step in the mechanical pruner design will be a design of the hydraulic circuit for the drive of an experimental model and its testing in field conditions.

After all the hidden problems have been solved, there will be automatic motion of the movable linkage added so that the operator could fully focus on the machine control in the hop interrows and on the visual control of the pruning device activity.

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