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Design a drive for interaxle mechanical cutter used in low trellises

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Abstract. A mechanical cutter (similar to a special sprinkler for chemical pruning) serves to prune new hopvine shoots in spring. Depending on the right timing and quality of pruning depends the later yield, which is why pruning is one of the most important agrotechnical operations. Double-disc mechanical cutter used with high trellises cannot be used with the technology of low trellises. Due to the effort to minimise the chemical environmental burden, special sprinklers for chemical pruning used abroad are considered inappropriate. This was the reason which led to a design for a mechanical cutter operating in low trellises. The article describes a hydraulic circuit design and laboratory measurements of an experimental model of mechanical cutter.

Key words: hops, mechanical cutter, low trellis systems.

INTRODUCTION

The system of hop growing in the low trellis system has brought new agro problems. Czech hop is currently offering three ways to perform this task. The first option is to inhibit sprouting shoots or removing through a chemical desiccant (chemical cut). The second way is to use hand hop cut – due to labour and financial costs is prohibitive. The third method is performed using mechanical cutters. A mechanical cutter is not currently mass produced (Křivánek, Ježek, 2010).

A mechanical pruner serves for spring pruning of new hop shoots. Depending on its proper timing and quality depends the later yield, which is why hop pruning is one of the most important agrotechnical operations (Kopecký, Ježek, 2008).

For low trellis systems the most effective proves to be the usage of a single-disc hop pruner with flat cutting disc of 600 mm in diameter (Štranc, 2007). The disc is made from abrasion-resistant steel with a cutting edge covered with a wolfram-carbide coating 1 mm thick and 20 mm wide. In case the disc is coated on one side only, 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 (Štranc, 2007). A flat disc may be further sharpened during the pruning by means of a grinder which is mechanically pushed to the cutting disc edge by a rectilinear hydraulic motor. The recommended disc rotational frequency is from 600 up to 750 min^{-1} (Štranc, 2007).

Equipment for hop cutting in a low trellis system must work in a relatively limited space (under the net, in the axis of hop plants and between the anchoring columns). For this reason, the design is a challenge.

METHOD AND MATERIALS

Basic requirements for mechanical pruner

The basic requirement is trimming the hopvine shoots (so called new wood) down to a depth of 50 mm below the terrain level. Thus the old hopvines are cut off from their root part (rootstock). The cutting mechanism operates in the space under the low trellis anchoring rope, which is stretched at the maximum height of 250 mm above the terrain. Such height, 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 cutting disc (Fig. 2) is, the more universal the mechanical pruner will be. On the anchoring rope of 6 mm in diameter there is usually hung a drop irrigation system which must not be damaged by the passing mechanical pruner. Some low trellises have the drop irrigation placed right on the ground in the axis under a plastic net. This type of low trellis excludes the usage of a mechanical pruner, where 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 rendering the rootstock more prone to mildew and pests. An automated motion of the mechanical pruner arm makes the operator's labour easier (tractor operator does not follow the trimming blade all the time) and above all minimises any mistake which might result in damage to the hop field equipment or the used machinery. The energetic means (tractor, sprayer, etc.) must move in the low trellis always in the same track rows, i.e. in the axis of hopvine inter-rows.

Mechanical pruner carrier

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 cutting disc from operating position and its return) is necessary so that the cutting disc edge would not meet the low trellis supporting pole, thus causing damage.

Owing to close cooperation with 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 a Wallner interaxle carrier (Fig. 1) was completed. The measurement of interaxle carrier was carried out on a Zetor 5245 tractor, from whose dimensions were based the design of the mechanical cutter.

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. Such a placement seems to be advantageous compared to the other ones in that the tractor operator can see the pruning device from the cab out of which they manipulate the carrier arm motion directly. Another advantage of using the interaxle carrier produced in series is the lower financial costs of acquiring a mechanical pruner. An interaxle carrier is a universal device enabling hanging of various working tools.

Figure 1. Wallner interaxle carrier.

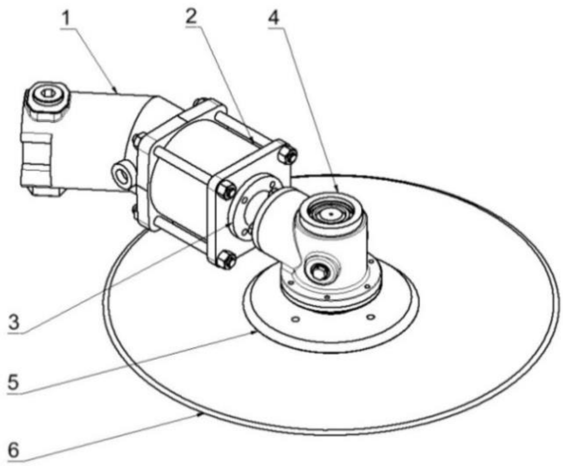

Figure 2. Rear transmission with hydromotor: 1 – axial piston hydromotor, 2 – coupler, 3 – extension, 4 – angular gear, 5 – carrier, 6 – cutting disc.

Model of mechanical cutter will be connected to the interaxle carrier with a clamping plate, which will be subsequently designed and manufactured.

RESULTS

Design for the rear transmission with hydromotor

The whole device set is depicted in Fig. 2. All the parts of the mechanical pruner design are connected in a way to keep their coaxiality. The piston axial hydromotor is connected through thread bars to the rear angular gear. Between those there is inserted a coupler with a connecting shaft. The conical wheel of the angular gear is further connected to the carrier with the cutting disc.

Design for the whole set

The rear transmission with the hydromotor is fixed by means of four eye screws with a loop onto a clamping plate (Fig. 3, position 4). By these screws we can set any cutting angle of the cutting disc we need. The clamping plate secures the connection between the rear transmission with the hydromotor and the interaxle carrier (Fig. 1). A little plough blade (Fig. 3, position 3) serves to wipe the soil carried by the cutting disc off the body of the axial hydromotor. This prevents stuffing the soil in the space between the cutting disc and the hydromotor block during hopvine cutting.

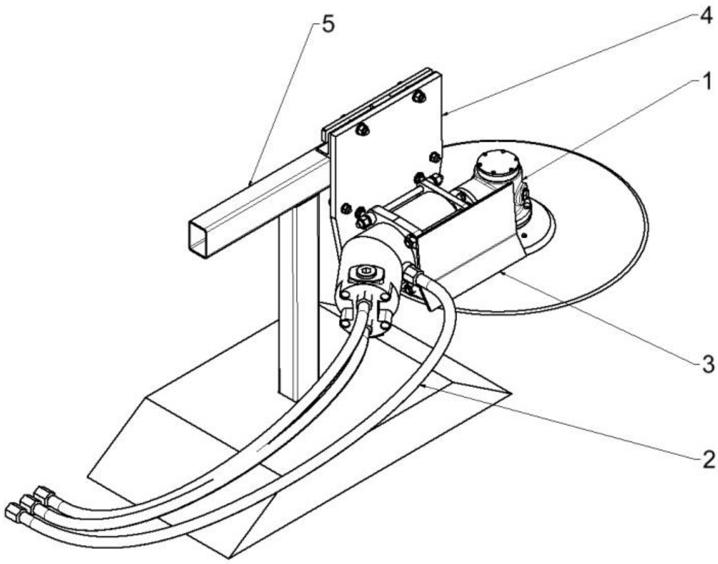

Figure 3. Laboratory set of mechanical pruner design: 1 – rear transmission with axial piston hydromotor, 2 – hydraulic lines, 3 – little plough blade, 4 – clamping plate, 5 – frame for laboratory measurement.

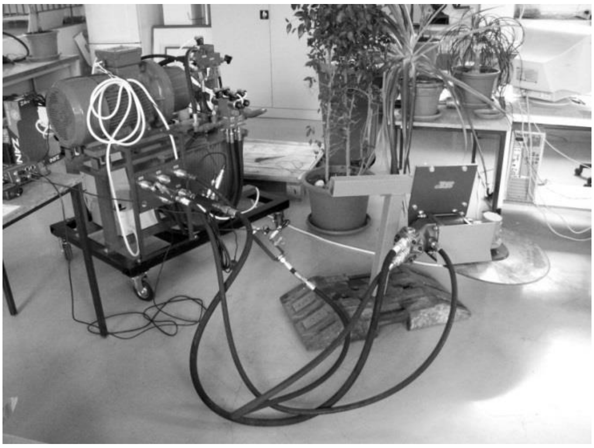

Figure 4. Laboratory set of mechanical pruner.

DISCUSSION

Laboratory measurement

The laboratory measurement set a goal to verify the right function of the designed set. For the purposes of the measurement the mechanical pruner was supplemented with a measuring frame (Fig. 3, position 5) which substitutes the interaxle carrier. The drive is provided by a mobile laboratory hydraulic aggregate by Bosch Rexroth company. Also a hydraulic circuit was assembled, which consists of three branches of hydraulic lines. A pressure branch, a waste branch and a branch for the outlet of leakage fluid.

The designed and installed hydraulic circuit did not enable a smooth stopping of the cutting disc. After the hydraulic drive had been turned off, influenced by the cutting disc kinetic energy, impacts against clamping plate (Fig. 3, position 4) occurred. For this reason the hydraulic circuit (Fig. 5) was supplemented with a one-way valve with a spring (Fig. 5, position 3). When the drive is stopped due to the negative pressure, a one-way valve switches the hydraulic oil flow from waste branch into pressure branch. Thus, when the drive is switched off, the cutting disc gradually stops.

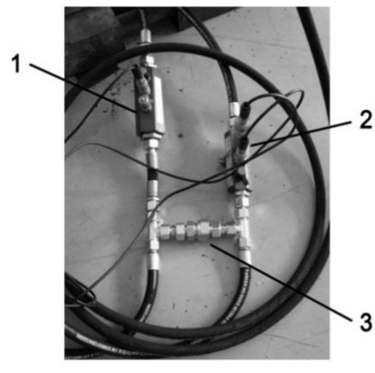

Figure 5. Hydraulic circuit supplemented by one-way valve: 1 – flowmeter on pressure branch (Q1), 2 – flowmeter on waste branch (Q2) with thermometer, 3 – one-way valve with spring.

The hydraulic circuit (Fig. 6) contains 2 flowmeters (positions 2 and 3), a thermometer (position 4), and a revolution counter (position 5). The flowmeters measure the flow of hydraulic oil. They are placed on the pressure and waste branches. To measure the rotational frequency we used a Photo/contact speedometer, model DT-2268, in the mode of non-contact measurement. A reflective mark was placed on the cutting disc. The measurement was carried out this way – the revolution counter laser beam is set on the spot where the reflective mark was moving. After stabilisation the actual value rpm (min^{-1}) could be read on the counter display.

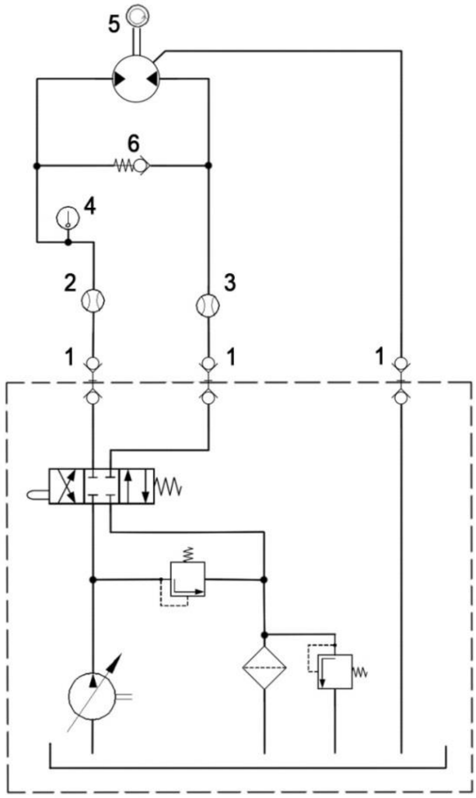

Figure 6. Designed hydraulic circuit: 1 – quick couplers, 2 – flowmeter on pressure branch, 3 – flowmeter on waste branch, 4 – thermometer, 5 – optical revolution counter of cutting disc, 6 – one-way valve with spring.

Axial piston hydromotor

The design uses the axial piston hydromotor with inclined block A2FM, size 62 by Bosch Rexroth. When measuring the flow depending on rotational frequency of the cutting disc of the mechanical hop pruner hydraulic circuit (HC), the hydraulic oil temperature was kept at 35 °C. The measurement was carried out by Multi System 5060 measuring equipment provided by Hydrotechnik company. The mechanical pruner was measured without load.

Rotational frequency changed every 10 min^{-1}, when after each change the actual values measured on the flowmeters were recorded. The difference between both flows can show the flow of leakage fluid.

The measured values are shown in the following graph (Fig. 7). The thermometer serves only to check the operating HC oil temperature.

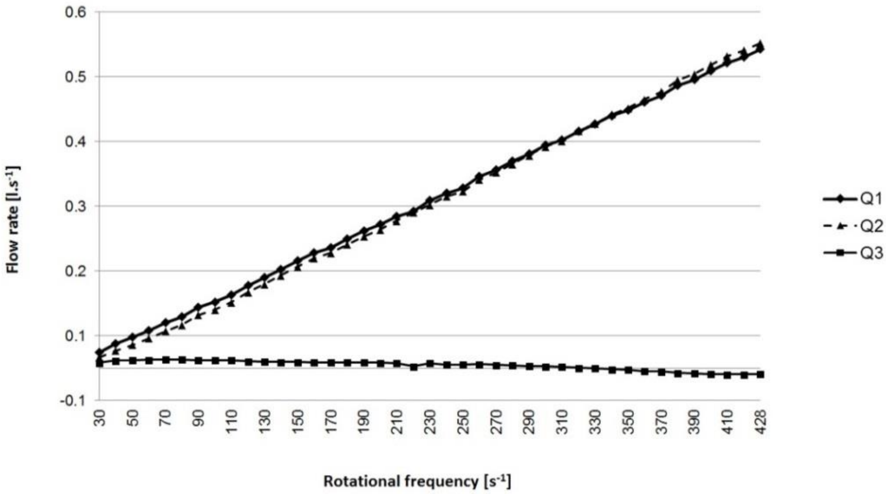

Figure 7. Graph of dependancy of hydraulic oil flow on cutting disc rotational frequency: Q1 – hydraulic oil flow in pressure branch, Q2 – hydraulic oil flow in waste branch, Q3 – calculated flow of leakage fluid.

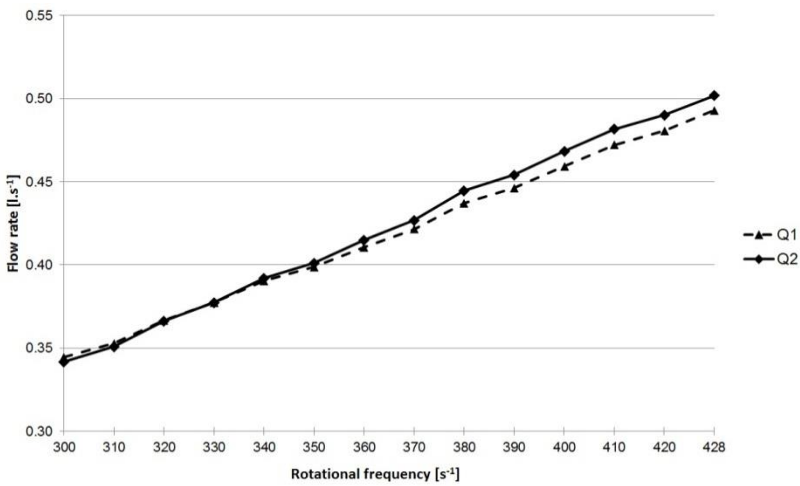

Figure 8. Detail of graph depicting dependency of hydraulic oil flow on cutting disc rotational frequency: Q1 – flow of hydraulic oil in pressure branch, Q2 – flow of hydraulic oil in waste branch.

By measuring the axial piston hydromotor we found out that with increasing rotational frequency the amount of leakage fluid decreases. This effect occurs up to 330 s^{-1}. Above this value the opposite effect starts occurring, when due to the influence of the risen negative pressure leakage fluid is sucked in. The graph (Fig. 8) depicts a detail of the flows dependency on rotational frequency at which the mentioned effect starts occurring. Laboratory measurements of the hydraulic motor (Fig. 8) shows, that at high speed the hydraulic motor also increases the flow efficiency.

CONCLUSIONS

The article presents a design for a mechanical pruner and its experimental verification in laboratory conditions. It is still necessary to deal with a range of issues and problems. As seen in Fig. 3 and 4, the block of the hydromotor is, owing to lack of handling space under the tractor to move, turned by 90°, i.e. into a horizontal position. Axial piston hydromotor of mechanical cutter is through the clamping plate connected to interaxle carrier.

Regarding the relatively high weight of the mechanical pruner (app. 90 kg), it will be necessary to supplement the design with a copying wheel, which would keep an even sinking of the cutting disc.

Another step we shall take will be a test of the mechanical pruner in field conditions. After all the hidden troubles have been settled, automated motion of the movable hanging will be added, so that the operator might focus fully only on the machine driving in the hopfield inter-rows and on the optical control of the pruning mechanism operation.

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