DESIGN FOR A DRIVE OF THE INTERAXLE MECHANICAL PRUNER USED IN LOW TRELLISES*

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

hops; mechanical cutter; low trellis

INTRODUCTION

A mechanical pruner serves for spring pruning of new hop shoots. Because on its proper timing and quality depends later yield, hop pruning is one of the most important agrotechnical operations (Tomlan, 1992; Kopecký, Ježek, 2008; Křivánek et al., 2008; Krofta, Ježek, 2010).

For low trellis systems the most effective proves to be the usage of single-disc hop pruner with flat cutting disc of 600 mm in diameter (Štranc et al., 2007; Hoffmann, Rybka, 2010). The disc is made of abrasion-resistant steel with cutting edge covered with wolfram-carbide coating 1 mm thick and 20 mm wide. In the 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 et al., 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 rectilinear hydraulic motor. The recommended disc rotational frequency is 600–750 rpm (Štranc et al., 2007).

A mechanical pruner for low trellis system is not currently mass-produced (Křivánek, Ježek, 2010).

The first option is to inhibit sprouting of new shoots or to remove them through a chemical desiccant (chemical cut) (Ebersold, 2004; Srečes et al., 2013).

MATERIAL AND METHODS

Basic requirements for a 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 their root part (rootstock) (Hoerner, Rabak, 1940; Royston et al., 1958). 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 is, the more universal the mechanical pruner will be. On the anchoring rope of 6 mm in diameter a drop irrigation system is usually hung 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, and in such cases 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 minimizes the idle time caused

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by disassembling, sharpening, and reassembling of the cutting disc. Without quality sharpening the cut would fray rendering the rootstock more prone to mildew and pest. An automated motion of the mechanical pruner arm makes the operators' labour easier and above all minimizes their mistake which might result in the damage of the hop field equipment or the used machinery. The energetic means in low trellis must move always in the same track rows, i.e. in the axis of hopvine interrows.

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 its damage.

Owing to a close cooperation of the Department of Agricultural Machines, Faculty of Engineering of the Czech University of Life Sciences 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 using a tractor Zetor 5245 (ZETOR TRACTORS a.s., Brno-Líšeň, Czech Republic).

There are three possible ways of placing the cutting mechanism to be considered: front three-point linkage, interaxle tool carrier, or rear three-point linkage. The presented design uses a placement of the mechanical pruner on the interaxle tool carrier produced in series. Compared to the other placements, this one seems to be advantageous in that the tractor operator can see the pruning device from the cab from where he directly manipulates the carrier arm motion. Another advantage of using the interaxle carrier that is produced in series is the lower financial costs at acquiring a mechanical pruner. The interaxle carrier is a universal device enabling hanging of various working tools.

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 them a coupler with a connecting shaft is inserted. 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 axial hydromotor. This prevents stuffing the soil in the space between the cutting disc and the hydromotor bloke during hopvine cutting.

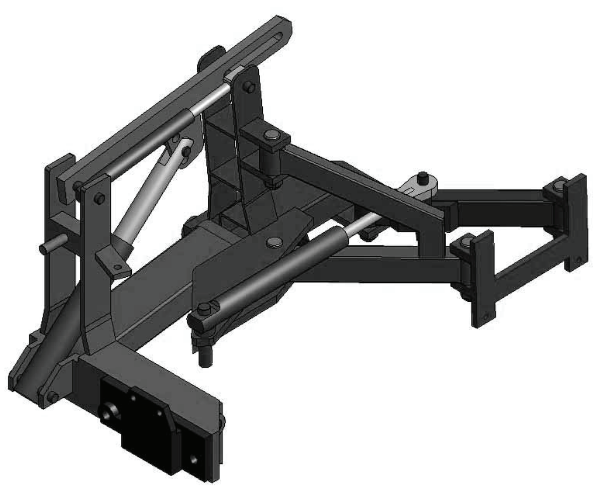

Fig. 1. Wallner interaxle carrier

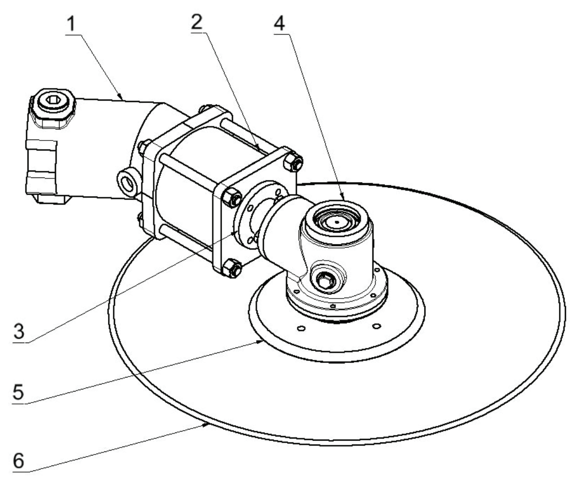

Fig. 2. Rear transmission with hydromotor

1 = axial piston hydromotor, 2 = coupler, 3 = extension, 4 = angular gear, 5 = carrier, 6 = cutting disc

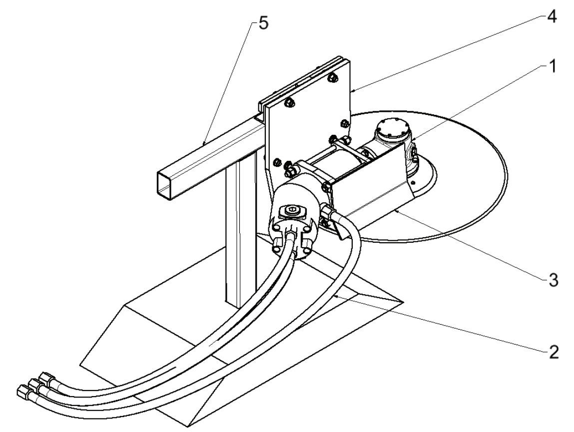

Fig. 3. Laboratory set of mechanical pruner design

1 = rear transmission with axial piston hydromotor, 2 = hydraulic lines, 3 = little plough blade, 4 = clamping plate, 5 = frame for laboratory measurement

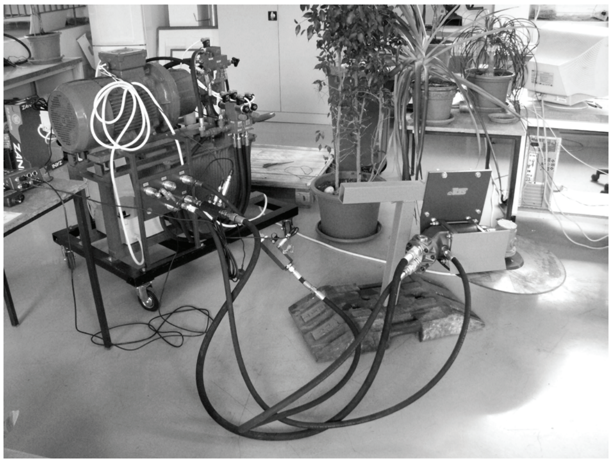

Fig. 4. Laboratory set of mechanical pruner

DISCUSSION

Laboratory measurement

The right function of the designed set was verified by the laboratory measurement. 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 (Bosch Rexroth, Lohr am Main, Germany). 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 the leakage fluid (Fig.4).

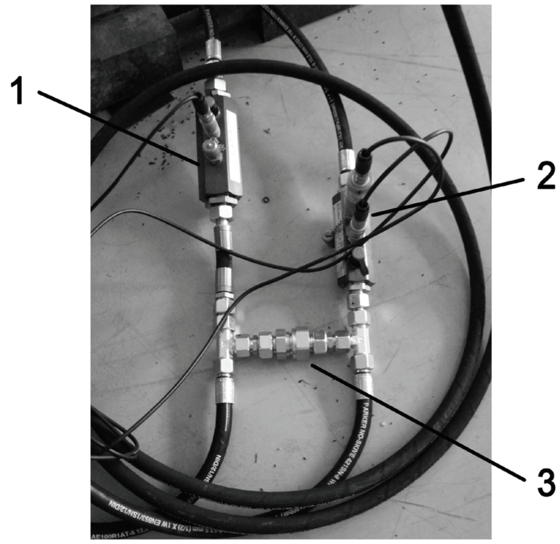

Fig. 5. Hydraulic circuit supplemented by one-way valve

1 = flow meter on pressure branch (Q1), 2 = flow meter on waste branch (Q2) with thermometer, 3 = one-way valve with spring

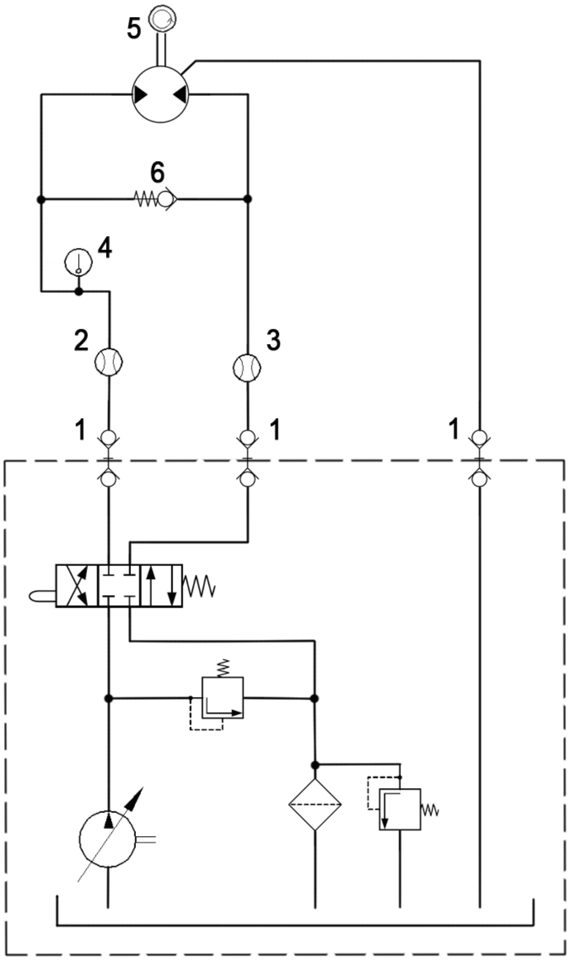

Fig. 6. Designed hydraulic circuit

1 = quick couplers, 2 = flow meter on pressure branch, 3 = flow meter on waste branch, 4 = thermometer, 5 = optical revolution counter of cutting disc, 6 = one-way valve with spring

The designed and installed hydraulic circuit did not enable a fluent stopping of the cutting disc. After the hydraulic drive had been turned off, influenced by the cutting disc kinetic energy, impacts against hanger 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.

The hydraulic circuit (Fig. 6) contains 2 flow meters (positions 2 and 3), a thermometer (position 4), and a revolution counter (position 5). The flow meters measure the flow of hydraulic oil. They are placed on the pressure and waste branches. To measure the rotational frequency, a Photo/Contact Tachometer (model DT-2268) in the mode of non-contact measurement was used. A reflective mark was placed on the cutting disc. The measurement was carried out as follows: the revolution counter laser beam is set on the spot where the reflective mark was moving. After stabilization, the actual value of rev per min (rpm) could be read on the counter display.

Axial piston hydromotor

The design uses the axial piston hydromotor with inclined block A2FM, size 62 (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 same temperature of hydraulic oil kept Kučera, Rousek (2005), Hujo et al. (2013), and Máchal et al. (2013). The measurement was carried out using a MultiSystem 5060 (Hydrotechnik GmbH, Limburg, Germany) measuring equipment. The mechanical pruner was measured without load.

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

The measured values are shown in Fig. 7.

The thermometer serves only to check the operating HC oil temperature.

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 to occur, when due to the influence of the risen negative pressure the leakage fluid is sucked in. Fig. 8 depicts a detail of the flows dependency on rotational frequency at which the mentioned effect starts occurring.

CONCLUSION

As seen in Figs. 3 and 4, the block of the hydromotor is, owing to the lack of handling space under the tractor to move, turned by 90°, i.e. into a horizontal position. Regarding the relatively high weight of the mechanical pruner (approximately 90 kg), it will be necessary to supplement the design with a coppying wheel, which would keep an even sinking of the cutting disc.

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. Another step we 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 interrows and on the optical control of the pruning mechanism operation.

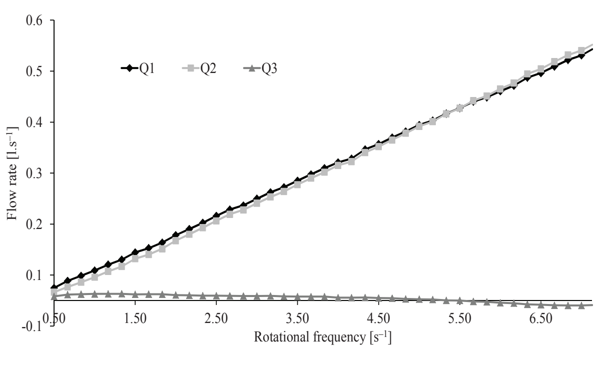

Fig. 7. Graph of dependancy of hydraulic oil flow on cutting disc rotational frequency

Q1 = hydraulic oil flow in pressure branch, Q2 = hydraulic oil flow in waste branch, Q3 = calculated flow of leakage fluid

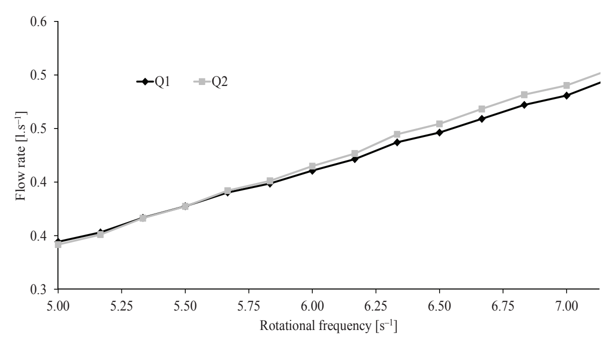

Fig. 8. Detail of graph depicting dependency of hydraulic oil flow on cutting disc rotational frequency

Q1 = flow of hydraulic oil in pressure branch, Q2 = flow of hydraulic oil in waste branch

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