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Herb Stem Cutter - Design and Research

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Abstract

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The article presents the results of investigations on a herb stem cutting machine. Investigations were performed as a series of controlled single-factor experiments. The basic target functions of the study were as follows: drive's absorbed power of the machine (kW); specific energy consumption (kWh/t) and average cutting length (mm). The levels of controlled trial factors were as follows: machine load capacity with herb stem mass: $Q = 0.5; 1$ and 1.5 kg/s and feeding velocity of stem mass to the cutting drum: $V = 2.0; 2.4$ and 2.8 m/s. Here are the factors, maintained at stable levels: cutting drum peripheral velocity - 25 m/s at rotation frequency of 1176 min^{-1} ; cutting drum working width - $B=0.558$ m; cutting drum diameter $D=0.406$ m; number of blades $z=6$; blade thickness $b=10$ mm; blade sharpening angle $\beta=34^\circ$; inclination of blades' edges to the counteredge $\alpha=15^\circ$; front cutting angle $\varphi=50^\circ$; gap between blade and counterblade edges $\Delta=0.5$ mm; sharpening angle of the counterblade $\beta_1=90^\circ$ and sharpness of counterblade cutting edge $\delta=0.2$ mm. The correlation between the variation of drive's absorbed power for start-up of the cutting drum, specific energy consumption and average cutting length, on the one hand, and the variation of controlled factors, on the other, was established. The respective adequate regression equations were simulated, describing the herb stem cutting processes with specific accuracy.

Key words: herbs, stems, cutting, energy, cutting machine

Introduction

Industrial herb production is an important segment of Bulgarian agriculture. The issue of mechanization of stem cutting of wild and cultivated herbs to a size, suitable for their consequent processing, remains unsolved. Literature provides data

on studies of the effect of physical and mechanical properties of some farm crops stems on the cutting process (Ivanov, 1984). There are statistic evaluations of the parameters of corn and other plants, directly related to the evaluation of energy consumption in stem cutting (Ivanov, 1983). A suitable methodics was devel-

oped as well as sieve classifier for estimation of stem cutting length of farm crops (Ivanov, 1984). We have the results of the research on a drum stem cutter (Ivanov and Lukov, 1984), which, as can be seen from the results in the publication (Lukov and Ivanov, 1983) on harvesting of corn stalks, has shown a potential for herb stem cutting as well. The investigations, described in the publication (Tsonev et al., 1985), show that the drum cutting unit can be incorporated into a machine for chopping (cutting) farm crop stems.

The need for a machine for herb stem cutting, reducing the dispergation rate as well as the results, quoted in literature, shaped the target to develop and investigate the basic parameters of an adequate cutting unit and its incorporation into a herb stem cutting machine.

Materials and Methods

The subject of the present study was a herb stem cutting machine, developed by the IMM, Sofia and operated at the premises of Trakia Export Ltd, Plovdiv (Figure 1). The machine consisted of a frame (1), on which the cutting unit with a blade drum was mounted (4), counterblade (5), upper feeding rollers(6) and lower feeding rollers(7). The feeding mechanism of the herb cutting machine was a chain conveyor (9) and feeding velocity was controlled by a vertical reducer (7). The cutting drum was driven by electric motor (3) and the vertical reducer - by electric motor (2).

In laboratory conditions, a mass of intact herb stems of 0.5 - 1.5 kg/s was evenly fed, securing a load of 1.8 - 5.4 t/h. The vertical reducer and change gears ensured three levels of feeding velocity for intact

herb stems to the cutting drum - 2, 2.4 and 2.8 m/s. The cutting machine was connected to an electronic device for measuring power consumption from 0 to 30 kW and the actual load (t/h) was used for the analytical estimation of specific energy consumption (kWh/t). The average cutting length was measured in laboratory conditions in five dimension classes and was identified by means of familiar statistical formulas.

The investigations were carried out as a series of controlled single-factor experiments. The major target functions of the investigation were as follows:

- drive's absorbed power for the start-up of the cutting drum, kW;
- specific energy consumption, kWh/t;
- average cutting length, mm.

The controlled factors of the experiment were as follows:

- Machine load with herb mass. Three load levels were studied:

Q=0.5 kg/s; Q=1 kg/s and Q=1.5 kg/s.

- Forward velocity of feeding the herb plants. Three levels of feeding velocity were investigated:

V=2 m/s; V=2.4 m/s and V=2.8 m/s.

Factors maintained at permanent levels were as follows: peripheral velocity of the cutting drum - 25 m/s at rotation frequency of 1176 min⁻¹; working width of the cutting drum - B=0.558 m; cutting drum diameter D=0.406 m; number of blades z=6; blade thickness b=10mm; blade sharpening angle $\beta=34^\circ$; inclination of blades' edges to the counteredge $\alpha=15^\circ$; front cutting angle $\varphi=50^\circ$; gap between blade and counterblade edges $\Delta=0.5$ mm; sharpening angle of the counterblade $\beta_1=90^\circ$ and sharpness of counterblade cutting edge $\delta=0.2$ mm.

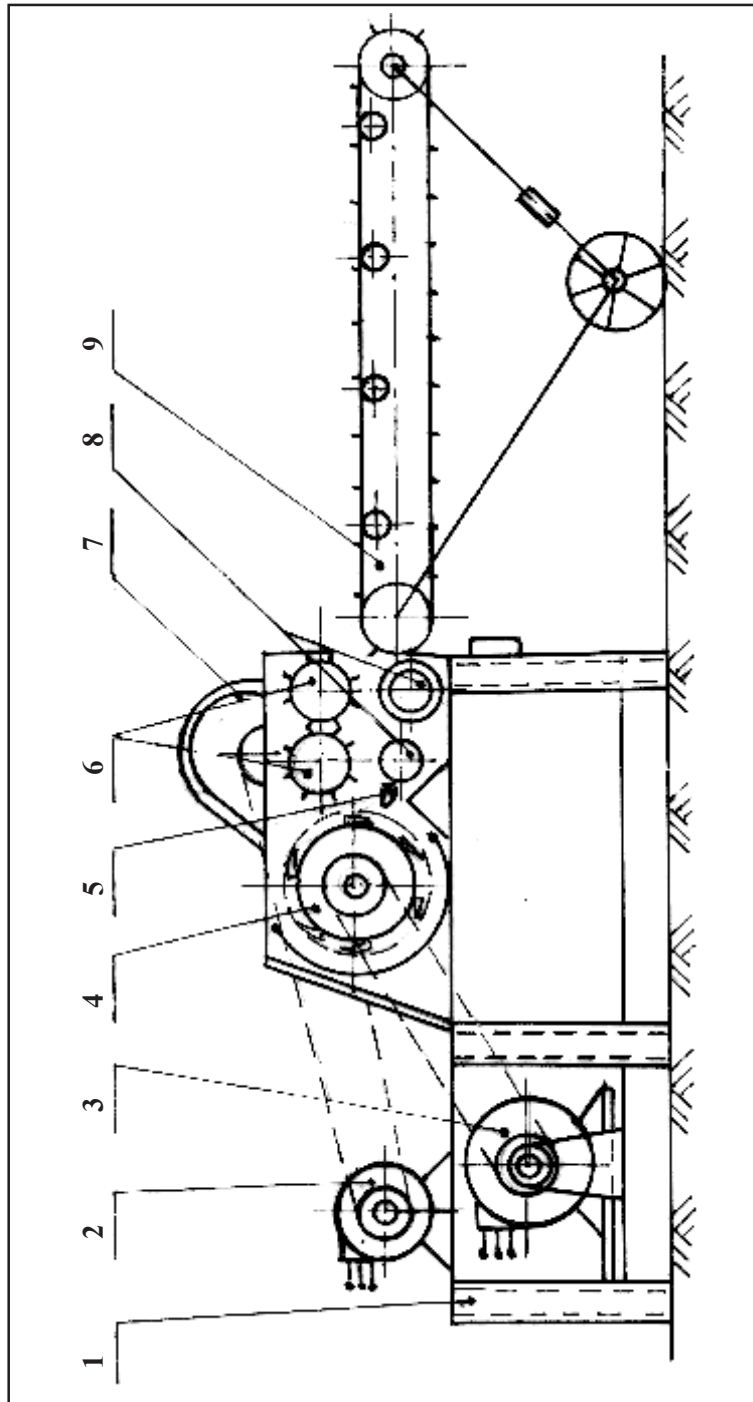


Fig. 1. Technical drawing of the stem cutting machine

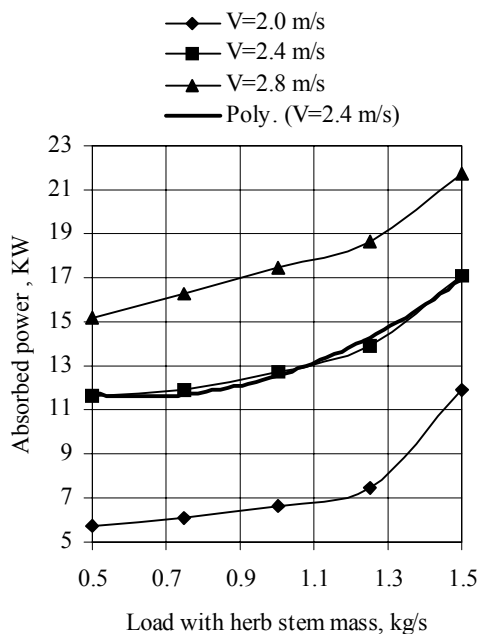


Fig. 2. Variation of absorbed power depending on load with herb stem mass

Results and Discussion

The analysis of graphically expressed correlations on Figure 2 showed that drive has absorbed power for the cutting drum start-up (P) at load varying (Q) from 0.5 to 1.5 kg/s increased from 5.5 to 21.5 kW. The increase was from 5.5 to approximately 12 kW at the lowest feeding velocity (V) of 2 m/s and from 15 to about 21.5 kW at the highest feeding velocity of 2.8 m/s. The variation of drive's absorbed power depending on load at an average mass feeding rate of 2.4 m/s with correlation coefficient 0.9866 can be expressed with the following regression equation:

$$P = 7.086Q^2 - 8.971Q + 14.441, \text{ kW} \quad (1)$$

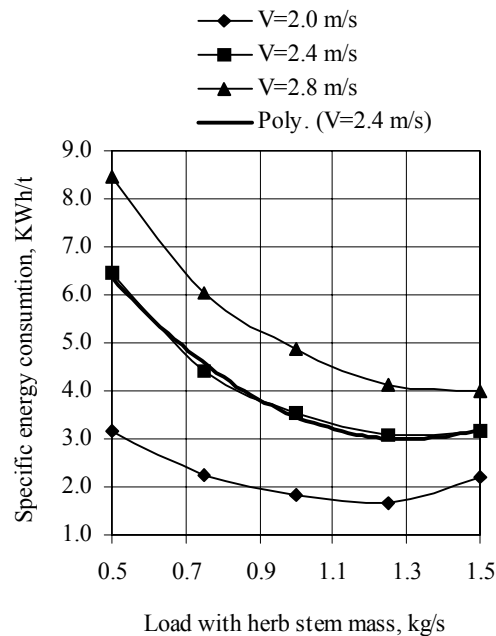


Fig. 3. Variation of specific energy consumption depending on load with herb stem mass

Specific energy consumption (E) on Figure 3 varied from 1.6 to 8.5 kWh/t with the change of load from 0.5 to 15 kg/s. The variation was within 1.6 and about 3.2 kWh/t at the lowest feeding velocity of 2 m/s and within 4 and about 8.5 kWh/t at the highest - 2.8 m/s. The minimum specific energy consumption at all levels of feeding velocity of herb stem mass was recorded at a load of about 1.2 - 1.3 kg/s. The variation of specific energy consumption depending on the load at an average feeding velocity of herb mass of 2.4 m/s with correlation coefficient of 0.9936 can be expressed with the following regression equation:

$$E = 5.338Q^2 - 13.825Q + 11.947, \text{ kWh/t} \quad (2)$$

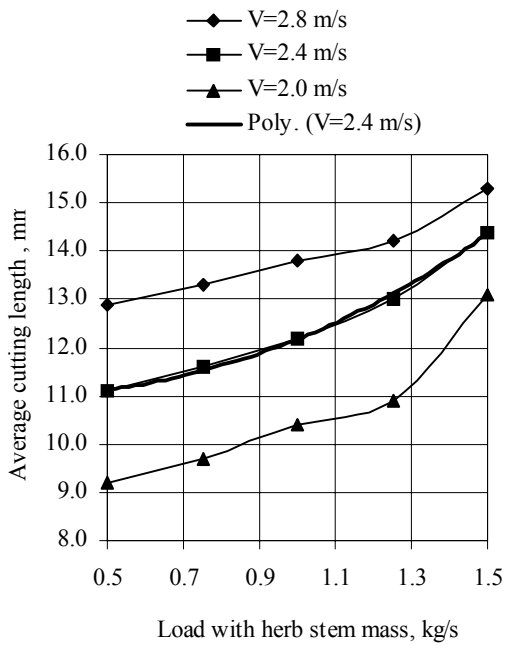


Fig. 4. Variation of average cutting length depending on load with herb stem mass

The average cutting length (L), given on Figure 4, increased from 9.1 to 15.4 mm with the load varying within 0.5 and 1.5 kg/s. The increase was from 9.1 to about 13 mm at the lowest feeding rate of 2 m/s and 13 to about 15.4 mm at the highest - 2.8 m/s. The variation of average cutting length of herb stems depending on the load at an average herb mass feeding velocity of 2.4 m/s with correlation coefficient of 0.9961 can be expressed with the following regression equation:

$$L = 2.286Q^2 - 1.371Q + 11.261, \text{ mm} \tag{3}$$

As shown on Figure 5, the drive's absorbed power for start-up of the cutting drum increased from 5.9 to 21.7 kW with the increase of feeding velocity of herb

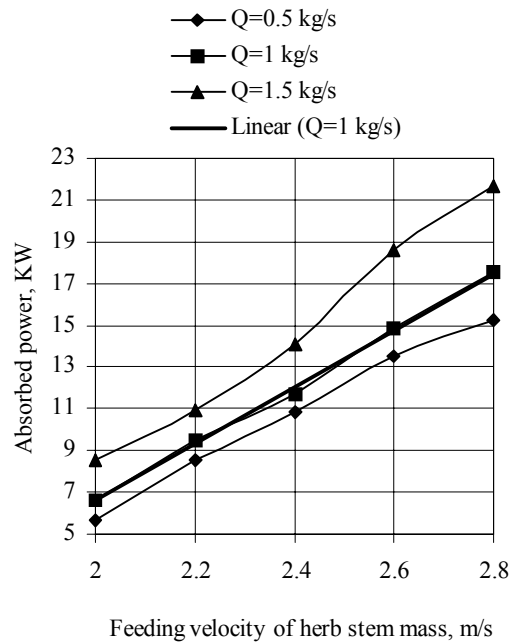


Fig. 5. Variation of absorbed power depending on feeding velocity of herb stem mass

stem mass from 2.0 to 2.8 m/s. The increase was within 5.9 to about 15 kW At the lowest load of 0.5 kg/s and 8.5 to about 21.7 kW at the highest - 1.5kg/s. The variation of drive's absorbed power for starting up the cutting drum related to the variation of feeding velocity of herb stem mass at an average load of 1 kg/s with correlation coefficient of 0.9977 can be expressed with the following linear equation:

$$P = 13.6V - 20.6, \text{ kW} \tag{4}$$

The specific energy consumption for the start-up of the cutting drum (Figure 6) with the feeding rate of herb stem mass increasing from 2.0 to 2.8 m/s increased from 1.6 to 8.5 kWh/t. The increase was

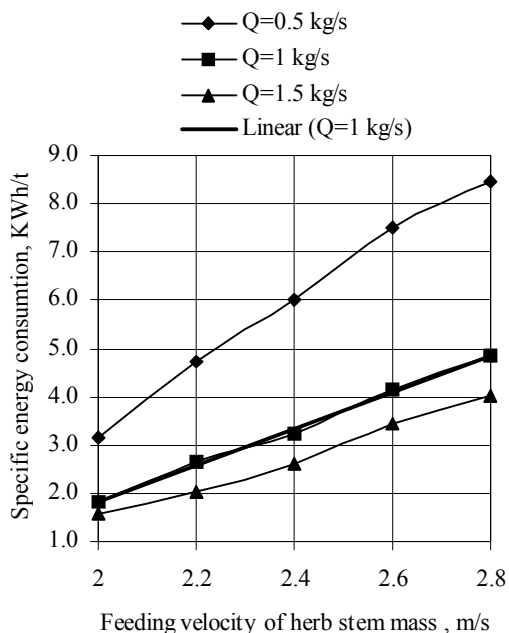


Fig. 6. Variation of specific energy consumption depending on feeding velocity of herb stem mass

from 1.6 to about 4 kWh/t at the lowest load rate of 0.5 kg/s and from 3.2 to about 8.5 kWh/t at the highest - 1.5 kg/s. The variation of specific energy consumption for starting the cutting drum depending on the variation of feeding velocity of herb stem mass at an average load of 1 kg/s with correlation coefficient of 0.9977 can be expressed with the following linear equation:

$$E = 3.778V - 5.722, \text{ kWh/t} \quad (5)$$

The average cutting length of herb stems (Figure 7) increased from 9.2 to about 15.4 mm with the increase of mass feeding rate from 2.0 to 2.8 m/s. The increase was within 9.2 to about 12.9 mm at the lowest load of 0.5 kg/s and from

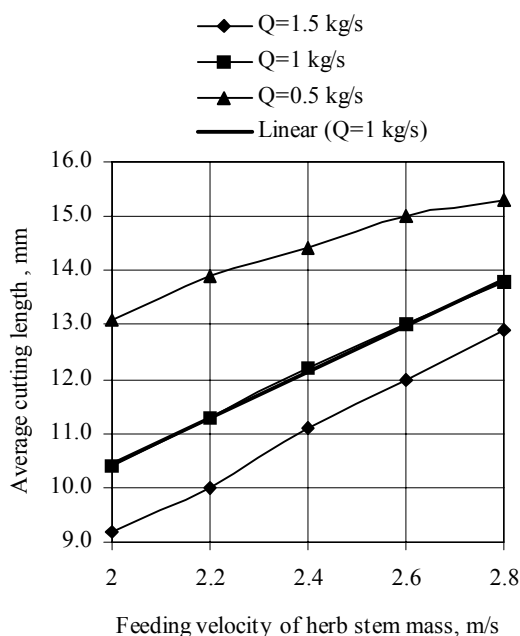


Fig. 7. Variation of average cutting length depending on feeding velocity of herb stem mass

13.1 to about 15.4 mm at the highest load of 1.5 kg/s. The variation of the average cutting length of herb stems depending on the variation of mass feeding velocity at an average load of 1 kg/s with correlation coefficient of 0.999 can be expressed with the following linear equation:

$$L = 4.25V + 1.94, \text{ mm} \quad (6)$$

Conclusions

- Drive's absorbed power for start-up of the cutting drum at load variation of 0.5 to 1.5 kg/s increased from 5.5 to 21.5 kW for the separate values of feeding velocity of herb stem mass.
- Specific energy consumption at load

variation from 0.5 to 1.5 kg/s for the separate values of feeding velocity of herb stem mass varied from 1.6 to 8.5 kWh/t.

- The minimum specific energy consumption at all velocity rates of herb stem feeding was recorded for a load of about 1.2 - 1.3 kg/s.

- The average cutting length increased from 9.1 to 15.4 mm with load variation from 0.5 to 1.5 kg/s for the separate feeding velocity rates of herb stems.

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