DEPENDENCE OF CONDITIONER POWER INPUT ON MOWING MACHINE MATERIAL FEED RATE.

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ABSTRACT

The objective of this research was to evaluate the possibility of material feed rate measurement of modern mowing machines equipped with conditioners. The machines are commonly used for harvest of grass, clover, alfalfa, and other forage plants. The method of material feed rate measurement was based on the conditioner power input measurement.

A mowing machine with finger conditioner was equipped with an electronic measuring unit for the purpose of our measurements. The mowing machine's conditioner shaft was supplied with strain gauges sensor torque-meter and with RPM optical sensor counter. Together with torque-meter the mowing machine was equipped with a DGPS receiver for last part of our measurement.

In the beginning it was decided to arrange a laboratory measurement to obtain information about the dependence of conditioner power input on material feed rate. A mixture of grass and alfalfa was used for our measurement. Infield measurement was arranged on the base of stationary measurement results as well.

Both types of measurement (laboratory and infield) carried out proved that a linear relationship existed between the power input of conditioner and mowing machine material feed rate. Further research relating to mowing machine feed rate sensors is planned in order that more accurate data may be obtained.

Key words

Precision farming, mowing machines, feed rate, conditioner, power input

INTRODUCTION

A forage crop feed rate sensor can be useful in several applications of precision farming. Information about the variable feed rate of forage can be used for calculating site-specific forage crop yield for a yield map.

Flow rate measurement techniques for forage harvesters have been published previously. Vansinchen and De Baerdemaeker (1993) calculated a yield from the torque on the harvester's blower. Another possibility is to measure the distance between feeder rolls of the harvester (Ehlert and Schmidt, 1995). Recently (1996) Auernhammer and Demmel measured yield by using a nuclear gauge sensor placed in the spout of a forage harvester. A mass flow sensor for pull type (trailed) forage harvester based on a reaction plate in the spout was constructed and tested by Missotten et al. (1997). This sensor was designed to be used for various crop properties and crop type. Schmittmann et al. (2001) tested three possibilities of material feed rate measurement on self-propelled forage harvester.

Site-specific measurement of biomass in growing crops has been proposed. A pivoted cylindrical body is moved horizontally through a plant population (moving pendulum), the angle of deviation of this pendulum varies with the plant properties. These measurements were performed on cereals (Ehlert and Schmidt, 1996).

The objective of this research was to develop of yield mapping capabilities for modern mowing machines equipped with conditioners that are commonly used for the harvest of grass, clover, alfalfa, etc. The measurement principle of the material feed rate evaluation is based on the conditioner power input measured by a torque-meter.

MATERIALS AND METHODS

A mowing ŽTR 216 H machine (Agrostroj Pelhřimov Company, Czech Republic) was used for our measurements. This machine consists of two working drums and a finger conditioner. Working width of the machine is 2,15 m. The mowing machine was equipped with electronic apparatus for measurement. The mowing machine's conditioner shaft was supplied with torque-meter based on resistant strain gauges and with a RPM optical sensor measuring number of conditioner shaft revolution.

Voltage signals obtained by the strain gauges placed on the torque-meter were amplified and converted into frequency by electronic measuring apparatus developed in our laboratory. The output frequency was proportional to the measured tension. All signals (together with RPM) were processed with a one-chip microcomputer and data obtained was transferred into a notebook for storage. The block diagram of electronic apparatus arrangement is shown in Fig. 1.

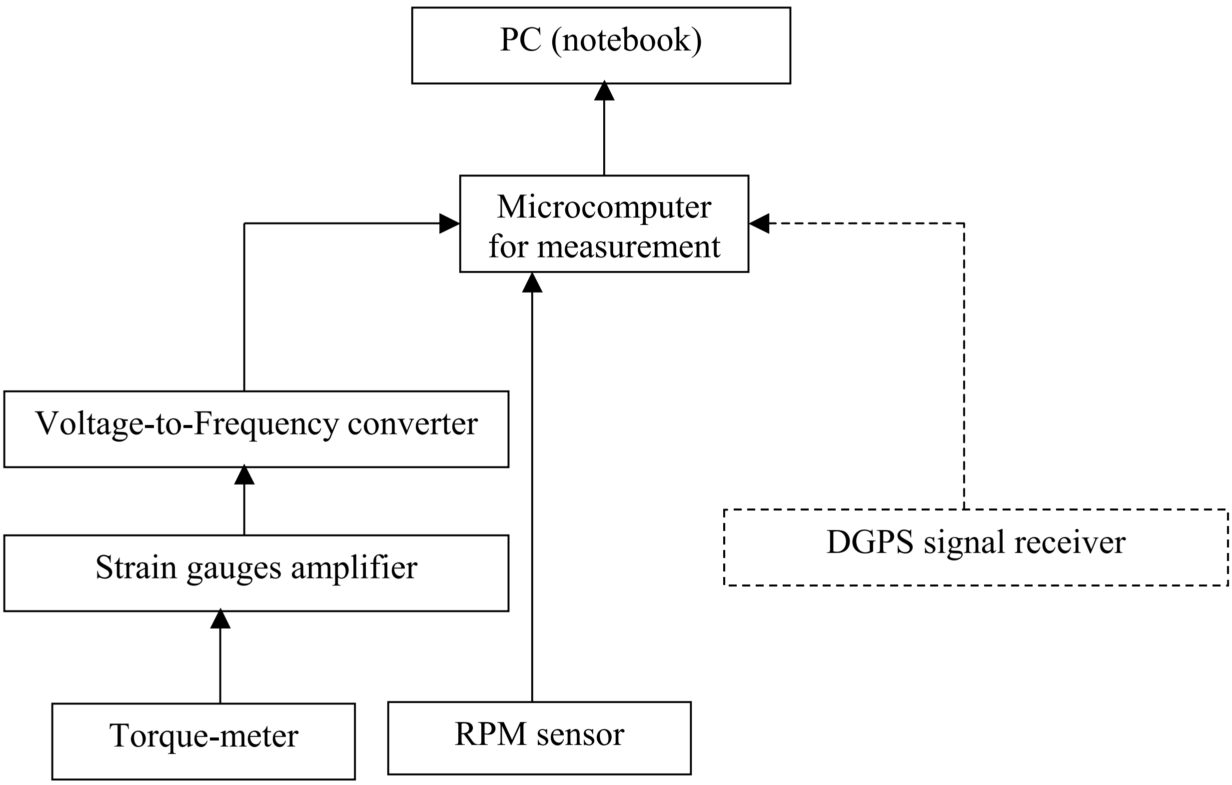

Figure 1. Block diagram of electronic apparatus arrangement for material feed rate measurement.

It was decided to arrange laboratory measurement in start to obtain information about the relationship of conditioner power input to material feed rate. It was necessary to find out the amount of conditioner's material feed rate. The laboratory set-up was composed of a conveyer belt carrying a measured quantity of material, a tractor and a rotary drum-mowing machine equipped with the electronic measurement apparatus.

First of all, torque-meter calibration were carried out to obtain measured values as exactly as possible. For the measurement of torque the torque-meter produced by Czech company VÚZT Prague was used. This torque-meter is based on resistance strain gauges. The output voltage from the bridge is amplified and converted to frequency in voltage-to-frequency converter. The counter included in one-chip microcomputer evaluates this frequency. The data from microcomputer were transferred to PC via serial link RS 232 and stored.

The torque-meter was calibrated by means of laboratory calibrating stand in the range from 0 to 600 Nm. The dependence of output frequency on the measured torque is on Fig. 2. Transfer characteristic obtained by calibration was then used for calculation of torque from known output frequency.

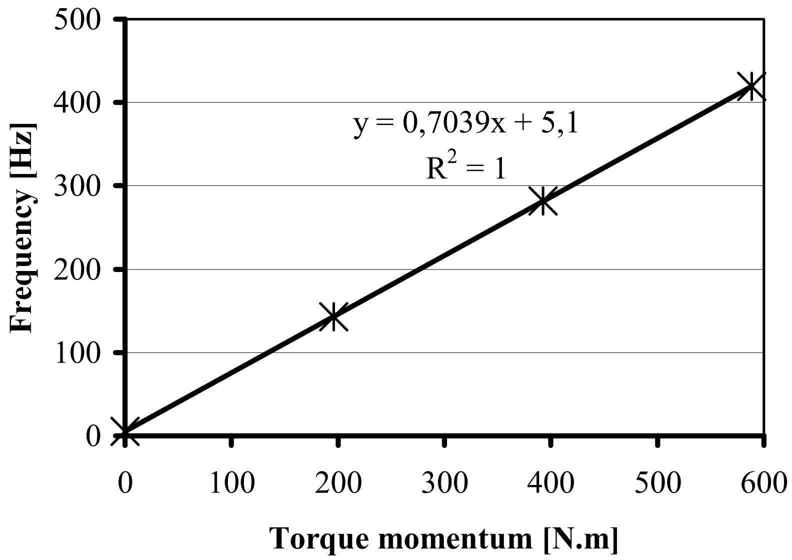

Figure 2. Torque-meter calibration. Dependence of torque-meter measurement apparatus output frequency on torque momentum.

The signal from optical sensor used for measurement of conditioner's number of revolution was processed by microcomputer as well.

Second part of the measurement was arranged as infield measurement. Mowing-conditioning machine was equipped with the torque-meter, RPM sensors and with DGPS signals receiver. Every five seconds the positioning signals of mowing machine from DGPS receiver and signals from torque and optical PTO sensors were recorded. All signals were processed in one chip microcomputer and obtained data were transferred into a notebook.

Electronic equipment used for infield measurements (described above) enabled to calculate machine location and corresponding energy consumption of the conditioner from obtained values later. Harvested field was divided into seven parts for infield measurement. Each part was presented by one harvested row of the crop. The length of harvested row was approximately 200 meters. The moment of DGPS signal interception (every five seconds) was marked on harvested row by card. Every section of harvested row between these cards was manually weighted after each overpass of the machine. It was assured that the data obtained from electronic measurement corresponds to the data obtained by weighting by this procedure. It was achieved seven files of electronic measurement and seven corresponding files of hand measurement. The feed rate of material was possible to calculate from hand measurement. It was possible to compare the values of conditioner power input with the values of material feed rate later (figure 5).

RESULTS AND DISCUSSION

A mixture of grass and alfalfa or pure alfalfa was used for laboratory measurement. Material was transported into the mowing machine for approximately five seconds for each measurement using a conveyer belt. The signals from the torque-meter and RPM sensor were measured every half second. Ten values of torque-meter measuring apparatus output frequency and RPM were obtained from one single measurement in this way. The measurement was repeated minimum three times for each determined amount of material. The values obtained from these measurements were used in calculation and charting.

Linear and exponential dependence was tested for all measurements carried out into stationary part of our measurement. Calculated coefficients of correlation were still better for linear trend. The linear trend of correlation only is charted in Fig. 3 and Fig. 4 from that reason.

Ten values were averaged to obtain a single measurement. The values obtained from this procedure were used for charting. Fig. 3 shows the first chart obtained from the laboratory measurements.

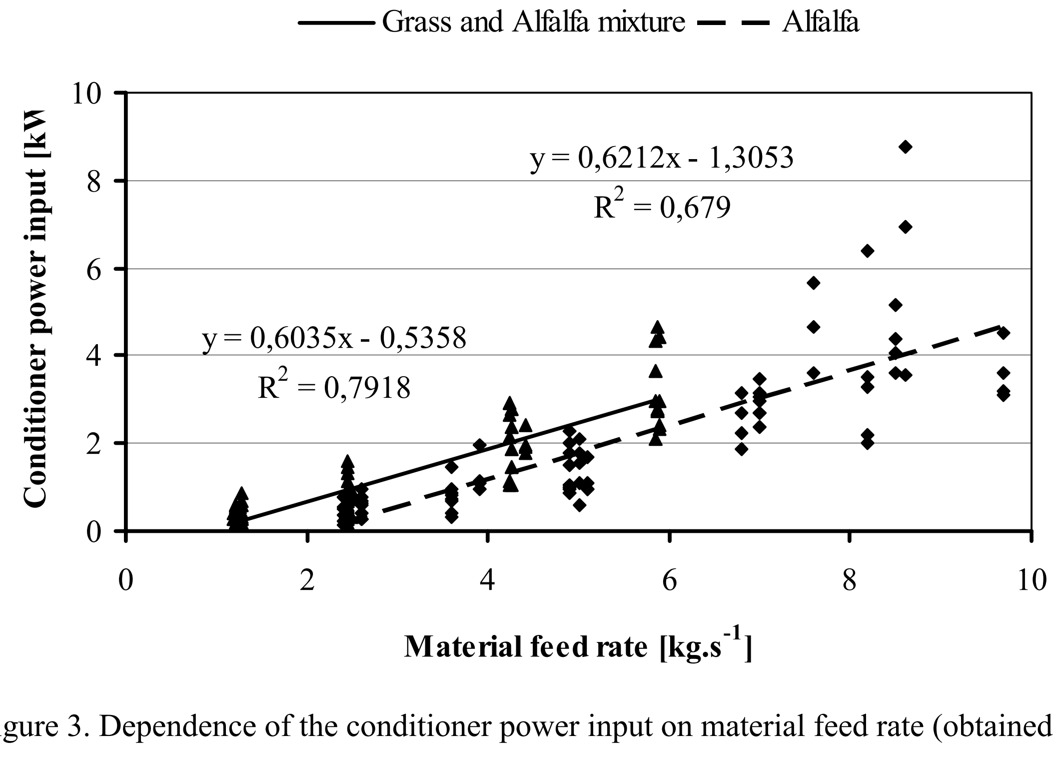

Figure 3. Dependence of the conditioner power input on material feed rate (obtained values).

According to the chart (Fig. 3), it is possible to see that power input of the conditioner depends on material feed rate linearly. It is evident that type of material has influence the conditioner power input. The coefficients of correlation were calculated for this chart as well. Their values were 0,79 for the measurements with grass and alfalfa mixture and 0,69 for the measurement with pure alfalfa. Unfortunately the dispersion of measured values was relatively high.

It was decided to calculate the average value of conditioner power input for each measurement from three obtained values. The curves derived from calculated values are shown on (see Fig. 4). The non-uniformity of measured values is becoming smaller in that case.

Coefficients of correlation calculated for exponential curves are 0,80 for mixture of grass and alfalfa and 0,76 for alfalfa (instead of 0,94 and 0,81 for linear trend). It is possible to say that linear correlation between material feed rate and conditioner power input is better to use. Fig. 4 is chart with correlation coefficients for linear trend only from that reason. Linear correlation is corresponding with other comparable measurements made by different authors (Schmittmann et al., 2001, Vansichen, De Baerdemaeker, 1993).

The main disadvantage of stationary measurements was non-uniformity of material throughput and non-possibility to measure higher throughputs of the material. It is possible to see in Fig. 3 and Fig. 4, that uniformity of measurement is relatively good up to 7 $kg.s^{-1}$ of material throughput. If higher value of material throughput is used, the uniformity of measured values becomes to be smaller. This was caused by measurement arrangement. The capacity of belt conveyer was not sufficient for higher material feed rate inserting. Therefore infield measurements were organised.

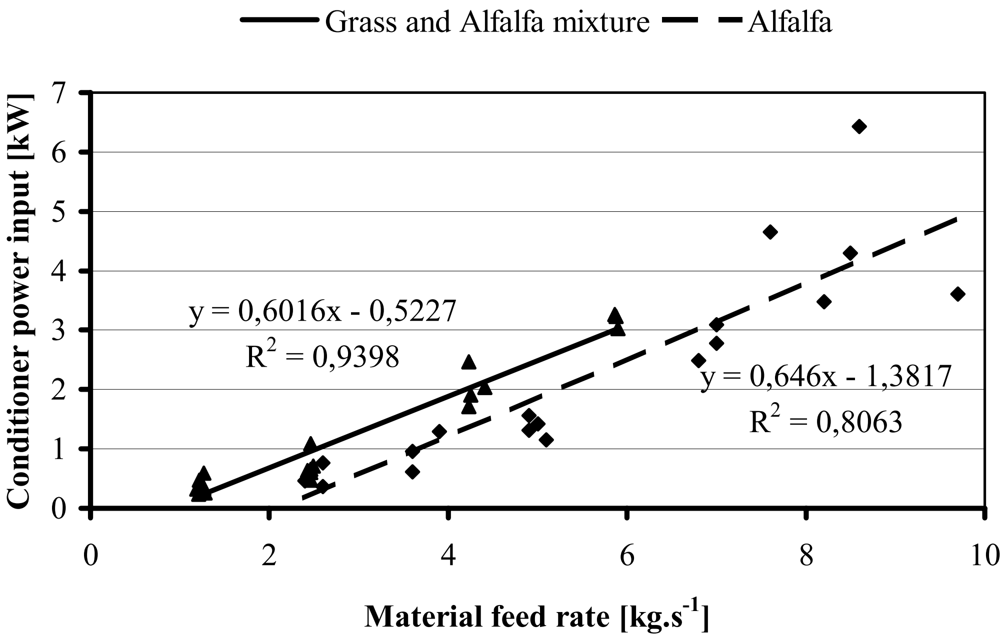

Figure 4. Dependence of the conditioner power input on material feed rate (averages).

Electronic equipment used for infield measurements (described above) enabled to calculate machine location and corresponding energy consumption of the conditioner from obtained values later. DGPS signal receiver was added. The moment of DGPS signal interception (every five seconds) was marked on harvested row by card.

As it was discussed above the data obtained from electronic measurement are corresponding with the data obtained by weighting. These data are comparable in that case. It is possible to observe the dependence of conditioner power input on conditioner material feed rate as well. It was possible to create a chart as example of both measured data curvature from every carried out measurement. Total number of measurements was 7. Pearson's coefficients of correlation were calculated for every carried out measurement as well.

It can be derived from these charts and coefficients that the linear dependence of conditioner power input on material feed rate very probably exists. Square Pearson's coefficient varied from app. 0,7 (four times) to 0,5 (two times). The smallest value (0,37) was calculated for last measurement. It can be explained by smaller number of obtained values for this measurement in comparison with others measurements.

Chart in Fig. 5 is example of data curvature comparison for measurement No. 1 with calculated Pearson's coefficient value 0,76. It can be seen on this chart that conditioner power input data almost copy the data of material feed rate measured by weighing.

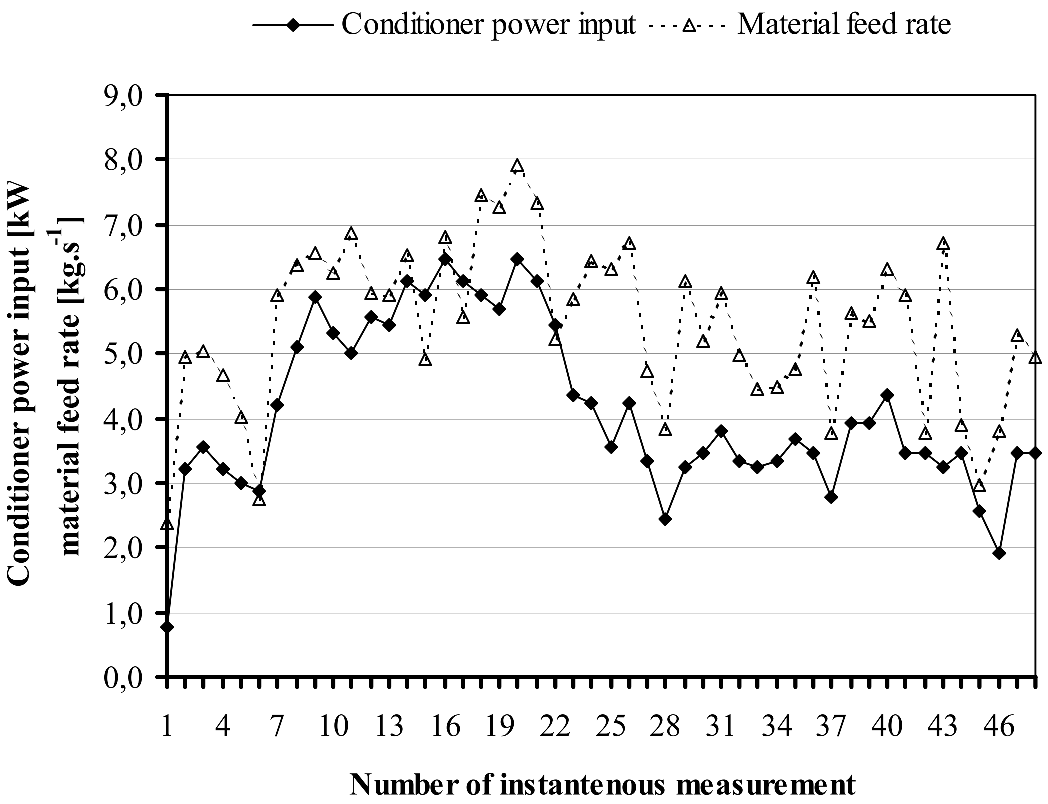

Figure 5. Data curvature of conditioner power input and material feed rate obtained during infield measurement. The calculated value of Pearson's coefficient is 0,76.

CONCLUSIONS

The objective of the research carried was to evaluate the possibility of material feed rate measurement on modern mowing machines equipped with conditioners. The machines are commonly used to harvest of grass, clover, alfalfa, etc. These measurements showed linear relationship of the conditioner's power input on material feed rate. The calculated correlation coefficients varied from value of 0,7 to 0,9. The correlation coefficients with smaller values were obtained sometimes and it was probably caused by stationary measurement arrangement used conveyer belt not sufficient for high material feed rate inserting. It was observed that type of material has influence the conditioner power input.

It would be useful to carry out other measurements in the near future with the aim of more precisely specifying the relationship. Not only type of harvested material, but also intensity of conditioning can influence conditioner power input. It probably will be necessary to carry out these measurements for different forage crops. Cultivars of forage crops as well as moisture of harvested material can influence these measurements as well. Maybe it can be useful to test another possibility of material feed rate measurement in future. Torque-meter is not ideal apparatus from the practical point of view. Maybe curved impact plate mounted at the exit of the machine can be used for the purpose of material feed rate measurement.

ACKNOWLEDGMENTS

The paper was supported by Research Intention of Czech University of Agriculture in Prague No. MSM 413100014

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