EXPERIMENTAL RESEARCH ON THE INFLUENCES OF RUNNING VELOCITY ON THE POWER CONSUMPTION OF TRACTOR - PULLED POTATO HARVESTING COMBINES

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Abstract: *The paper presents the method employed for the experimental determination of the following parameters of the tractor-pulled potato harvesting combine: traction force and running velocity of the tractor and the toque and speed of the tractor power take-off shaft during working.*
The processing the experimental data obtained in the testing of two types of potato harvesting aggregates (U-650 M tractor + SL 750 Grimme - combine, and Renault 145 tractor + Reekie-150 combine, respectively) allowed the plotting of the graphs showing the influence of the running (working) velocity of the machines on traction force and power of the tractor, as well as on the torque and power transmitted to the combine by the tractor power take-off. Further the distribution of the tractor engine power on the two consumption fluxes of the machine is analyzed: traction and cardan shaft drive (actuated by the power take-off shaft).
Key words: *potato harvester, power consumption; influence of the working velocity.*

INTRODUCTION

Potato harvesting combines used at the moment are generally half-carried (via a rigid traction hitch of the tractor). As a result, the traction force and part of the load acting upon the machine (machine weight and the components normal on the soil surface of the interaction forces between the dislocation parts and the soil) transfer by means of the coupling device (hitch) on the tractor body.

When moving in aggregate with potato harvesters, the tractor develops a traction force at the hitch, necessary to overcome the resistance to traction of the dislocation organs and the resistance to rolling on the soil of the supporting wheels of the machine. Simultaneously with pulling the machine, the tractor activates by means of the power take-off the working organs of the combine (alimentation transporters, separation device of the soil and stalks from the potato mass, unloading equipment, etc.). The values of the traction forces and of the torques transmitted through the power take-off shaft depend on the moving (working) velocity of the machine, as the flow of dislocated material introduced into the combine (for processing) depends directly on the moving velocity. As a result the powers consumed for pulling and driving the machine by the power take-off depend also on the moving velocity of the machine (the power take-off speed varies within tight limits around the standard values of 540 and 1000 rot/min, respectively).

Starting from these considerations, the paper presents the experimental results obtained in the research of the influence of moving velocities (falling within the interval of technological velocities) on the values of the powers consumed for pulling and driving combines by means of the tractor power take-off. The research was carried out on the one-row potato harvester combine of *Grimme SL* 750 type, aggregated with wheel tractor *U-650 M* (47.8 kW engine power) and on the two-row harvester combine of *Reekie-1500 M* type, aggregated with wheel tractor *Renault 145.14* (99 kW engine power).

EXPERIMENTAL RESEARCH

In order to achieve the set objectives, the following parameters have been simultaneously measured, recorded and acquisitioned: traction force F_t and the vertical pressure force R_z at the traction bar of the tractor; the torque M_p transmitted by the power take-off shaft of the tractor; the moving velocity of the machine v; the speed of the power take-off shaft of the tractor, n_p. Transducers and sensors appropriate for the electrical measurement of the mentioned parameters were placed on the machine and tractor, while the data recording and acquisition equipment was placed in the tractor cabin. (fig. 1)

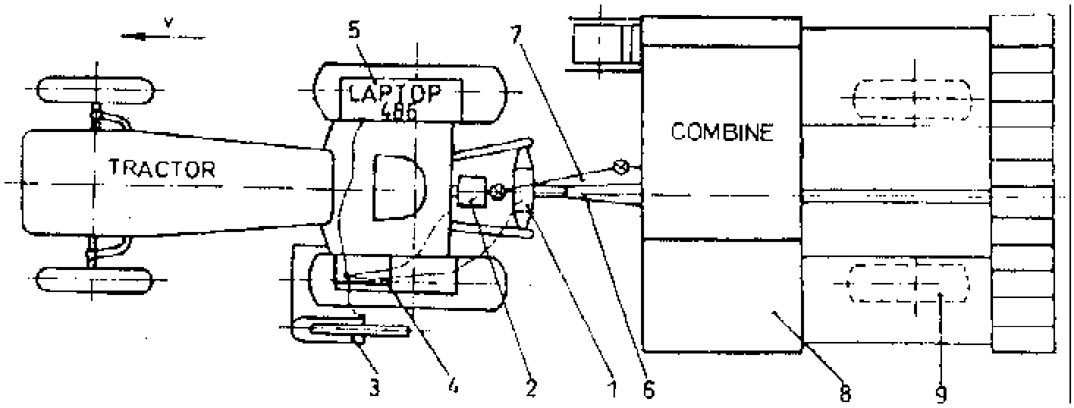


Fig. 1 Location scheme of transducers and measuring equipment on the potato harvesting combine – tractor system:

1 – tensiometer bar for coupling to the tractor (for determination of the traction force and vertical pressure force; 2 – device for the determination of the torque and of the angular speed of the power take-off shaft; 3 – supplementary wheel for determining the real velocity of the machine; 4 – energy source (storage battery); 5 – measured data acquisition and processing equipment; 6 – hitch for coupling the machine; 7 – cardan shaft for driving the machine; 8 – combine; 9 – supporting wheel of the combine

Based on the processed experimental data, curves have been plotted expressing the influence of the machines moving velocity v on the traction force F_t, the vertical pressure force R_z, the traction bar of the tractor, the torque M_p transmitted by the power take-off shaft, and on the powers consumed for traction P_t and for the power take-off P_p.

INFLUENCE OF MOVING VELOCITIES ON TRACTION FORCES AND ON THE TORQUE AT THE POWER TAKE-OFF

The influence of the moving velocity on the traction force F_t and on the vertical pressure force R_z of the machine hitch in the case of the Renault 145 + Reekie system is presented in *figure 2* and in the case of system *U 650* +Grimme in *figure 3*.

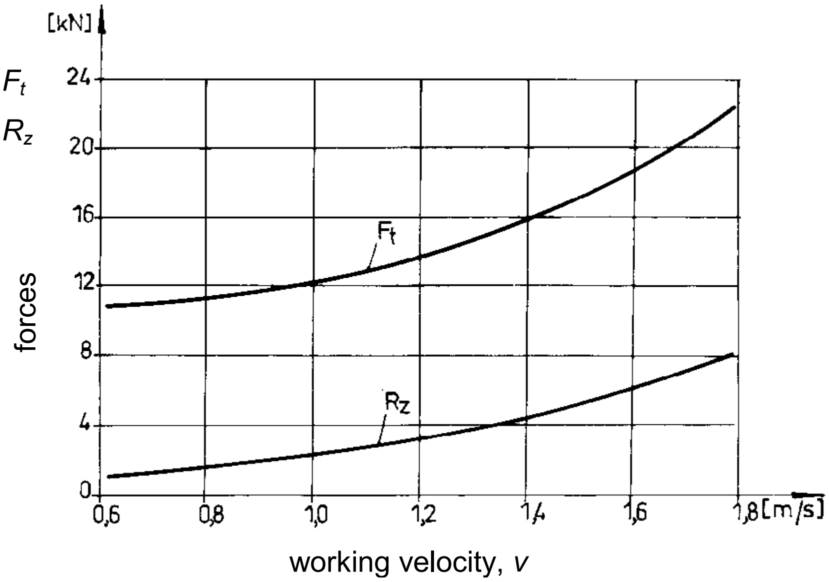


Fig. 2 The variation of traction forces F_t and vertical pressure force R_z in dependence on the working velocity v of the Renault 145 + Reekie - system.

From the graphs it results that in both cases the traction force F_t and the vertical pressure force R_z increase in direct proportion with the working velocity. In the case of the *Renault + Reekie* system the influence of magnitude of working velocity *v* on the growth of the traction force F_t and the vertical pressure force R_z is greater than in the case of the *U 650 + Grimee* system. Thus, it may be noticed that at the *Renault + Reekie* system for a velocity increase from 0.91 m/s to 1.55 m/s, that is 1.7 times, the traction force will increase 1.45 times and the pressure force 1.7 times; in the case of *U 650 + Grimee* system (with empty bunker) for an increase of the working velocity from 1.05 m/s to 1.72 m/s, that is 1.64 times, the traction force will increase 1.4 times and the pressure force 1.7 times.

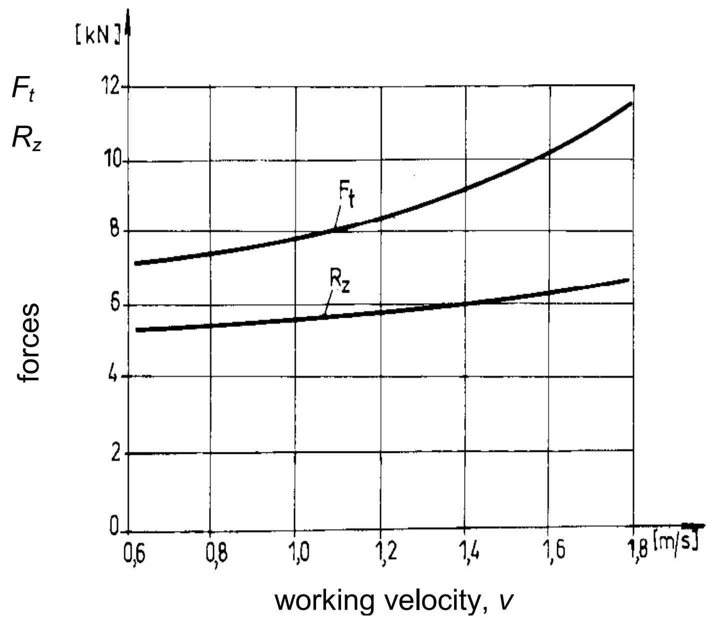


Fig. 3 Variation of traction forces F_t and vertical pressure force R_z in dependence on the working velocity v for the U 650 +Grimme - system

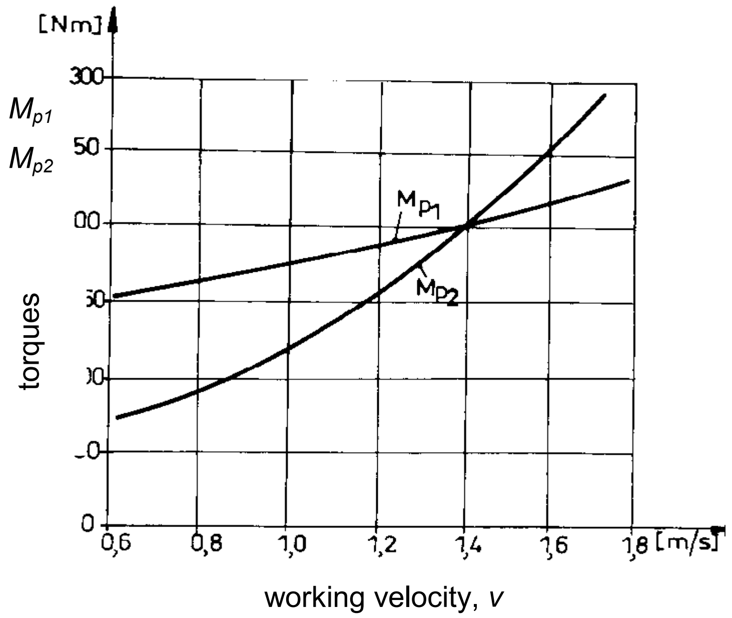
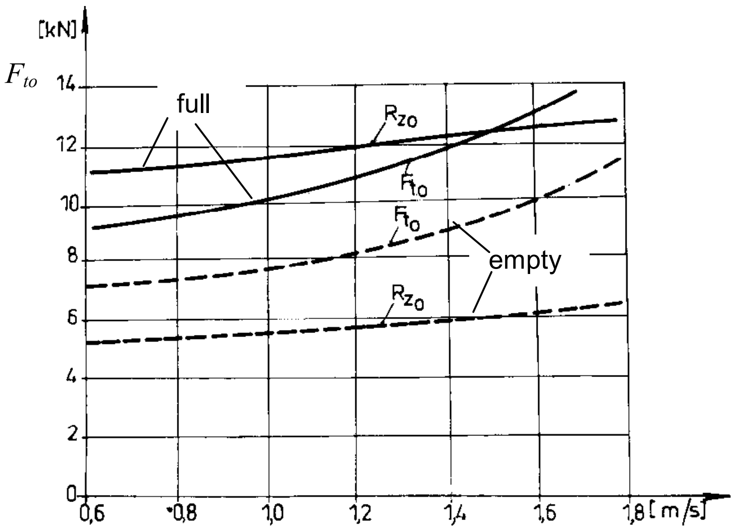


Fig.4 Variation of torques M_p transmitted at the power take-offs in dependence on the working velocity v: M_{p1} – Reekie - combine; M_{p2} – Grimme – combine.

The flow of material entering the combines (mixture of tubercles with soil and vegetal remains) is directly proportional with the machine running velocity, and for this reason the torque M_p transmitted through the power take-off increases in direct proportion with the working velocity. Thus, *figure 4* illustrates on the same graphs the influence of the moving velocity on the torques M_p transmitted through the power take-off shafts to the two types of combines, wherefrom it follows that the increase of the torque with velocity is more obvious at the Reekie - combine (curve M_{p1}) than at the Grimme combine (curve M_{p2}). However, it has to be mentioned that the standard speeds of the power take-off shafts are different: 1000 rot/min for the *Renault 145* tractor, and 540 rot/min for the *U-650 M.* It is to be noticed that for a velocity increase from 0.91 m/s to 1.55 m/s (an 1.7 times increase) in the case of the Reekie - combine, the torque consumed at the power take-off increases 2.33 times. In the case of the Grimme - combine, for a velocity increase from 1.05 m/s to 1.72 m/s (an 1.64 times increase) the torque consumed at the power take-off has a more reduced increase of only 1.11 times.



working velocity, *v*

Fig. 5 Variation of traction forces F_t and pressure force R_z in dependence on the working velocity v for the U 650 + Grimme system (for a full and empty bunker).

The Grimme - combine is equipped with a collecting bunker (with a maximum volume corresponding to a mass of tubercles of about 1800 kg). The mass of the collected tubercles increases in direct proportion with the covered distance. The variations of traction forces F_t and vertical pressure forces R_z in the hitch depending on the working velocity *v*, for both empty and full bunker operation of the combine are presented comparatively in *figure 5*. From the analysis of the graph it can be observed (as was to be expected) that in the two different situations the variations of the traction forces take place by nearly parallel curves *(*F_{tp} and R_{zp} -for a full bunker; F_{tg} and R_{zg} for an empty bunker), the resistances to traction in the case of the full bunker combine being greater by an average of 6 kN than those in the case of the empty bunker combine.

The resistances of the combines to traction at no-load running are generated only by the rolling resistances of the supporting wheels. Consequently, the weight of the machine in a transport position (the weight of the dislocation section included) and the vertical pressure force on the hitch being known, the rolling resistance coefficients of the machine, f_s, can be calculated. The calculations have yielded, that the values of the coefficients are practically the same, f_s = 0.1.

4. THE INFLUENCE OF THE MOVING VELOCITY ON THE POWERS CONSUMED BY THE COMBINES.

The traction power P_t transmitted by the tractor for pulling the combine is determined by the following relation:

$$P_t = F_t \cdot v \cdot 10^{-3} \text{ [kW]}, \qquad (1)$$

where: F_t is the traction resistance force of the machine (N) and v - the velocity of the machine (m/s).

The power take-off power P_p transmitted through the cardan transmission for driving the combine is determined by the relation:

$$P_p = M_p \cdot \omega_p \cdot 10^{-3} \text{ [kW]}, \qquad (2)$$

where: M_p is the torque transmitted by the power take-off shaft of the tractor (Nm); $\omega = \pi n_p/30$ – the angular speed of the power take-off shaft (rad/s); n_p - the speed of the power take-off shaft (rot/min).

The total working power P_l (useful power) consumed by the combine in the working process is given by the sum of the power at traction and at the power take-off, P_t and P_p, and is determined by the relation:

$$P_l = (F_t \cdot v + M_p \cdot \omega_p) \cdot 10^{-3} \text{ [kW]}. \qquad (3)$$

The effective power P_{et} transmitted by the engine of the tractor for pulling the machine is determined by the relation:

$$P_{et} = \frac{P_t}{\eta_t} = \frac{F_t \cdot v}{\eta_t} \cdot 10^{-3} \text{ [kW]}, \qquad (4)$$

Where η_t is the traction efficiency of the tractor, ranging between η_t = 0.55…..0.65 [1].

The effective power P_{ep} transmitted by the tractor engine for driving the machine through the power take-off shaft is determined by the relation:

$$P_{ep} = \frac{P_p}{\eta_p} = \frac{M_p \cdot \omega_p}{\eta_p} \cdot 10^{-3} \text{ [kW]}, \qquad (5)$$

where η_p is the efficiency of the power take-off transmission, ranging between η_p = 0.92….0.95 [1, 2]

The total effective power P_{em} transmitted by the tractor engine for pulling and driving simultaneously through the power take-off is given by the relation:

$$P_{em} = \left(\frac{F_t \cdot v}{\eta_t} + \frac{M_p \cdot \omega_p}{\eta_p}\right) 10^{-3} \text{ [kW]} \qquad (6)$$

Relation (6) represents, in fact, the equation of the power balance of the harvesting combine - tractor system at a constant working velocity on horizontal ground.

On the power consumptions at traction P_t both traction forces F_t and working velocities v have an influence. However, on the power consumption at the power take-off P_p only the torques M_p (variable with the machine motion velocities) transmitted by the tractor power take-off have an influence, as the speed of the power take-off n_p does not depend on the motion velocity, but only on the speed of the tractor engine.

Figure 5 presents the graph highlighting the variation depending on velocity of the medium powers necessary for pulling (P_t) and driving through the power take -off of the tractor (P_p) for the Reekie combine; *figure 6* presents the same dependence for the Grimme combine.

Analyzing the two graphs it results that in the case of the *Reekie* combine the working velocity has a greater influence on the power consumption. Thus, for a velocity

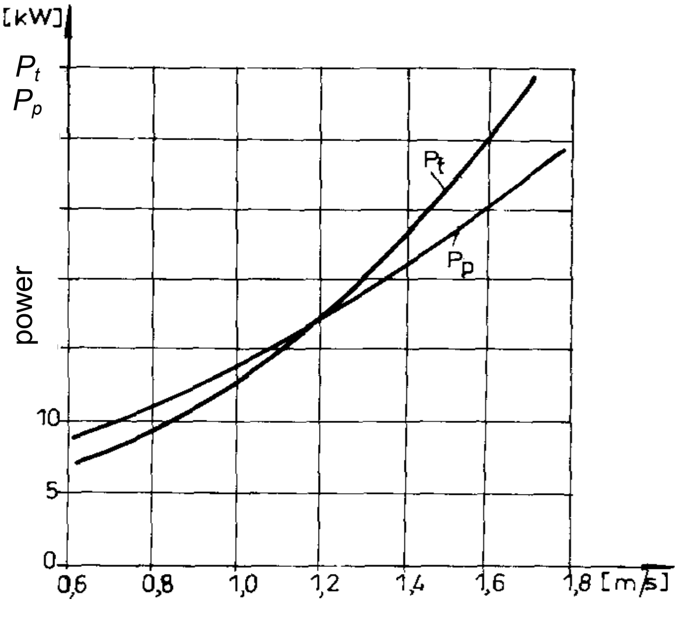


Fig. 6 Variation of consumed powers for traction (P_t) and driving through PTO (P_p) in dependence on the working velocity v for the Renault + Reekie - system.

increase from 0.91 m/s to 1.55 m/s (1.7 times) the power consumed at traction P_t increases 2.48 times and the power consumed at the power take-off P_p increases 1.87 times. In the case of the *Grimme* combine, for a velocity increase from 1.05 m/s to 1.72 m/s (1.64 times) the power consumed at traction P_t increases 2.28 times and the power consumed at the power take-off P_p increases 1.31 times.

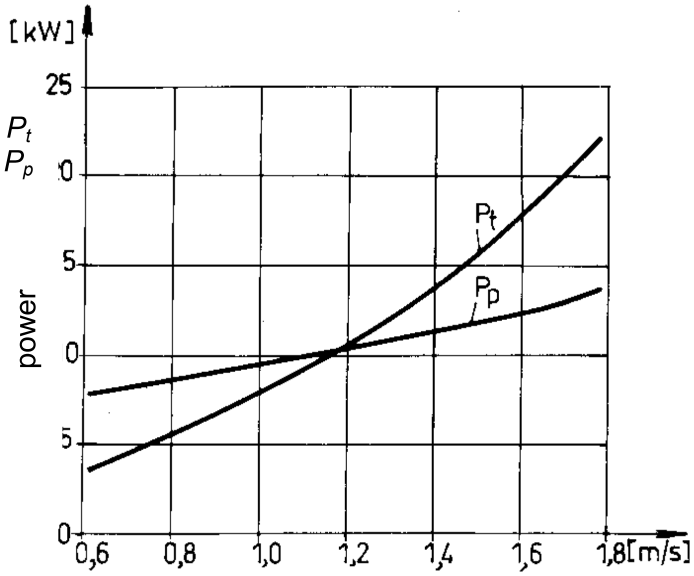


Fig. 7 Variation of consumed powers for traction (P_t)and driving through PTO (P_p)in dependence on the working velocity v for the U650M + Grimme - system

A cc [illegible] ies highlights the fact that although the *Reekie* combine works on two rows, the power consumptions for this machine are not double in comparison to the *Grimme* combine (that works on one row), the power consumption increasing only by 60….80 % for traction powers and by 60….90 % for the powers transmitted through the tractors power take-off.

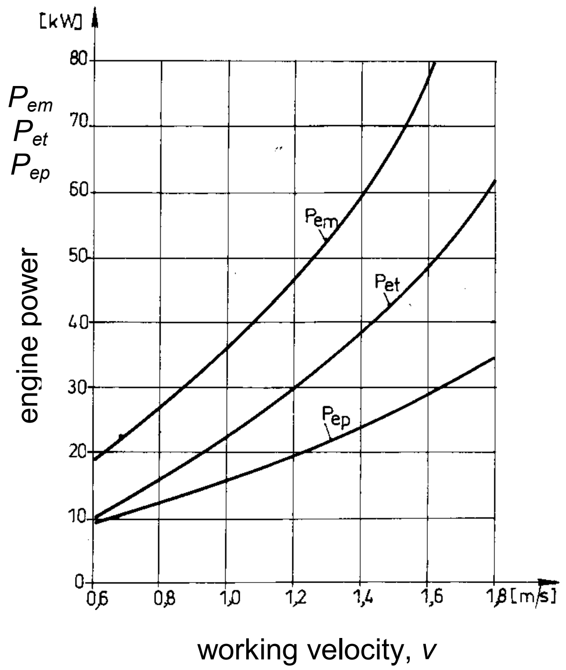


Fig. 8 Variation of effective powers transmitted by the tractor engine in dependence on the working velocity v for the Reekie - combine

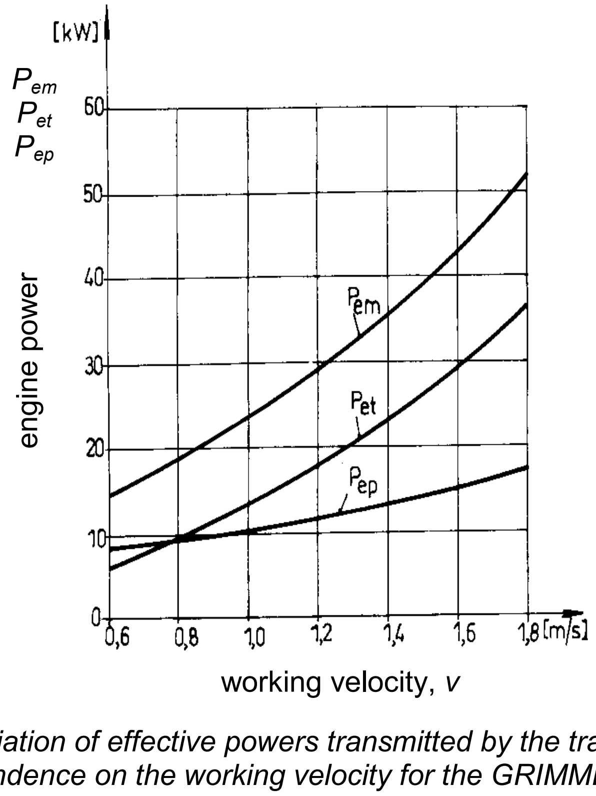


Fig. 9 Variation of effective powers transmitted by the tractor engine in dependence on the working velocity for the GRIMME combine

The average effective total power P_{em} developed by the engine for traction P_{et} and for the power take-off P_{ep} calculated for medium efficiencies of the power take-off transmissions η_p and medium traction efficiencies of tractors η_t [1], depends also on the working velocity, as shown in the graphs of *figure 7* (REEKIE combine) and 8 (GRIMME combine).

From the graphs of *figures 7* and *8* it results that the engine of the U-650M tractor (47.8 kW power) tractor has a load of nearly 90% when running at a velocity of about 1.6 m/s (5.75 km/h) aggregated with the (one-row) Grimme - combine, while the engine of the *Renault 145* tractor (99 kW power) tractor has a load of nearly 80% when running at the same working velocity, aggregated with the (two-row) Reekie - combine.

CONCLUSIONS

The analysis of the results of the experimental tests conducted on the two studied types of potato harvesting combines has shown that by increasing the moving velocity of the machine, the power consumptions for both traction and driving through the power take-off shaft are increasing in direct proportion. The powers transmitted by the tractor engine via the two power fluxes, traction and cardan shaft drive, (actuated by the power take-off) at normal working velocity represent 35….49% for pulling the machine and 60….65% for driving the machine through the power take-off.

REFERENCES

[1]. Popescu, S., Zaman, M., Mugea, N. 2000 Necesarul de putere al tractoarelor pentru acționarea maşinilor de recoltat şi transportat. (Power requirement for tractors driving harvesting and transport machines). In*: Mecanizarea Agriculturii*, nr. 5, 2000 , p. 6….10

[2]. Paler, A. 2000. Studiul dinamicii şi energeticii sistemelor tractor maşini de recoltat cartofi (Study of the dynamics and energetics of tractor – potato harvester systems). Ph.D. Thesis, "Transilvania" University of Brasov, 2000.

[3]. Neculăiasa, V., Dănilă, I. 1995. Procese de lucru şi maşini agricole de recoltat (Working processes and agricultural harvesting machines). Editura A92, Iaşi, 1995.

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