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STATIC CUTTING RESISTANCE AND ENERGY OF STALK OF WINTER WHEAT AND RYE

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INTRODUCTION

Modern agricultural technology includes many operations involving the process of comminution of stalk materials by shearing. In many cases they are extremely energy consuming operations. Thus for instance the cutting of green fodder, hay and straw for dry fodder, the bricketting, require enormous energy inputs, the limitation of which can decisively influence the production costs.

A similar, from the point of the mechanics of the process phenomenon occurs at the harvesting of cereal and green plants with cutting apparati of various constructions.

In every case it becomes extremely important for the constructor trying to optimize the machine to determine the mean values of the cutting forces, cutting strains, cutting energy, and the deformations accompanying the process. We stress the necessity of paying attention to the relationships between the strains and deformations taking place during the process, since further technology of processing can determine closely the state of destruction of the structure of the cut material. Thus it also becomes important to investigate the characteristics of the material in the sense of determining the enumerated parameters as functions of the position of the place of cutting on the length of stalk.

It should be emphatically stressed that because of the very high individual variability, all the characterizations must have statistical form, and usually it is not enough to determine the mean values and the elementary measures of distribution, but it is necessary to characterize in detail the parameters of the functions of distribution.

The process of stalk shearing is not sufficiently known, since we know neither the rheological model of the material itself, nor the structure and texture of stalk as a mechanical construction that is subject to deformation during the process of shearing. Here we mean for instance the crushing of the stalk pipe before the beginning of shearing, which also can be a proces of considerable energy consumption. The introductory destruction of stalks by crushing can be of vital significance for the energy consumption of the whole process.

So far this situation makes it impossible to approach the process purely physically by the determination of the material constants necessary for rheological description of materials which in connection with an accurate knowledge of the construction structure of stalk would allow for the modelling, and, what follows, the predicting of the course of the process.

However, practical considerations, and first of all the necessity of providing the constructors of machines with information, would suggest, independent from looking for model solutions, the necessity of carrying out immediate application research, assuming from the start that their results will not have the character of generalizations, but concern only one concrete case determined by the conditions of the experiment. Still, we can expect that such an experiment will point to the most important elements of the process that will require the concentration of basic research. Because if, like in the experiments described below, it will turn out that there exist clear extremums of the force and energy of shearing on the length of stalk, then the subsequent looking for the explanation of this phenomenon becomes obvious. The reasons for it can be both in the material itself and in the spatial form of stalk, expressed only by the diameter, thickness of walls, distribution of fibers.

The objective of the reported research was the determination of the course of the force and energy of shearing a single cereal stalk as a function of its length. Such results allow not only to obtain the mean values and the distributions of the parameters determined, but also to indicate practically for ex. the height of cutting with a cutting apparatus, on which there will occur the minimum of the theoretical distributions of energy.

Such research works were fragmentarily conducted [2], and this made the authors to choose this subject of investigations. The authors threated the investigations as piloting ones, as their objective putting up first of all the establishing if the problem exists at all and if so what is its scale. This is the reason for the considerable restriction of parameters included in the investigations. The authors decided to carry out the experiment at a quasi static movement of the shearing blade. Considering the fact that the material cut is equivalent to the rheological model with a clear influence of the deformation speed on the strain value, and so probably to the Maxwell St. Venant's model and having no possibility of carrying out investigations of the appropriate material constants we did not want to introduce factors unknown to us even as to their scale.

On the other hand, considering the practical purposes, that is the working out of new constructions of shearing equipment [4] and the choice of the working parameters [1, 3], we applied a cutting device of a shape characteristic of a typical shearing apparatus. Thus the only variables in the experiment left were the cereal variety and the place of shearing on the stalk.

METHODOLOGY OF INVESTIGATIONS

The investigations of the resistance and energy of static shearing os cereal stalk were carried out within the scientific cooperation of the Institute of Agrophysics of Polish Academy of Sciences in Lublin with the Institute of Agricultural Technology in Rovinka (Czechoslovakia). The measurements were carried out on the resistance measuring apparatus Instron type 1112, with a recording and integrating system. The measuring system consisted of a special table with a knife (of the shape of blade analogous to that of blades in a shearing system of harvesters) placed vertically (with the cutting edge perpendicular to the axis of stalk fixed to the table). The counter-cutting knife was fitted to a tensometric head measuring loadings. The speed of static shearing was 20 mm/min. The object of investigations were 8 varieties of winter wheat (Aurora, Balta, Helenka, Grana, Kaukaz, Luna, Promesse, Multiweiss), and 3 varieties of rye (Dańkowskie Złote, Dańkowskie Selekcyjne, Pancerne). The material was harvested in the period of full maturity from the regionizing experiments of the Experimental Station of Evaluation of Varieties in Czesławice (Lublin region) in the period 1973—1974. In every case 30 stalks were randomly chosen from each variety, cut just at the propagation nodium. The investigations were carried out on sections 30 cm in length, making measurements at every 2 cm (starting from the propagation nodium). In effect 900 values of the force and energy for the characterization of each variety.

RESULTS OF INVESTIGATIONS

The results obtained were subjected to statistical analysis, and the concluding was done at the level of significance = 0.05.

The mean values of the cutting resistance for winter wheat formed the range from 24.43 to 54.54 N, and significant differences were found in the majority of the varieties and stalk sections compared. The variability of the values is characteristic for all the varieties. The maximum values occur up to 8 cm from the propagation nodium, and here there are very clear and statistically significant intervariety differences exceeding 20 N. On the section from 10 to 16 cm there is a rapid decrease of the force value. The Kaukaz, Luna, Multiweiss, Promesse, Helenka and Balta varieties have their minimums here (24—43 N), which in the case of the Grana variety move even higher (18 cm). In all the varieties above 16—18 cm the cutting resistance values increase considerably, reaching values of about 50 N at the height of 28 cm (Kaukaz, Aurora). Examplary courses of this variability are presented in Fig. 1.

Mean values of the energy used during the cutting of a single stalk form the range from 34.21 to 74.36 mJ. The character of the distribution is similar to that of the force values. The maximum occurs at the propagation nodium up to the height of 8 cm, and the minimum within the range 16—20 cm. Above this level the cutting energy increases again (Fig. 2).

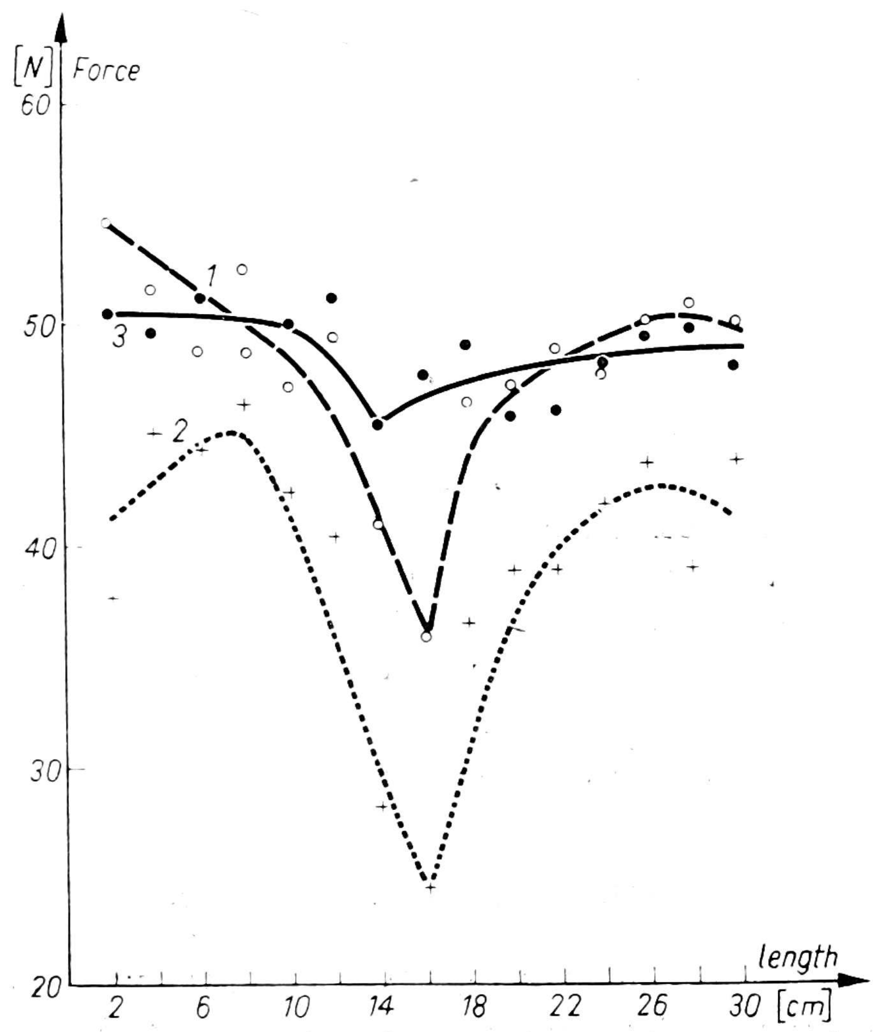

Fig. 1. Distribution of the static shearing resistance on the length of stalk of winter wheat: *1* — Kaukaz, *2* — Multiweiss, *3* — Aurora

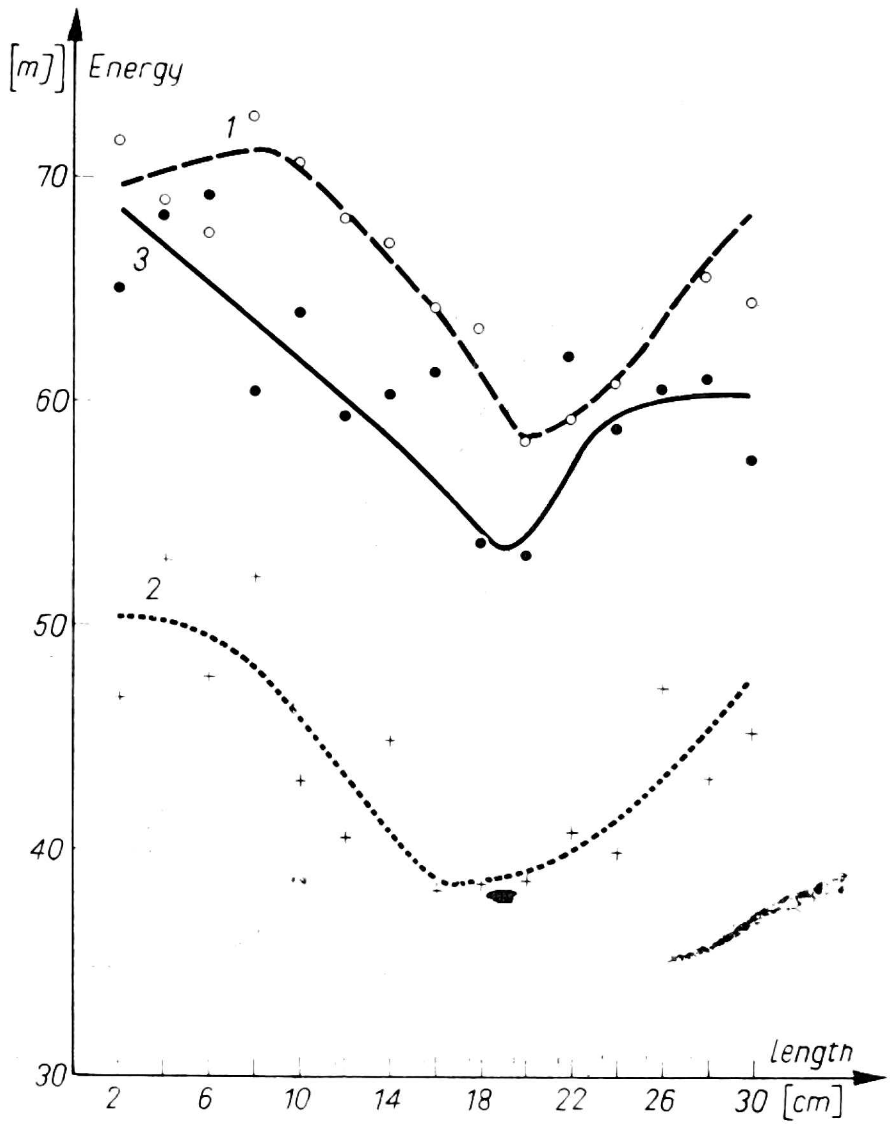

Fig. 2. Distribution nf the shearing energy on the length of stalk of winter wheat: *1* — Kaukaz, *2* — Multiweiss, *3* — Aurora

The cutting resistance of rye stalk varies from 44.73 to 67.20 N. So they are on the average 11 N higher than in the case of wheat, and the distribution of the force values is totally different. From the propagation nodium they decrease very rapidly reaching their minimum at the height of 30 cm. The intervariety differences are not so great as in the case of wheat, although the Dańkowskie. Złote variety is characterized by decidely lower values in comparison with the other varieties. Exemplary distributions are illustrated in Fig. 3.

The values of the cutting energy are on the average about 24 mJ higher than those of wheat, and the limit values are within the range from 61.30 to 101.99 mJ. The minimum of energy occurs at the cutting on the height of 28—30 cm, and the maximum at the propagation nodium. The character of the distribution (Fig. 4) is also connected with the decrease of the force value with the height of cutting.

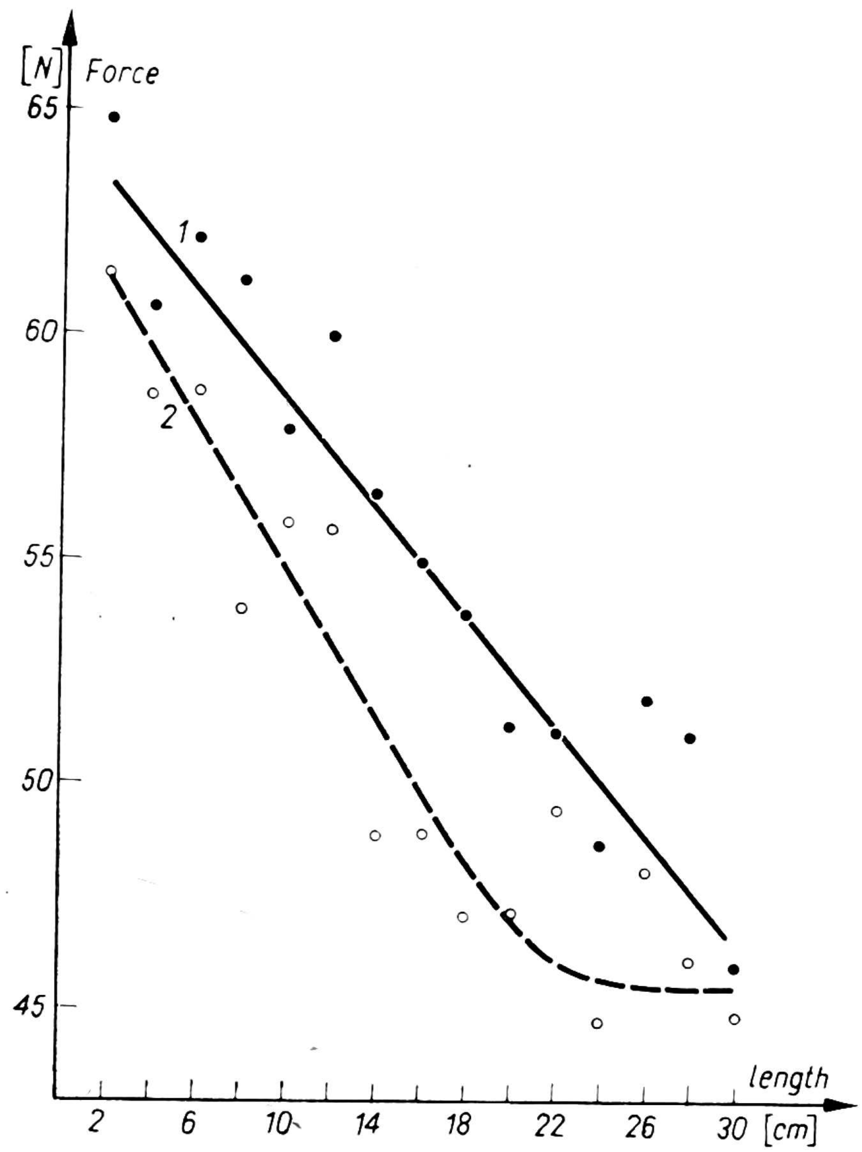

Fig. 3. Distribution of the static shearing resistance on the length of stalk of rye: *1* — Dańkowskie Złote, *2* — Dańkowskie Selekcyjne

RECAPITULATION

The incompleteness of the results in the sense of the restriction of variable parameters of the experiment does not allow for drawing conclusions of practical importance for the constructor of machines. It seems, however, that it is possible to postulate on their basis further development of investigations and to determine their character.

1. The monotonic course of the function in the case of rye seems to limit it as an object of further investigations, which should be concerned first of all with wheats.

2. It is necessary to introduce at least two new factors — the speed of cutting and the term of harvesting, and the speed of cutting should be of the order of several m/s.

3. Investigations should be concentrated on the seeking of reasons for the occurence of the minimums of the function in the section 15—20 cm.

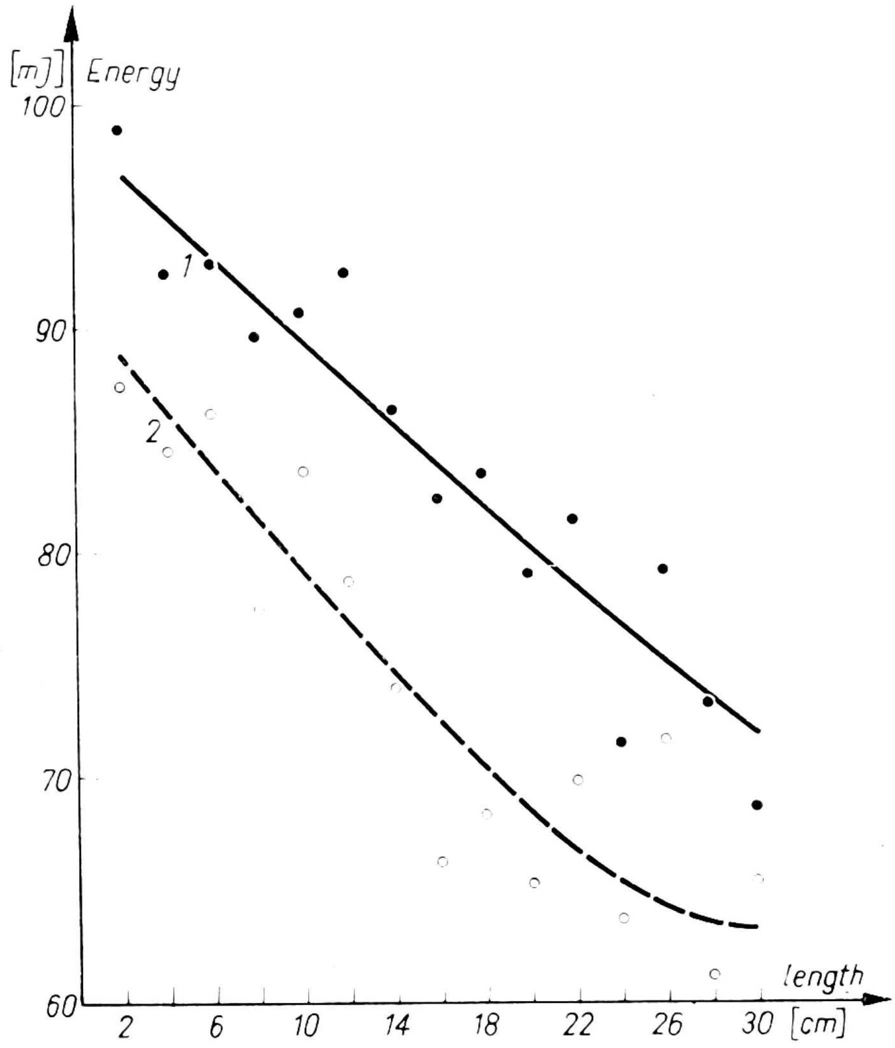

Fig. 4. Distribution of the shearing energy on the length of stalk of rye: *1* — Dańkowskie Złote, *2* — Dańkowskie Selekcyjne

For this purpose attention should be paid to a detailed geometrical characterization and anatomical as well of stalk. Investigations of the material constants of the wall of stalk should be carried out, and first of all those of the elasticity moduluses, the functions of creep and relaxation.

4. It should be investigated whether there is any corelation between the cutting force and energy, and the orientation of stalk.

5. It should be investigated whether there is any corelation between the cutting force and the local resistance to bending, which would allowed to evaluate the possibilities of measurement with indirect methods. Other investigations indicate that stalk as a whole shows particular connections between the longitudinal elasticity modulus and the modulus of perpendicular elasticity, which suggests the mentioned corelations.

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OPORY I ENERGIA CIĘCIA STATYCZNEGO ŹDŹBŁA PSZENICY I ŻYTA

Streszczenie

Pomiary oporów i energii cięcia statycznego źdźbła 8 odmian pszenicy ozimej i 3 odmian żyta przeprowadzono na aparaturze wytrzymałościowej Instron. Na 30 cm odcinkach źdźbła (od węzła krzewienia) dokonano po 15 pomiarów (co 2 cm).

Otrzymane wyniki wskazują na duże podobieństwo przebiegu zmienności oporów cięcia u pszenicy. Maksymalne wartości zawarte są między 2 a 8 cm (do 55 N). Od 8 do 16 cm następuje gwałtowny spadek wartości siły, który tworzy zdecydowane minimum (ok. 24 N). U wszystkich odmian powyżej 16 cm opór cięcia wyraźnie rośnie (do 51 N).

Podobny charakter zmienności wykazuje energia cięcia (72—34—65 mJ).

Zupełnie inny przebieg zmian oporów i energii cięcia stwierdzono u badanych odmian żyta. Wielkości te zdecydowanie maleją od węzła krzewienia (67 N, 101 mJ) ku górze (45 N, 61 mJ).

Na podstawie otrzymanych wyników można przypuszczać, że oprócz celów poznawczych badania tego typu mogą mieć bardzo istotne znaczenie dla praktyki rolniczej, a przede wszystkim dla optymalizacji procesu technologii zbioru.

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СОПРОТИВЛЕНИЯ И ЭНЕРГИЯ СТАТИЧЕСКОЙ РЕЗКИ СТЕБЛЯ ПШЕНИЦЫ И РЖИ

Резюме

Измерения сопротивлений и энергии оптической резки стебля 8 сортов озимой пшеницы и 3 сортов ржи провели на аппаратуре для прочностных исследований „Инстрон". На 30-сантиметровых участках (от узла кущения) провели по 15 измерений (через каждые 2 см).

Полученные результаты указывают на большое сходство развития изменчивости сопротивлений резке у пшеницы. Максимальные значения располагаются между 2 и 8 см (до 55 Н). С 8 по 16 см следует резкое уменьшение значения

силы, образующей решительный минимум (ок. 24 Н). У всех сортов выше 16 см сопротивление резке отчетливо растет (до 51 Н).

Подобный характер изменчивости показывает резки (72-34-65 мдж).

Совсем иное развитие изменений сопротивлений и энергии резки констатировали у исследуемых сортов ржи. Эти величины решительно уменьшаются от узла кущения (67 Н, 101 мдж) кверху (45 Н, 61 мдж).

На основании полученных результатов можно предполагать, что кроме познавательных целей исследования этого типа могут иметь очень существенное значение для сельскохозяйственной практики, а прежде всего — для оптимализации процесса технологии уборки.

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