Test of a Device to the Combine Harvesters for Cutting into Very Small Pieces and Spreading of the Straw

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Abstract


An appliance with hinge installed knives for cutting into small pieces and spreading of the straw on the field, simultaneously with grain gathering, has been created and tested. The study has been carried out through a set of controlled one-factor experiments. The main purposive functions of the study are as follows: necessary operation power for the appliance (KW); specific power consumption (KWh/t) and average length of cut (mm); The cases of controlled factors of the experiments are: re-covering of knives and contra-knives: L = 20, 50 and 80mm; loading of the appliance with straw mass: Q = 5, 8 and 11t/h; peripheral speed of the rotor (cutting speed): V = 13, 16 and 19m/s; distance (clearances) between knives and contra-knives: B = 12, 18 and 24 mm; The constant factors are: hinge installed knives; working wide – 1200m; diameter of the auger – 500 mm; thickness of the knives and contra-knives – 200mm; position angle between knives and contra-knives – 15grad.; wedge angle of knives and contra-knives – 30grad.; location of leading blades – middle.

The variation charts of necessary operation power for the appliance, specific power consumption and average length of cut to variation of the controlled factors, have been determined. The respective adequate equations of regression, describing the processes of cutting the straw into small pieces at the same time with grain gathering, have been settled.

Key words: combine harvester, device, spreading, straw, cutting

Introduction

In the advanced grain-producers’ countries, like the USA, France, Germany, Denmark, the Netherlands and Canada, a significant part of the cereal straw has been cut into very small pieces and spread over the field, at the same time with the gathering of the grained part and after that the ploughing is started (Ivanov, 2000a; 2000b).
In the well known structures, made by company “CLAAS” (Patent for Invention, No 3438609 A1, CLAAS- Germany), the cutting device consists of rotor, towards which four rows of knives are attached through hinges. The straw is taken by the straw-shakers through a storage hopper and is cut into small pieces by the knives and contra-knives. The cut straw is passed on into deflectioned pipe, and there through the distributing blades, it is distributed and spread over the field. The peripheral speed of the knives is selected in such a way as to ensure sufficient quality of cut and spread of the aggregation.

The combine harvesters, equipped with conveyer type threshing device (69 SIMA, 1998a), are mainly intended for gathering of rice, but in a number of cases, they are also intended for gathering of barley, wheat etc. In such cases, the classic straw-separators are replaced by consecutive spinning beaters, supplied with peripheral jagged lamellae and fixed one next other. The uniform spreading of straw on the field is realized through two disks, equipped with peripheral fixed rubber blades and set into motion by two hydraulic motors from the combine harvester’s hydraulic system.

At the models – “D7200”, “D8500” and others, equipped with classical type threshing devices of combine harvesters made by company “CASE” (69 SIMA, 1998b), are cutting – spreading devices for straw also installed. The cutting – spreading device is mounted through hinges at the back end of the combine harvester and is set into motion by a V-belt drive from the harvester’s engine. The uniform distribution of straw cut into pieces is achieved through appropriate designed distributed blades, installed in such a way as to cover almost the entire working width of the header.

Company “JOHN DEERE” – USA (69 SIMA, 1998c), has also developed and is batch producing cutting – spreading devices for straw and other plant remnants to the combine harvesters. The knives are mounted to the rotor through hinges, and the uniform distribution of straw cut into pieces is adjusted mainly by the location of the distributed blades. Other distinctiveness of this device is that the distributed blades are installed only to the upper surface of the deflected pipe and practically the lower part is absent.

Company “MASSEY FERGUSON” – USA (69 SIMA, 1998d), has developed two kind of devices to their models “MF-850” and “MF-860” of combine harvesters with classic type of threshing devices. One of them is a cutting – spreading device – rotor type, analogous to above described. The other one is a spreading device – blade type, what is set into motion by hydraulic motors and is used only for spreading of plant remnants. The first one is used mainly for straw, that needs additional cutting into small pieces, and the second one – is used for gathering of grains of maize etc., where only spreading of cobs, wrapping leaves and other small fractions, cut by the threshing auger is done.

At the models “TX-32”, “TX-34” and “TX-36” with classic type of threshing devices of combine harvesters, made by company “NEW HOLLAND” – USA (69 SIMA, 1998e), analogous cutting – spreading devices for straw are mounted. The models “TF-42”, “TF-44” and “TF-46” of combine harvesters of the same company, are distinguished by the type of threshing devices, where besides the auger of classic type and contra-auger, are installed elements of conveyer type straw-separators and additional axial-rotor treat-
ment of the straw. In this form, the straw is enough cut into small peaces and crumpled, and after that it could be spread on the field.

**Materials and Methods**

The object of the present study is the appliance, shown on Figure 1, created by the Institute of Land Reclamation and Mechanization – Sofia. The pilot pattern consists of a frame /4/ on which through the bearings /8/, a rotor /2/ with working width of 1200 mm and four rows of hunge fixed knives /1/ is installed and through axes /7/ there is a possibility for adjustment of the distances between the knives in a row, from 24 mm - up to 48 mm, through replaceable medial sleeves. The knives, in two consecutive rows are placed in a chess-board order, and these placed in two radial rows – are re-covered. The diameter of the knife’s rotor is \( d = 500 \) mm and through the replaceable washers /5/ peripheral speed of 13, 16 and 19 m/s could be achieved. To the main body of the appliance a distributed deflected pipe /6/ is also mounted with guided blades for uniform spreading of the cut straw and contra-knives beam /3/. To the contra–knives beam contra – knives are mounted with a possibility, through distanced sleeves, to adjust the distance between them from \( B=24 – 48 \) mm and the area of re-cover of the knives from \( L=10 – 80 \) mm.

A possibility has been created, for working under laboratorial conditions for uniform supplying with uncut (packed in

![Fig.1. Design of appliance to the combine harvesters with hinge installed knives for cutting into very small pieces and spreading of the straw](image-url)
bales) straw from 1.4 to 3.1 kg/s, which ensures a load of 11 t/h. The rotor of the appliance is set into motion by an electric motor and by the set of replaceable washers in case the rotor’s diameter is 500mm, the peripheral speed of 13, 16 and 19 m/s could be achieved. To the pilot pattern an electro-measurement device is switched to measure the power consumption from 0 to 30 KW, and by the realized loading (t/h) the specific power consumption is determined analytically (KWh/t). The average length of cut is measured in laboratorial conditions in five measuring categories and is determined by statistical formulas, well-known from the literature.

**Results and Discussion**

The analysis of received graphic charts (Figure 2) shows that the necessary operation power for the cutting device, in case of load variation from 5 to 11 t/h and re-covering of the knives from 10 to 80 mm, is increasing from 5 to 16KW. In the case of lowest loading of 5 t/h, depending of re-covering, the necessary power is varying from 5.04 to 10.07 KW, while in case of loading of 11 t/h, the necessary power is increasing from 10.04 to 16.07 KW.

The specific power consumption (Figure 3), in case of loading from 5 to 11 t/h and variation of re-covering from 10 to 80 mm, practically remains a constant value of about 1KWh/t. while in case of re-covering of 80 mm, the specific power consumption is decreasing exponentially from 2.01 to 1.46KWh/t. In all cases of loading, the specific power consumption is increasing with the rise of re-covering of knives and contra-knives from 10 to 80 mm, and the increasing is highest in case of loading of 5t/h – from 1.01 to 2..01K Wh/t, and it is lowest in case of loading of 11t/h – from 1.01 to 1.46KWh/t.

The average length of cut (Figure 4), in case of varying of the loading from 5 to 11 t/h in all cases of re-covering of the knives and contra-knives, is varying in limited margins – up to 12 mm. In case of variation of the re-covering of the knives
and contra-knives from 10 to 80 mm in all cases of loading, the average length of cut is varying in wide margins up to 62 mm. The shortest average length of cut of 51 mm, is achieving through loading of 5 t/h and re-covering of knives and contra-knives of 80 mm, while the longest – amounting to 125 mm, is reaching through loading of 11 t/h and re-covering of knives and contra-knives of 10 mm. The peripheral speed of cutting auger in this case is 16 m/s and the distance between the knives and contra-knives is 18 mm.

The necessary operation power for the cutting device (Figure 5), in case of variation of the power from 5 to 12 t/h and peripheral speed of the cutting auger from 13 to 19 m/s, is increases from 5.96 to 14.87 KW. In case of lowest loading of 5 t/h, depending of the peripheral speed of the cutting auger, the necessary power is increases by about 2 KW – from 5.96 to 8.06 KW, while in case of loading of 12 t/h, the necessary power is increased from 12.77 to 14.87 KW, i.e. on the average of about 6 KW. The re-covering of knives and contra-knives in this case is 18 mm.

Specific power consumption (Figure 6) in case of loading from 5 to 12 t/h and all cases of peripheral speed of the cutting auger, is decreases. In the lower cases of peripheral speed of 13 m/s, the decrease is about 0.13 KWh/t – from 1.191 to 1.064 KWh/t. In the higher cases of peripheral speed of 19 m/s, the decrease is about 0.37 KWh/t – from 1.611 to 1.239 KWh/t. The re-covering of knives and contra-knives in this case is 50 mm and the distance between knives and contra-knives is 18 mm.

The average length of cut (Figure 7), in case of variation of the loading from 5 to 12 t/h in all cases of peripheral speed of cutting auger, decreases on average about 12 mm. The average length of cut, in case of variation of peripheral speed of cutting auger from 13 to 19 m/s in all cases of loading, decreases on average about 30 mm. The shortest average length of 60.71 mm, is achieved through loading of
12 t/h and peripheral speed of cutting auger of 19 m/s, while the longest – amounting to 102.79 mm, is achieved through loading of 5 t/h and peripheral speed of 13 m/s. The re-covering of knives and contra-knives in these cases is 50 mm and the distance between the knives and contra-knives is 18 mm.

The necessary operation power for the cutting device (Figure 8), in case increase of the re-covering of knives and contra-knives from 20 to 80 mm in all different cases of peripheral speed of the cutting auger, increases on the average by 3.78 KW. In case of smallest re-covering between knives and contra-knives of 10 mm, depending of the peripheral speed of the cutting auger, the necessary power is increases from 5.52 to 11.77 KW, while in case of re-covering between knives and contra-knives of 80 mm, the necessary power increases from 9.3 to 15.54 KW. The loading in this case is 8 t/h and the distance between knives and contra-knives is 18 mm.

The specific power consumption (Figure 9), in case increase of the re-covering of knives and contra-knives from 20 to 80 mm in all different cases of peripheral speed of the cutting auger, increases. In slower cases of peripheral speed of 12 m/s, the increase is about 0.47 KWH/t – from 0.69 to 1.162 KWh/t. In faster cases of peripheral speed of 19 m/s, the increase is from 1.471 to 1.943 KWh/t. The loading in this case is 8 t/h and the distance between knives and contra-knives is 18 mm. The lowest specific power consump-
tion of 0.69 KWh/t is achieved in case of re-covering between knives and contra-knives of 20 mm and peripheral speed of 12 m/s, while the highest of 1,162 KWh/t. with 80 mm and 12 m/s.

The average length of cut (Figure 10), in case of increasing of the re-covering between knives and contra-knives from 20 to 80 mm in all cases of peripheral speed of the cutting auger, decreases. In case of peripheral speed of cutting auger of 12 m/s, the decrease is on average of about 54 mm, while in case of peripheral speed of cutting auger of 19 m/s, the decrease is approximately the same. The average length of cut in case of variation of the peripheral speed of cutting auger from 12 to 19 m/s and in all cases of re-covering between knives and contra-knives, is decreases on average of about 49 mm. The shortest average length of cut of 37.26 mm is achieved in case of re-covering between knives and contra-knives of 80 mm and peripheral speed of cutting auger of 19 m/s, while the longest one of 140.25 mm is achieved in case of re-covering between

Fig. 9. Variation of the specific power consumption depending on the peripheral speed of the cutting auger and the re-covering of knives and contra-knives

knives and contra-knives of 20 mm and peripheral speed of cutting auger of 12 m/s. The loading in this case is 8 t/h and the distance between knives and contra-knives is 18 mm.

The necessary operation power for the cutting device (Figure 11), in case of in-

Fig. 10. Variation of the average length of cut depending on the peripheral speed of the cutting auger and the re-covering of knives and contra-knives

Fig. 11. Variation of the necessary power depending on the loading in cases of different clearances between knives and contra-knives and the loading
creases of the distance between knives and contra-knives from 12 to 24 mm in different cases of loading, increases on average by 4.8 KW. In case of smallest distance between knives and contra-knives of 12 mm, depending of the increase of the loading from 5 to 12 t/h, the necessary power is increases from 8.123 to 19.942 KW, while in case of distance between knives and contra-knives of 24 mm, the necessary power increases from 3.355 to 10.173 KW. The lowest necessary operation power for the cutting device of 3.355 KW is achieved in case of distance between knives and contra-knives of 24 mm and loading of 5 t/h, while the highest necessary operation power for the cutting device of 14.942 KW is achieved in case of distance between knives and contra-knives of 12 mm and loading of 12 t/h. The recovering between knives and contra-knives in this case is 50 mm, and the peripheral speed is 16 mm/s.

The specific power consumption (Figure 12), in case of increased of the distance between knives and contra-knives from 12 to 24 mm in all cases of loading, decreased. In the lower cases of loading of 5 t/h, the decrease is about 0.75 KWh/t – from 1.625 to 0.671 KWh/t. In the higher cases of loading of 12 t/h, the decrease is 0.39 KWh/t - from 1.245 to 0.848 KWh/t. The lowest specific power consumption of 0.671 KWh/t is achieved in case of distance between knives and contra-knives of 24 mm and loading of 5 t/h, while the highest one of 1.625 KWh/t in case of distance between knives and contra-knives of 12 mm and loading of 5 t/h. The re-covering between knives and contra-knives in this case is 50 mm.and the peripheral speed is 16 m/s.

The average length of cut (Figure 13),
average length of cut in case of variation of the loading from 5 to 12 t/h and in case of distance between knives and contra-knives of 12 mm, decreases by 12.08 mm, while in case of distance between knives and contra-knives of 24 mm, decreases by 12 mm. The shortest average length of cut of 46.09 mm is achieved in case of distance between knives and contra-knives of 12 mm and loading of 12 t/h, while the longest one of 129.43 mm is achieved in case of distance between knives and contra-knives is 24 mm and the loading is 5 t/h. The re-covering between knives and contra-knives in this case is 50 mm and the peripheral speed is 16 m/s.

**Conclusions**

- The necessary operation power for the cutting device with hinge installed blades, in case of variation of the loading from 5 to 12 t/h and re-covering of knives from 10 to 80 mm, increases from 5 to 16 KW. In case of lowest loading of 5 t/h, depending of the re-covering, the necessary operation power varies from 5.04 to 10.07 KW, while in case of loading of 11 t/h, the necessary operation power is increases from 10.04 to 16.07 KW.

- The specific power consumption, in case of loading from 5 to 11 t/h and variation of the re-covering between knives and contra-knives from 10 to 80 mm, practically remains a constant value of about 1KWh/t, while in case of re-covering of knives and contra-knives of 80 mm, the specific power consumption decreases exponentially from 2.01 to 1.46 KWh/t.

- The average length of cut, in case of variation of the loading from 5 to 11 t/h and all cases of re-covering of knives and contra-knives, varies in limited margins – up to 12 mm. In case of variation of the re-covering of knives and contra-knives from 10 to 80 mm and in all cases of loading, the average length of cut varies in wide margins – up to 62 mm. The shortest average length of cut of 51 mm is achieved in case of loading of 5 t/h and re-covering of knives and contra-knives of 80 mm, while the longest one of 125 mm is achieving in case of loading of 11 t/h and re-covering of knives and contra-knives of 10 mm.

- The necessary operation power for the cutting device with hinge installed blades, in case of increase of the re-covering of knives and contra-knives from 20 to 80 mm in all cases of peripheral speed of the cutting auger, is increases on average of about 3.78 KW.

- The specific power consumption, in case of increase of the re-covering between knives and contra-knives from 20 to 80 mm and in all cases of peripheral speed of the cutting auger, is increases. In the slower cases of peripheral speed of 12 m/s, the increase is approximately 0.47 KWh/t – from 0.69 to 1.162 KWh/t. In faster cases of peripheral speed of 19 m/s, the increase is from 1.471 to 1.943 KWh/t.

- The average length of cut, in case of increase of the peripheral speed of the cutting auger of 12 m/s, the decrease is on average about 54 mm, while in case of peripheral speed of the cutting auger of 19 m/s, the decrease is approximately the same. The average length of cut in case of variation of the peripheral speed of the cutting auger from 12 to 19 m/s and in all cases of re-covering between the knives and contra-knives, decreases on average about 49 mm.
References

Patent for invention “Appliance for cutting into small pieces and spreading of the straw”, №3438609, A1 of company “CLAAS”- Germany.


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