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A STUDY ON THRESHING DEVICE WEARING BEHAVIOR FOR RICE HARVESTING COMBINE

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Abstract

The auxiliary roll of the rice combine harvester were developed and manufactured from local material to reduce wearing rate for threshing device also minimize fuel consumption and energy requirements. Replacing auxiliary roll knives arranged in a spiral instead by forks separating on length were 90 cm with seven rows and each row has four blades to increase the efficiency of separating the seed. The measurement indices of the auxiliary roll before and after development were threshing efficiency, threshing capacity, fuel consumption, power required, energy requirements, device mass losses percent, wearing rate, wearing resistance, critical wearing value, specific wear and expected life. during the harvesting operation of rice crop the rustles showed It is recommended to use the knife as a threshing device because auxiliary roll threshing efficiency increased by 0.2% threshing capacity increased by 16.83 %, fuel consumption decreased by 0.16 %, power required decreased by 0.15 %, energy requirements decreased by 0.33 % device mass losses percent decreased by 1.4 %, wearing rate decreased by 0.11 % wearing resistance decreased by 0.12%. critical wearing value increased by 34 %, specific wear decreased by 25 % and expected life increased by 78.60% all this result tested after 500h operating time.

Key words: *rice, threshing, capacity ,wearing, ,fuel, power and energy*

INTRODUCTION

The paddy is threshed by the pull force from threshing components. With bow tooth threshing, the grain is not easy to be damaged. Containing small power consumption, it can be adapted to thresh paddy. Wear cause from material rubbing between parts have the same or different materials. The rice threshing processing the use of certain materials that provide greater wear resistance. In these applications, specific alloys have been developed to eliminate certain types of wear.

Varenberg, (2013) [9] Classified of wear according to part moving wear occur in isolation or complex interaction. wear classified to surface fatigue, adhesive, abrasive wear, erosive and corrosion wear and oxidation wear other, less common types of wear are impact, cavitation and diffusive wear.

Rabinowicz, (1995) [7] The effect of volume percentage of reinforcement, applied load and sliding velocity on abrasive wear behavior was analyzed in detail. To judge the efficiency and ability of the model, the comparison of predicted and experimental response values outside the design conditions was carried out. The result shows, good correspondence, implying that, empirical models derived from response surface approach can be used to describe the tribological behavior of the above composite.

ASM Committee (2002) [1] stated that the kind of contact regulates the type of abrasive wear. The two styles of abrasive wear are known as two-body and three-body abrasive wear. Two-body wear occurs when the hard particles remove material from the opposite surface. The material being removed and displaced by a cutting operation. Three-body wear occurs when the particles are not constrained, and are free to roll and slide down a surface. The contact environment controls whether the wear is categorized as open and closed.

Fouda, T. and M. El-Tarhuny (2007) [3] test the wearing performance at different shares tillage and measure the wearing indictors for tillage share with sandy loam soil.

Helmy et al. (2010) [5] developed the cutting blade crank of the combine for harvesting rice crop and selecting the combine optimum conditions. Also estimate the expected life for the cutting blade crank before and after development. Results indicated that by increasing operating time from 250 to 1,000 h. the wearing rate in combine cutting device increased from 0.044 to 0.062 g/h and from 0.03 to 0.04 g/h before and after development respectively. While the wearing resistance decreased from 79.5 to 56.45 km.g-1 and from 116.7 to 87.5 km.g-1 at the same condition.

Fu et al (2018) [4] said that Harvesting operations are related to grain loss because they touch the processes of rubbing, combing and grinding. Different contact patterns were established between the grain components and the contact points in all the previous processes. The results showed that the grain damage is a function of the peripheral velocity and the contact pattern of the effect. The grain loss can be considered as a function of the contact pattern

L. Xu, et al (2014) [10] Explain that threshing efficiency is of most importance when using a feed rate of 5 kg/s. The combinational threshing and separating unit with a transverse tangential cylinder and axial rotor was designed.

The design focused on the designing process of structural and operational parameters of transverse tangential cylinder tangential concave, transition section between transverse tangential concave and rotor concave, axial rotor and concave. Field test showed that the total loss was 1.47% and the damage rate was 0.2%, when the feed rate was 4.86 kg/s, which met the demands of the design.

The research problem appeared during the harvesting process when using the rice combine harvesting machine noticed increase in the accumulation of straw inside the auxiliary roll, which leads to Increase the spikes wearing rate , Increasing losses during the separation process, Low separation efficiency, Increase the harvest time addition to increase in wearing rate in spike. Thus, the spikes were replaced by cutting knife and fixed on a spiral bar made of iron. This knife cut the straw and have not accumulate and have a extended expected life.

The main objectives of this work to test the modifying of the auxiliary roll by estimate the expected life for spikes and knife under the experimental conditions.

MATERIALS AND METHODS

This experiment was carried out in Beheira Governorate, Dilangat Center, Abu Saifa district, during the two seasons of rice harvest 2018-2019.

Experimental design

Experiments were carried out to study the effect of device development on threshing drum. The wearing behavior tested under working time (from 1-500 hours) before and after development. Measuring indicators were threshing efficiency, threshing capacity, fuel consumption, power required, energy requirements, device mass losses percent, wearing rate, wearing resistance, critical wearing value, specific wear and expected life.

Rice characteristics:

Rice (Sakha 101) variety was used mean values of some rice characteristics are shown in Table 1.

Table 1. Rice variety (Sakha 101) specifications

Characteristic	Value
Plant height, cm	90
No. of grain per panicle.	115
No. of panicles/m^2	520
No of panicles/hill	22
Mass of mature grain/10 panicle, g	34
Mass of 1,000 grain, g	29
Yield, ton/fed	4.5

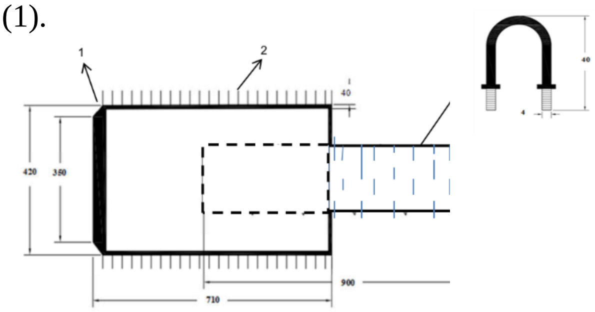
Source: Authors' determination.

The rice combines harvester adjustment

Combine harvester yanmar CA-385 Diesel, 3 cylinder, 4 strokes, water cooled were used. The optimum and constant operating conditions of 3.5 km/h forward speed, 23% grain moisture content.

Threshing drum before development

The threshing drum unit was made of hard steel metal, the unit consists of forks are installed in the threshing cylinder and randomly distributed, which reduces the efficiency of grain extraction as shown in Fig (1).

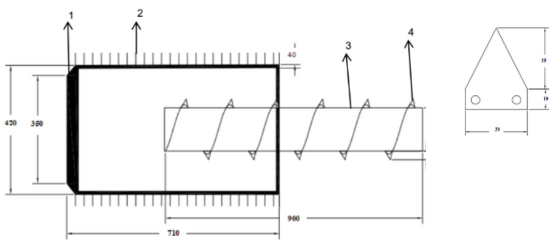


No	1	2	3	4
Part	Drum	Fork	cylinder	Fork

Fig. 1. Threshing drum device before development and fork shape
Source: Authors' drawing.

Threshing drum after development.

The threshing unit consists of 28 sharp knife blades instead of forks and made of hard steel with 30 mm in width and 40 in height. It was installed in a steel strip wrapped around the threshing cylinder in a spiral shape for easy exit of hay residues and it was fixed to the threshing cylinder by a solid tape shown in Fig. 2.



No	1	2	3	4
Part	Drum	Knife	cylinder	Knife

Fig. 2. Threshing drum device before development and Knife blades shape
Source: Author drawing.

The rice combine harvester and wearing measurements:

1-Threshing efficiency

The threshing efficiency was calculated from the following expression in Equation

$$\text{Threshing efficiency} = 100 - \frac{\text{Unthreshed grain}}{\text{threshed grain}} * 100, \%$$

2-Threshing capacity

The capacity was calculated using the following Equation

$$\text{Threshing capacity} = \frac{\text{Weight of total grain output main outlet}}{\text{Time recorded (min)}} * 60$$

3-Fuel consumption

Fuel consumption calculated by this equation:

$Fc = Ci - Cc$

Fc = Fuel consumption Ci = Full tank capacity Cc = Amount of remaining fuel in the tank after a specific period of time

Fc is used to calculate the fuel consumption per hour and the fuel consumption per kg of crop.

4-Power required

The following formula was used to estimate power

$$\text{Power required (EP)} = \frac{fc \times \rho \times l.c.v \times 427 \times \eta_{th} \times \eta_m}{3600 \times 75 \times 1.36}$$

where:

EP = engine power, Kw,

f.c = the fuel consumption in l/h.

PE = the density of fuel in kg/l(for gas oil = 0.85)

L.C.V = the lower calorific value of fuel in 11 k.cal/kg,

η_{th} = thermal efficiency of the engine (35 % for diesel),

η_m = mechanical efficiency of the engine (80% for diesel and 85% for Otto).

5- Energy requirements

Specific energy = 3.163 Fc/Ap , kW.h/ ton

where: Fc = the required power, kW

Fc = fuel consumption, L/h.

Ap = Actual system productivity = Wg * Pr , ton/h

6-Device mass losses percent

Device mass losses percent was calculated as follows:

$$\text{Device mass losses percent} = \frac{W_0 - W}{W_0}, \%$$

where: W_0 = mass of device before using and W = mass of device after using

7-Wearing rate

Wearing rate was calculated as a removal weight g., or removal area from device surface divided by operating time h., as follows:

$$\text{Wearing rate} = \frac{\text{The removal of materials from device surfaces , g.}}{\text{time h.,}}$$

8-Wearing resistance

Wearing resistance was calculated as inverted wearing rate (Kantarc 1982) [6].

$$\text{Wearing resistance, km/g.} = \frac{1}{\text{Wearing rate , g/km}}$$

9-Critical wearing value

Critical wearing value was calculated as hardness device surface, St divided by hardness of abrasion At = 1,060 quartz hardness, (Eyre 1976) [2].

$$\text{Critical wearing value} = \frac{S_T}{A_T}$$

10-Specific wear

Specific wear was calculated as follows:

$$\text{Specific waer} = \frac{\text{The removal of materials from device surfaces , g.}}{\text{volume of rice } m^3}$$

11- Expected life

Expected life was calculated as follows:

$$\text{EL, h.} = \frac{\text{weight of new device, g - weight of worn device after the expected wear, g.}}{\text{wearing rate, g/h.}}$$

weight of worn device after the expected wear =1/3*weight of new device (Ulusoy, 1977) [8].

RESULTS AND DISCUSSIONS

The obtained results will be discussed under the following items:

Threshing efficiency

The threshing efficiency were tested under two device fork and knife as a threshing device before and after development (Fig. 3).

It clearly revealed that, the average of threshing efficiency increased after development to reach at maximum value with 98.80 % at 50 h. from operating time.

The relationship of operating time and threshing efficiency when used knife be expressed using regression equation as:

$y = -0.1097x + 99.033$ $R^2 = 0.9918$.

Also Linear relationship was obtained. when used fork $y = -0.1145x + 98.82$ $R^2 = 0.994$

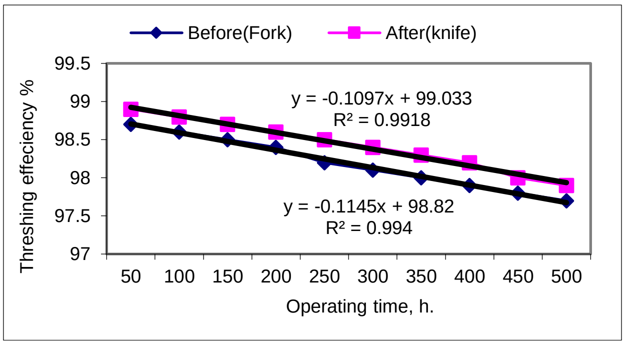


Fig. 3. Effect of operating time on threshing efficiency before and after development (used fork and knife)
Source: Authors' determination.

Threshing capacity

Increasing of operating time from 50 to 500 h the threshing capacity decreased from 3,547 to 2,198 kg/h. before development at a constant grain moisture content of 23% and forward speed of 3.5 km/h Also, by increasing of operating time from 50 to 500 h the threshing capacity decreased from 4,000 to 2,643 kg/h. after development at the same condition. The relationship of operating time and threshing capacity when used knife be expressed using regression equation as:

$y = -166.73x + 4305.5$ and $R^2 = 0.9877$. Also, Linear relationship was obtained. when used fork $y = -177.89x + 3939.2$ and $R^2 = 0.9632$ as showing in Fig.4

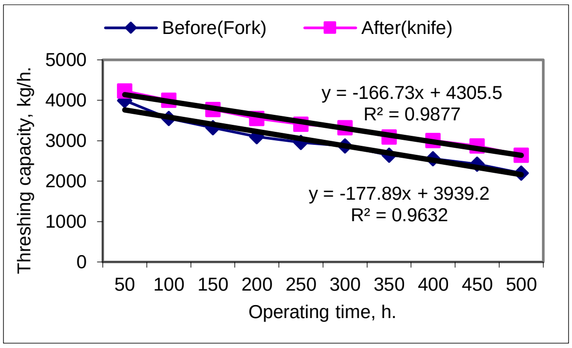


Fig. 4. Effect of operating time on threshing capacity before and after development (used fork and knife) at constant rice moisture content 23%
Source: Authors' determination.

The fuel consumption

The effect of operating time on fuel consumption using Yanmar combine before and after development. is shown in Fig. 5 the results revealed that increasing of operating time from 50 to 500 h the fuel consumption increased from 4.7 to 8.4 l/fed. before development at a constant grain moisture content of 23% and forward speed of 3.5km/h. Also, by increasing of operating time from 50 to 500 h the fuel consumption increased from 4.4 to 7 l/fed at the same conditions. Also, the results show the lower fuel consumption decreased of the developed drum than the original drum. Where the lowest value for fuel consumption was 4.7 L/fed, 4.4 L/fed in the original drum, the developed drum respectively.

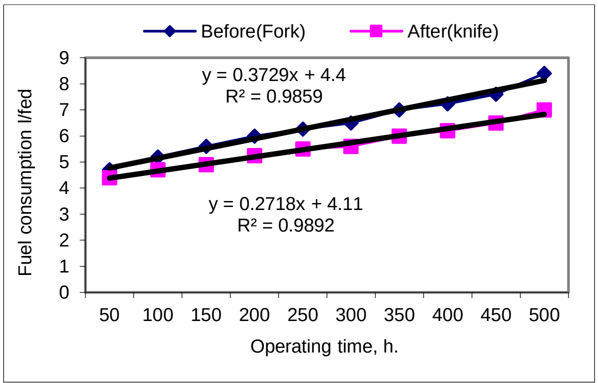


Fig. 5. Effect of operating time on fuel consumption before and after development (used fork and knife) at constant rice moisture content 23%
Source: Authors' determination.

The power required.

Fig. 6 illustrate the effect of operating time on required power before and after development. The results evident that increasing of operating time from 50 to 500 h the required power increased from 14.9 to 26.54 kW before development at a constant grain moisture content of 23% and forward speed of 3.5 km/h.

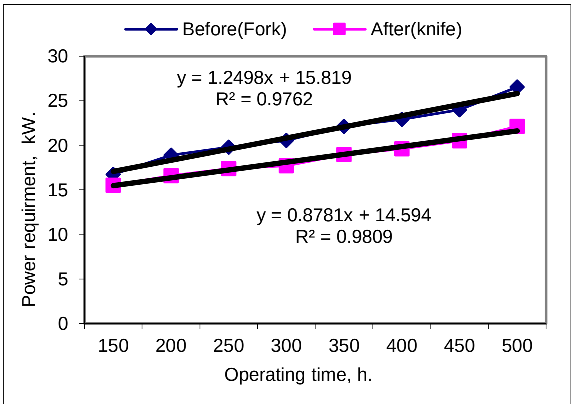


Fig. 6. Effect of operating time on power requirement before and after development (used fork and knife)
Source: Authors' determination.

Also, by increasing of operating time from 50 to 500 h the required power increased from 13.9 to 22.12 kw after development at the same condition. The results show the lower required power decreased of the developed drum than the original drum. Where the lowest value for required power was 14.9%, 13.9% in the original drum, the developed drum respectively.

The energy requirements

Fig. 7. reflects the results which point out that increasing of operating time from 50 to 500 h the energy requirement increased from 3.73 to 12.07 kw.h/ton before development at a constant grain moisture content of 23% and forward speed of 3.5 km/h. Also, by increasing of operating time from 50 to 500 h the energy requirement increased from 3.28 to 8.37 kw.h/ton after development at the same condition. The relationship of operating time and threshing capacity when used knife be expressed using regression equation as:

$y = 0.494x + 2.6173$ and $R^2 = 0.9155$. Also, Linear relationship was obtained. when used fork: $y = 0.838x + 2.6613$ and $R^2 = 0.969$.

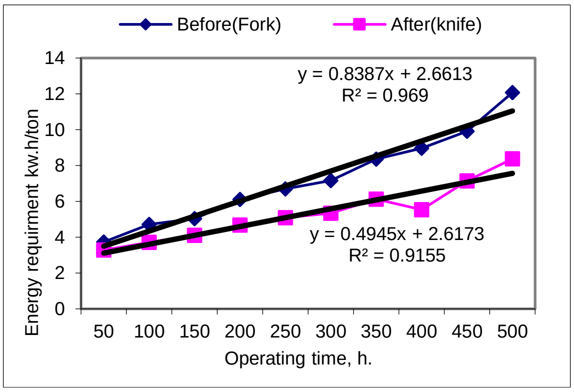


Fig. 7. Effect of operating time on power requirement before and after development (used fork and knife)
Source: Authors' determination.

The device mass losses percent

Fig. 8 showed the effect of operating time on device mass losses present. Data obtained show that increasing operating time from 50 to 500 decreases device mass losses present from 1.2 to 17.3% and from 0.6 to 11.4 % at constant forward speed 3.5 km/h and grain moisture content 23% before and after development respectively. Also and the results show that the highest device mass losses present which decreases from17.3to

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11.4% in the original drum, the developed drum respectively, and the lowest device mass losses present which increases from 1.2 to 0.6 in the original drum, the developed drum respectively.

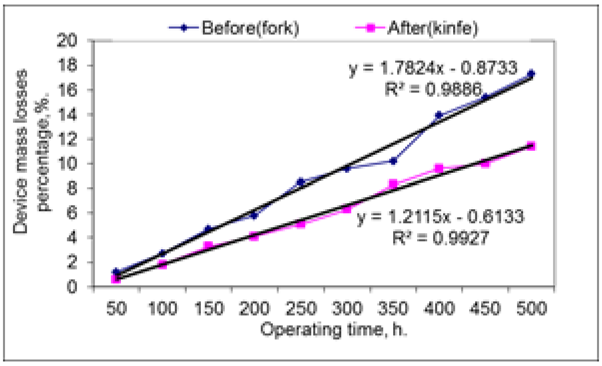

Fig. 8. Effect of operating time on device mass losses present before and after development (used fork and knife)
Source: Authors' determination.

The wearing rate

The effect of operating time and device shape before and after development in auxiliary roll on device wearing rate in threshing combine harvest shown in Fig. 9. The results showed that the increase of operating time resulted in increased in wearing rate in both original and modified drum under all operating periods. In all cases original drum showed higher wearing rates under operating periods than modified drum.

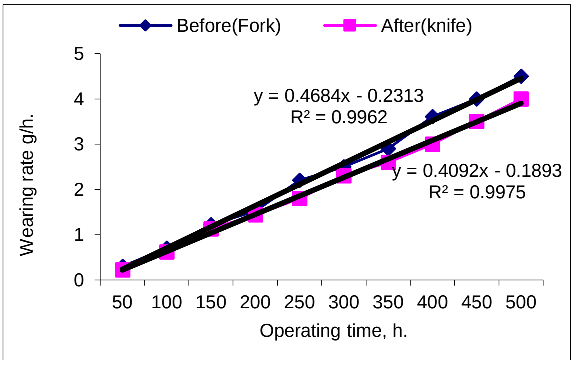

Fig. 9. Effect of operating time on wearing rate before and after development (used fork and knife)
Source: Authors' determination.

Results indicated that by increasing operating time from 50 to 500 h. the wearing rate in threshing combine harvest device increased from 0.3 to 4.5 g/h. and from 0.22 to 4.0 g/h before and after development respectively. The results showed that, the lowest wearing rate was 0.3 and 0.22 g/h. presented at 50 h. before and after development respectively, while the highest wearing rate was presented at 500 hrs. 4.5 and 4 g/h. in both original and modified drums, respectively. Due to the increase of friction with the increase in the operating periods.

The wearing resistance

The relationship between operating time and wearing resistance in threshing combine harvest device before and after development shown in Fig. 10. Results indicated that by increasing operating time from 50 to 500 h. the wearing resistance decreased from 3.33 to 0.22 h/g. and from 4.54 to 0.25 h/g. before and after development the relationship of operating time and wearing resistance when used knife be expressed using regression equation as: $y = 3.9473x^{-1.212}$ and $R^2 = 0.9919$. Also, Linear relationship was obtained when used fork: $y = 3.23x^{-1.158}$ and $R^2 = 0.9966$.

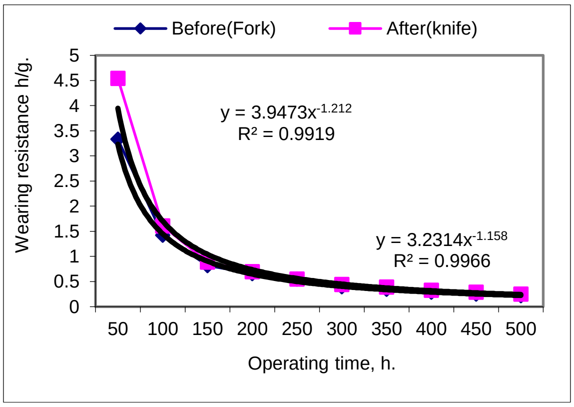

Fig. 10. Effect of operating time on wearing resistance before and after development (used fork and knife)
Source: Author determination.

The critical wearing value

Fig. 11 showed that, the effect of operating time and device shape before and after development in auxiliary roll on critical wear value. Data obtained show that increasing operating time from 50 to 500 decreases critical wear value from 1.92 to 1.6 and from 8.43 to 7.5 at constant forward speed 3.5km/h and grain moisture content 23% before and after development respectively .Also and the results show that the highest critical wear value which increases from 1.92 to 8.43 in the original drum, the developed drum respectively, and the lowest critical wear value which increases from1.6 to 7.5in the original drum, the developed drum respectively, The obtained results prove that the knife can resist the wear by increasing its critical wear value.

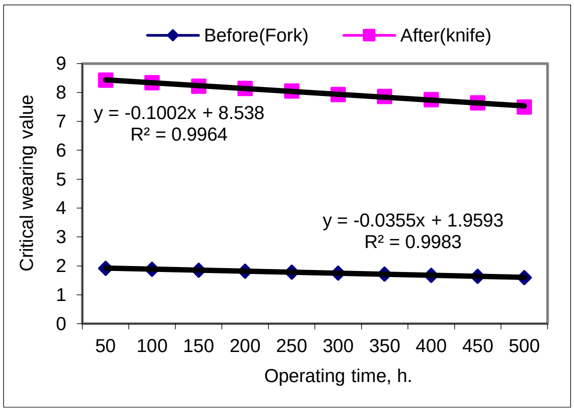

Fig. 11. Effect of operating time on critical wear value before and after development (used fork and knife)
Source: Authors' determination

The specific wear

The relationship between operating time and specific wear in threshing combine harvest device before and after development shown in Fig. 12. Results indicated that by increasing operating time from 50 to 500 h. the specific wear decreased from 0.60 to 1.60 g/m^3. and from 0.4 to 1.20 g/m^3. before and after development The relationship of operating time and specific wear when used knife be expressed using regression equation as:
$y = 0.1669x - 0.212$ and $R^2 = 0.9778$. Also, Linear relationship was obtained. when used fork: $y = 0.1221x - 0.1293$ and $R^2 = 0.9783$.

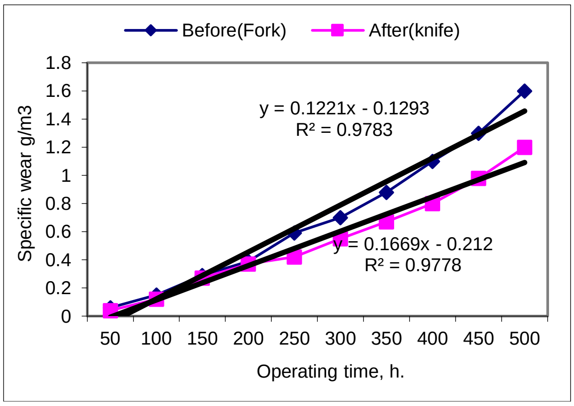

Fig. 12. Effect of operating time on specific wear before and after development (used fork and knife)
Source: Authors' determination.

The device expected life

Fig. 13 shows the effect of operating time on device expected life Data obtained show that increasing operating time from 50 to 500 decreases device Expected Life from 57.7 h to 3.8 h and from 105.9 h to 5.8 h before and after development respectively. Also, the results show that the highest device Expected Life which increases from 57.7 h to 105.9 h before and after development, and the lowest device Expected Life which increases from 3.8to 5.8 in the original drum, the developed drum respectively, The obtained results prove that the knife can resist the wear by increasing its Share Expected Life.

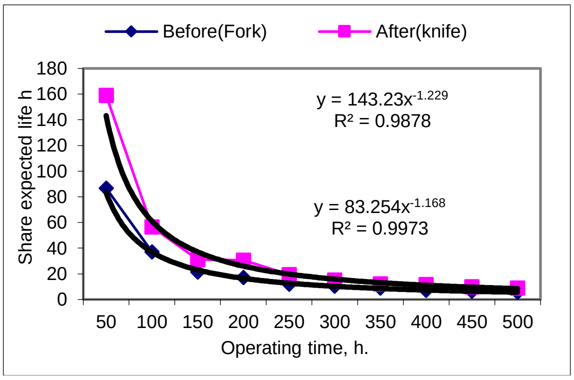

Fig. 13. Effect of operating time on device expected life before and after development (used fork and knife)
Source: Authors' determination.

CONCLUSIONS

The development of the combine threshing device during harvesting rice crop gave to maximum threshing efficiency, threshing capacity, wearing resistance and share expected life minimum required power, energy, wearing rate, fuel consumption and device mass losses percent. With the optimum conditions for operating the combine during harvesting rice crop.

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