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DESIGNING AND MANUFACTURING A NEW AND INNOVATIVE MACHINE FOR PUMPING IRRIGATION WATER AND CUTTING OF CROP RESIDUES USING ONE ENGINE ONLY

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Abstract

To reduce costs for smallholder farmers and poor purchasing power an innovative unit for managing irrigation pump and cutting machine of crop residues by one engine only is designed and manufactured. This innovative unit combines the function of two machines with increasing the productivity and efficiency for the process of cutting machine of crop residues in addition to its original function is the process of pumping irrigation water. The results showed the positive superiority of the new and modified machine. The modified and new machine achieved more than a positive result: (1) increasing the productivity and crop cutting efficiency,(2) low fuel consumption when cutting crop residues, (3) their disposal was equal to that of the irrigation pump prior to development, (4) lower their manufacturing price when compared to the total cost of both.

Keyword: Cutting of crop residues, Pumping irrigation water, Design, Manufacturing

Introduction

There are many challenges faced by Egypt in the current period, including the fragmentation of agricultural holdings where the percentage of agricultural holdings, which is less than 5 acres to about 88% of the size of agricultural holdings in Egypt, especially in the old lands. The smaller the size of agricultural tenure, the less effective the role of agricultural mechanization. As a result, the farmers relied on manual labor or the simplest and cheapest tools available for various agricultural operations, as they simply would not provide small-scale farms with the purchase of machinery and expensive agricultural equipment**.** When conducting an inventory of all agricultural operations carried out in small farms, it was found that there are two agricultural processes are indispensable, namely the process of irrigation and the process of chopping and shredding of agricultural waste, where each process is required for the engine to accomplish where irrigation needs irrigation pump diesel engine and the process of agricultural waste shredder machine to cut agricultural waste Self-propelled by a motor or managed by tractor if any. Increasing the number of engines needed to operate and manage agricultural machinery increases the costs required to purchase these machines, which in no way fit the purchasing power of simple farmers with small agricultural areas of less than five feddans.

The quantity of crop residues in Egypt was determined to be about 25.4 million Mg /year, beside 4 million Mg/year of horticultural according to the statistical survey of the Egyptian Ministry of Agriculture (2009) (in Arabic). A bad effect on economic, environment, public health and others, can be done by increasing crop residues quantities of all kinds and forms if doesn't be treated in suitable ways.

The mechanical treatment by cutting or grinding of crop residues are the most important and primary step should be done to make it great useful. Suliman, *et al.*, 2003 reported that, the advantages of cutting crop residues can be summaries as 1- It makes crop residues in a small particle, so it becomes suitable for further steps of compost processing. Due to increasing the surface area for microbial attack Perr *et al*., 1982. 2- Easily controlling and easy to handling of chopped materials. 3- Collection of chopped materials of crop residues in a minimum storage area, so burning and pollution of the environment can be avoided, 4-raise the nutritive value to suitable lengths of crop residues by easy addition of certain materials Aly *et al*., 1988. Pavankumar *et al*., 2018 mentioned that, the cutting machine is used to cut the total residues of agriculture and food waste into a small, decomposable form that can be used as organic fertilizer. Small-scale waste will degrade faster than large or total waste. These degraded wastes can be used in crops and this improves crop growth and quality as well as improving chemical properties of soils such as the provision and retention of soil nutrients, and promotes chemical reactions. Hashish (1981) stated that increasing fodder production from residues such as cotton stalks by crushing or milling them alone as roughages or together with other fodder materials. In addition, protein substitutes can be added to raise their nutritive value. In addition, the same author determined the lengths of the residues accepted by the animals as 2.34 cm to 3.81 cm and sometimes reached 5.2 cm, length.

Nowadays, In Egypt there are three types of cutting machines or cutting crop residues, Flail – Flywheel and cylinder type and the most current models is a flywheel type for its productivity and high efficiency in the cutting process as well as easy to use.

The objective of this study was to design and manufacture an innovative unit for managing irrigation pump and cutting machine of crop residues by one engine only in order to reduce costs for smallholder farmers and poor purchasing power.

Materials and Methods

Materials

Cutting machine of crop residues, CMCR: Specifications of CMCR are as follow: a) Cutting cylinder: 50 cm diameter skeleton cylinder with one cutting drum and three cutter knives. b) The knives. Knife dimensions are 20 cm long, 12 cm wide, 1cm thickness and edge angle 30 degree c) Feeding

opening: 15 cm width x 10 cm height and the clearance between shear head and cutting knives was 4 mm and the engine required was diesel engine with 5 horse power for operating that machine.

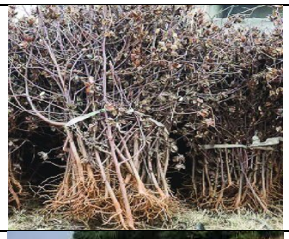
Diesel irrigation water pumps: Table 1 indicates of the specifications diesel irrigation water pumps which used in the study.

Table (1) the specifications diesel irrigation water pumps which used in the study

Product Details	
Material of Construction	Cast Iron
Power Source	Diesel
Type of end use	Agricultural
Suction Delivery Size	$5^{//}/5^{//}$
Revolution Per Minute	1500 rpm
Prime Mover Capacity	6.5 hp.
Discharge Capacity	252 m^3/hr.
Pumping Head	Up to 11 meter.
Suction Head	Max 6 meter

Physical and mechanical properties of cotton, maize stalks and sugar cane waste: The Physical and mechanical properties of cotton, maize stalks and sugar cane waste were collected in the table (2).

Table 2 : Physical and mechanical properties of cotton, maize stalks and sugar cane waste

Residue Property		Shear strength (MPa)	Stem length, cm	Stem diameter, mm	Mass of one stalk, (g)	Moisture content, %	
Cotton Stalks	Top	6.54	147.69	7.83	106.72	11.15, 16.2 and 21.9	
	Middle	8.73					
	Bottom	14.20					
Maize Stalks	Top	5.14	281.16	23.83	746.78	10.1, 46.8 and 65.6	
	Middle	7.06					
	Bottom	8.49					
Sugarcane waste	Top	3.47	185.8	25.1	188.5	8.1, 15.31 and 24	
	Middle	3.62					
	Bottom	3.97					

Amer Eissa *et al*., 2008

Speedometer:

It used to measure the rotation with three ranges available. (40 – 500 rpm, 400 – 5000 rpm and 4000 – 50000 rpm)

Evaluation parameters

Machine production: Time of chopping was measured by means of a stopwatch to determine the machine production in Mglb (Arif, 1999).

Cutting efficiency, CE %: The cutting length of final product is an important parameter to evaluate the performance of cutting process. Where, the suitable cutting length that can be used to produce the compost and the forage is in the range of 0< Lc < 50 mm. There are standard sieves used for segregation of a specific mass, Sb, from the chopped production to several weights, having cutting length 0< Lc < 50 mm. Consequently, the cutting efficiency can be calculated as following:

$$CE = Sa / Sb \times 100 \quad ....(1)$$

Where: Sb is the mass of the chopped production before segregation, g; Sa is the mass of the chopped production after segregation of cutting length 0< Lc < 50 mm, g (Habib, 2002)

Fuel consumption rate: The fuel tank was filled to full capacity before and after each trial. A graduated cylinder was used for each test trial to measure the amount of refueling.

The rate of fuel consumption was calculated (Imbabi, 2001) as follow:

Fuel consumption rate, L/h = Amount of fuel consumption, L / Time elapsed, h ....(2)

Water pump discharge: The operation of the irrigation pump (Q, m^3/hr = volume of water, m^3 / time, hr) was estimated by calculating the time required to fill a certain size and is known in advance to an empty basin with three dimensions as shown in Fig. (1).

Fig. 1 : Measuring water pump discharge in the field

Cost of machine manufacturing: After calculating the cost of purchasing the iron ore used in the manufacturing process, the cost of the lathing and welding as well as the cost of coating, the total cost of the machine manufacturing process according to the prices of 2019.

The relation between pulley velocity and pulley diameter: the following relation is used for determination the pulleys diameters and the velocities which will be installed on cutting machine of crop residues (shredder machine for cutting agricultural wastes).

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \quad \text{....(3)}$$

Where, N_1= velocity of driver pulley, rpm, D_1= diameter of driver pulley, cm, N_2= velocity of driven pulley, rpm, D_2= diameter of driven pulley, cm

Statistical Analysis: All the obtained data of the study were statistically analyzed using the analysis of variance method according to Snedecor and Cochran (1980). While, the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of different treatments.

Results and Discussion

To reach the study objective, the results were presented and discussed as follows in the following steps: (1) Evaluation of the performance of both the irrigation pump and the cutting machine of crop residues before they are combined into one, (2) Designing a new machine for cutting machine of crop residues and pumping irrigation water with one engine only, (3) Manufacturing a new machine for cutting machine of crop residues and pumping irrigation water with one engine only, (4) Initial evaluation of the new machine model and making adjustments, if any and (5) Comparative study between using new machine for pumping irrigation water and cutting machine of crop residues with one engine and between separated machines each one has engine as summarized in figure (2).

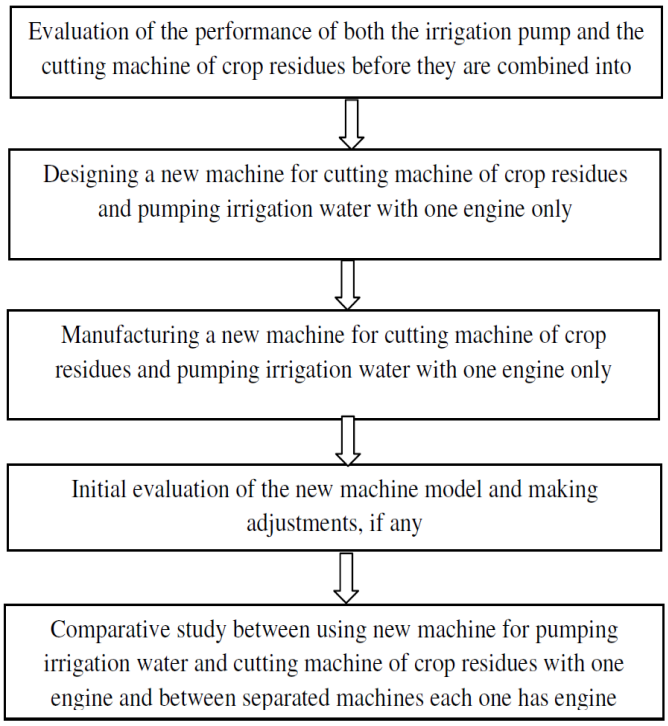


Fig. 2 : Summarized steps of evaluation, designing and manufacturing of new machine for pumping irrigation water and cutting machine of crop residues with one engine

3.1. Evaluation the performance of both the irrigation pump and the cutting machine of crop residues before they are combined into one.

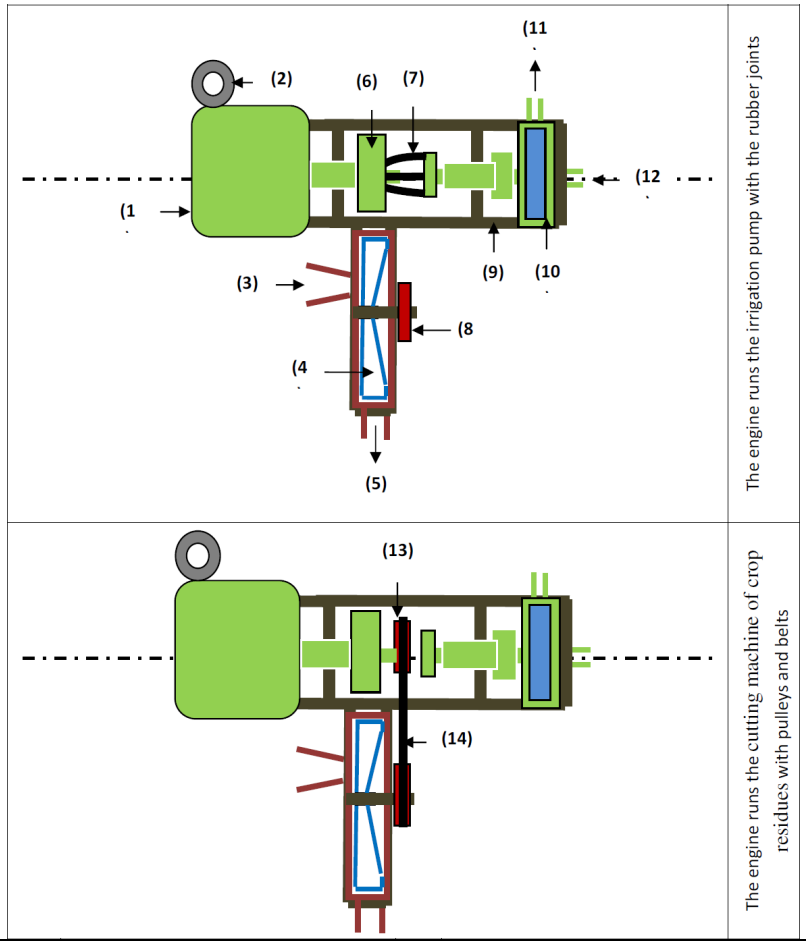
The first step in the development, design and manufacture of a machine that can pump irrigation water and at the same time have the ability to cut crop residues with only one engine is to determine the performance of the original machines for pumping water and cutting crop residues separately and each machine has a separate engine. Evaluation of the performance of separated machines of irrigation pump and the cutting machine of crop residues before they are combined into one. Water discharge of irrigation pump, fuel consumption, machine production of cutting crop residues, cutting efficiency of cutting machine of crop residues and cost of machine manufacturing are presented in table (3). The speed of rotation of the irrigation pump was 1500 rpm, which is also the same as the speed of the cutter drum in the cutting machine of crop residues. The cutting machine was vibrated when the speed was increased to 1600 rpm therefore; the speed was stabilized at 1500 rpm. The values in Table (3) shall be compared with the completion of the new machine manufacturing process and the initial test, in addition to comparing the final values of the new and modified machine after the initial evaluation.

Table 3 : Evaluation of the performance of both the irrigation pump and the cutting machine of crop residues before they are combined into one.

Evaluation parameters	Type of crop residue	cutting machine of crop residues	Irrigation pump
Water discharge of irrigation pump, m^3/hr			251
Fuel consumption, l/hr	Cotton Stalks	6.12	6.71
	Maize Stalks	4.56	
	Sugarcane waste after harvest	5.01	
Machine production of cutting machine of crop residues, ton /hr	Cotton Stalks	0.62	
	Maize Stalks	0.66	
	Sugarcane waste after harvest	0.57	
Cutting efficiency of cutting machine of crop residues, %	Cotton Stalks	70.4	
	Maize Stalks	76.8	
	Sugarcane waste after harvest	75.3	
Cost of machine manufacturing, L.E.		10000	11000

3.2. Designing a new machine for pumping irrigation water and cutting of crop residues with one engine only

In order to reach the target at the lowest cost, the scheme was developed in the number (3) of the innovative bundled machine for water pumping and cutting of crop residues with one engine only. In figure (3) the cutting machine was designed with the same original self-engine characteristics and was installed on the irrigation pump chassis in the transmission medium with pulleys and belts. When the purpose is to pump the irrigation water, the means of transmission will change to its original position through the rubber flexible joints. Figure (3) indicated the innovative machine design and putting its engine to operate the irrigation pump with rubber joints and manages cutting machine of crop residues with pulleys and belts.



1	The engine	8	Driven pulley of cutting machine of crop residues
2	Exhaust engine	9	Iron chassis
3	Feeding input of crop residues	10	Irrigation pump
4	Cutting knives	11	Output of irrigation water
5	Output of cutting crop residues	12	Input of irrigation water
6	Flywheel	13	Driver pulley of cutting machine of crop residues
7	The rubber joints	14	Belts

Fig. 3 : Innovative machine design and putting its engine to operate the irrigation pump with rubber joints and manages cutting machine of crop residues with pulleys and belts

3.3. Manufacturing a new machine for pumping irrigation water and cutting machine of crop residues with one engine only

After the design process was completed, the manufacturing process was started directly. The main steps of the manufacturing process as described in figure (4) were as follows (1) Dimensions of irrigation pump before development, (2) Turning some parts of cutting machine of crop residues, (3) Assembly of parts and welding of cutting machine of crop residues after manufacturing each part separately, and finally (4) Installation and loading of the cutting machine of crop residues on the chassis of the irrigation pump after changing the means of transmission with the pulleys and belts.

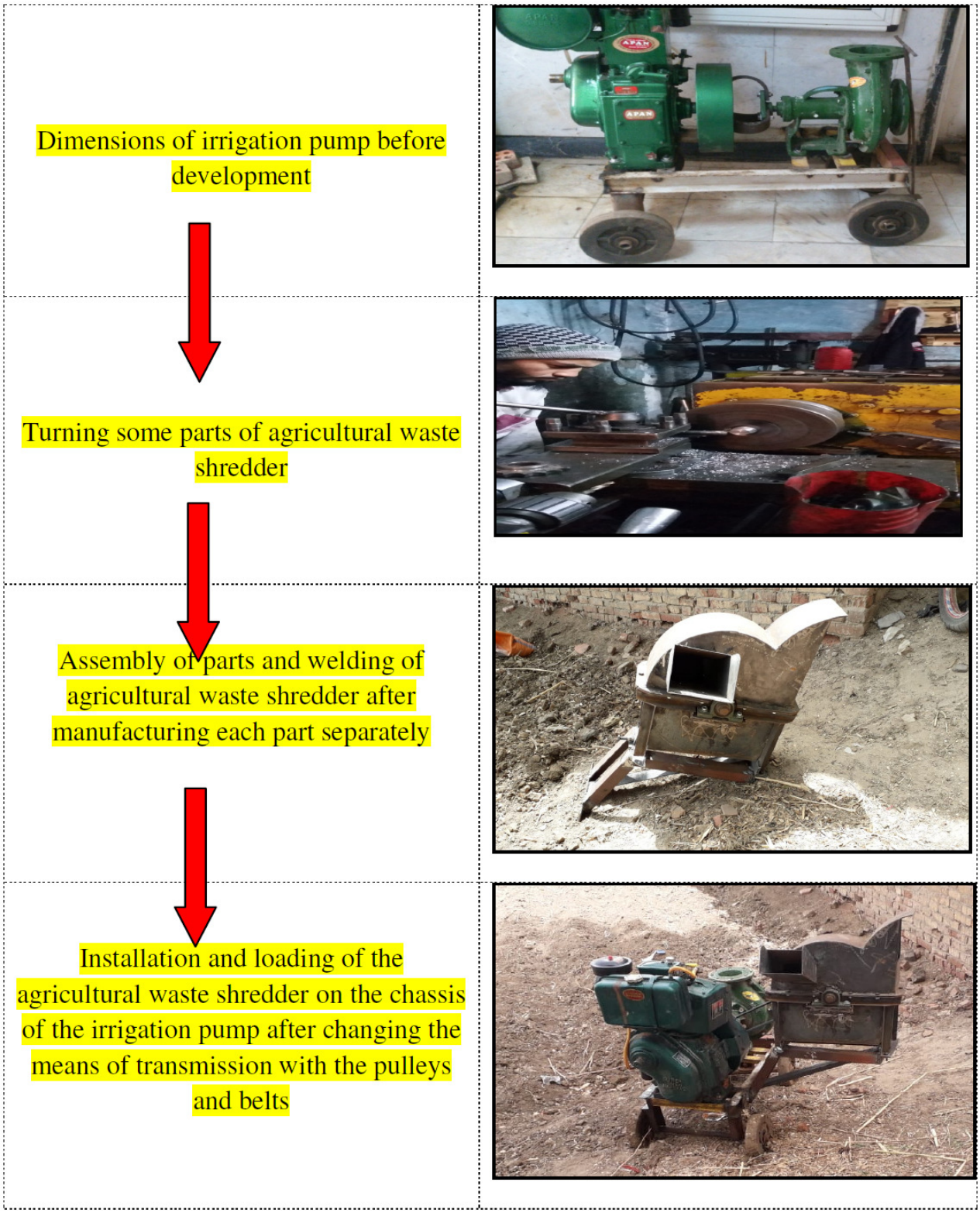


Fig. 4 : The main steps of manufacturing a new machine for pumping irrigation water and cutting machine of crop residues with one engine only

3.4. Initial evaluation of the new machine model and making adjustments, if any

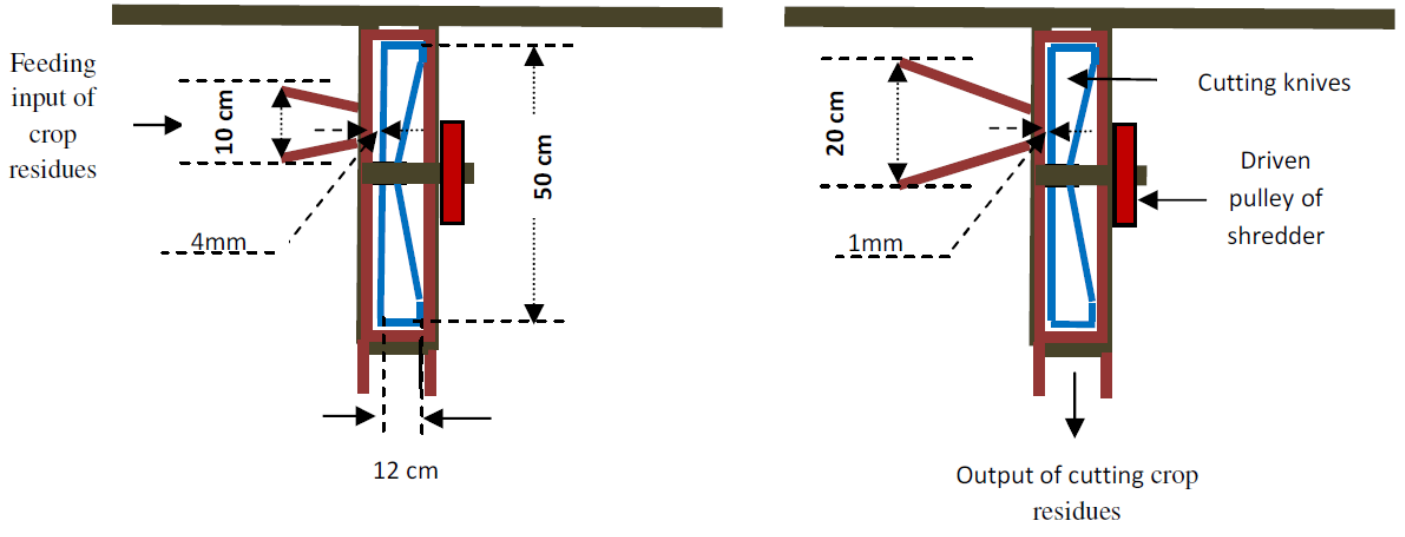
After the completion of the manufacturing process, the initial evaluation process of the new agency was started directly to determine its performance. Is it equivalent to the performance of the two machines separately or is there an adjustment that can be made to achieve the same latency. The data and the results in Table (4) show that there is no

difference between the results. The new machine that pumps water and cutting crop residues with one meter only achieved the same results for the two separate machines, each of which operates independently. The cost of manufacturing the new machine was much less than the total cost of manufacturing both together. It is noted that there is a development that can be achieved at the same cost. It has been observed that better results can be achieved through the development of a new addition to the innovative machine, which is to reduce the clearance between cutting knives and the shear head, as well as to expand the feeding slot of the cutting machine, which will increase the productivity and efficiency of cutting and energy consumption as shown in figure (5). Where, Ige and Finner (1976) stated that the effect of the clearance distance is reduced to that of a simple cantilever beam. Before shearing, the knife usually bends the forge over shear head. Mathematically, the energy used for bending the forage is thus super-imposed onto the shearing energy. If the system was assumed to be represented by that of a cantilever beam, this additional energy would be proportional to the clearance distance to the third power. If it is assumed to be the bending of a plate, where it would be proportional to the clearance distance squared. Figure (6) showed the new and modified machine for pumping irrigation water and cutting crop residues with one motor in the frame of final product and after the process of development.

Table 4 : Initial evaluation of the new machine model

Evaluation parameters	Type of crop residue	Crop shredder with its engine	Irrigation pump with its engine	New machine for pumping irrigation water and cutting agricultural waste with one engine	
				Crop shredder	Irrigation pump
Water discharge of irrigation pump, m^3/hr			251		251
Fuel consumption, l/hr	Cotton Stalks	6.12	6.71	6.11	6.71
	Maize Stalks	4.56		4.52	
	Sugarcane waste	5.01		5.03	
Machine production of shredder machine, ton /hr	Cotton Stalks	0.62		0.61	
	Maize Stalks	0.66		0.65	
	Sugarcane waste	0.57		0.58	
Cutting efficiency of shredder machine, %	Cotton Stalks	70.4		70.5	
	Maize Stalks	76.8		76.7	
	Sugarcane waste	75.3		75.2	
Cost of machine manufacturing, L.E.		10000	11000	15000	

Total cost of the machine manufacturing process according to the prices of 2019



Dimensions of feeding input and clearance between cutting knives and shear head of new machine

Changing the dimensions of feeding input and clearance between cutting knives and shear head of new and modified machine

Fig. 5 : The process of development of the new machine for cutting crop residues with one motor

The process of cutting crop residues after development

Irrigation water pumping after development

Fig. 6 : The new and modified machine for pumping irrigation water and cutting crop residues with one motor in the frame of final product and after the process of development

3.5. Comparative study between using new machine and new and modified machine for pumping irrigation water and cutting crop residues with one engine and between separated machines each one has engine

The results showed in table (8) and shapes (8 to 11) showed the positive superiority of the new and modified machine. The new modified machine achieved more than a positive result: (1) productivity and crop cutting efficiency increased (2) Crop residues (3) their behavior was equal to the disposal of the irrigation pump before development (4) the lower their manufacturing price when compared to the total cost of both.

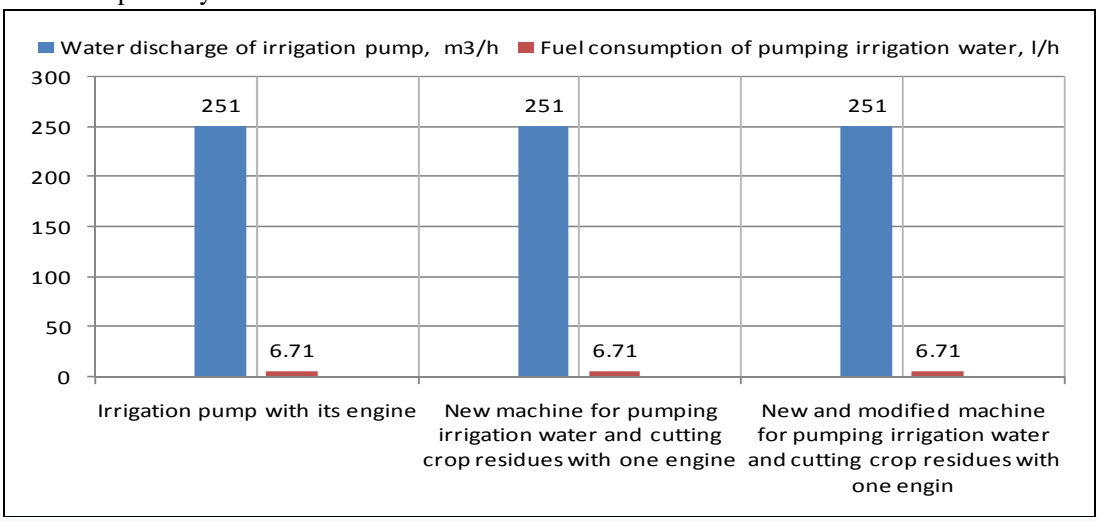


Fig. 7 : The stability of the irrigation pump and the consumption of fuel in three cases

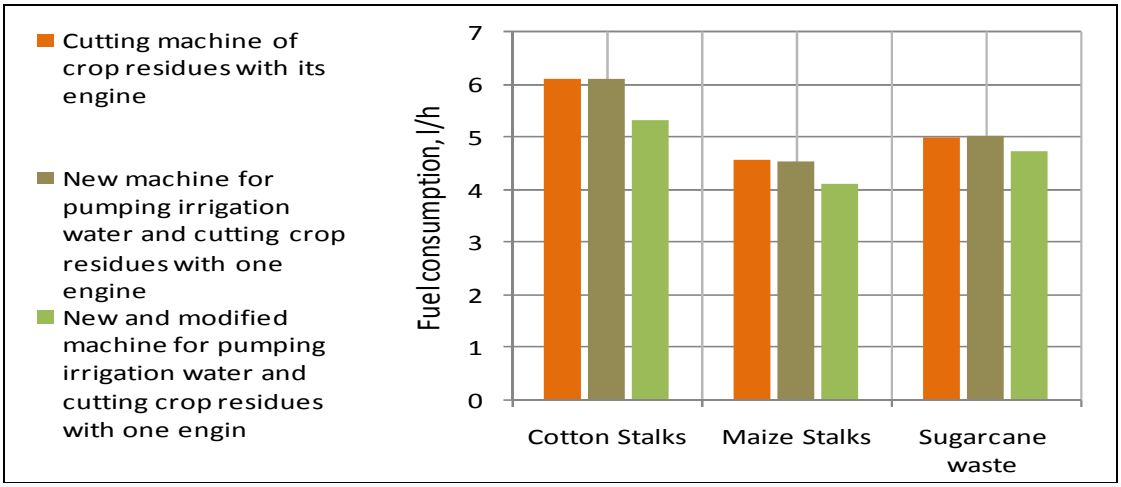


Fig. 8 : Stability of fuel consumption for both engine cutting machine of crop residues and new machine for irrigation pump and cutting machine of crop residues while less fuel consumption with new advanced machine for irrigation pump and cutting machine of crop residues

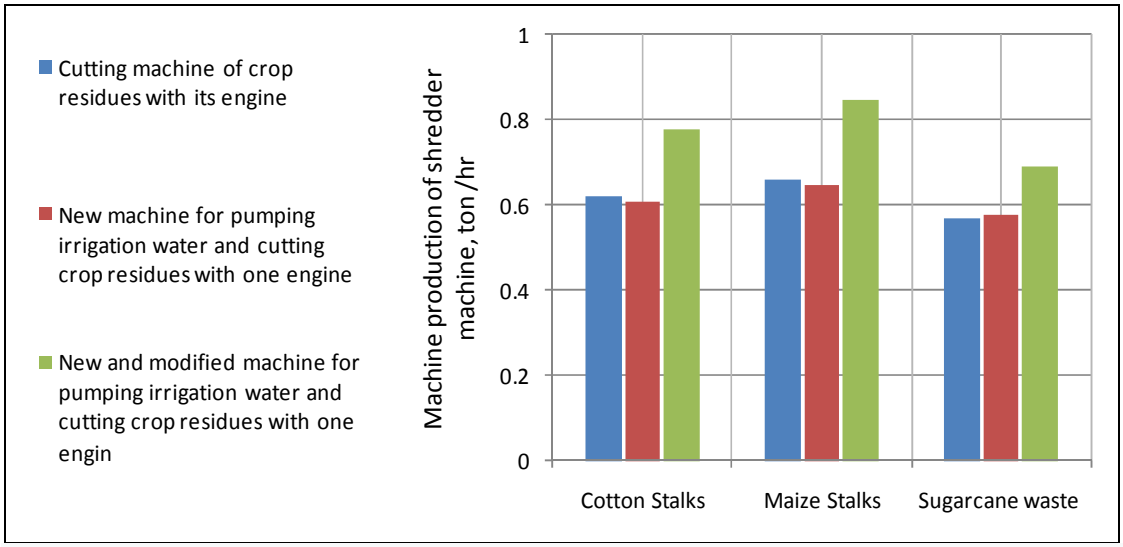


Fig. 9 : Stability of machine production of cutting machine of crop residues for both cutting machine of crop residues and new machine for irrigation pump and cutting machine of crop residues while increasing machine production with new advanced machine for irrigation pump and cutting machine of crop residues

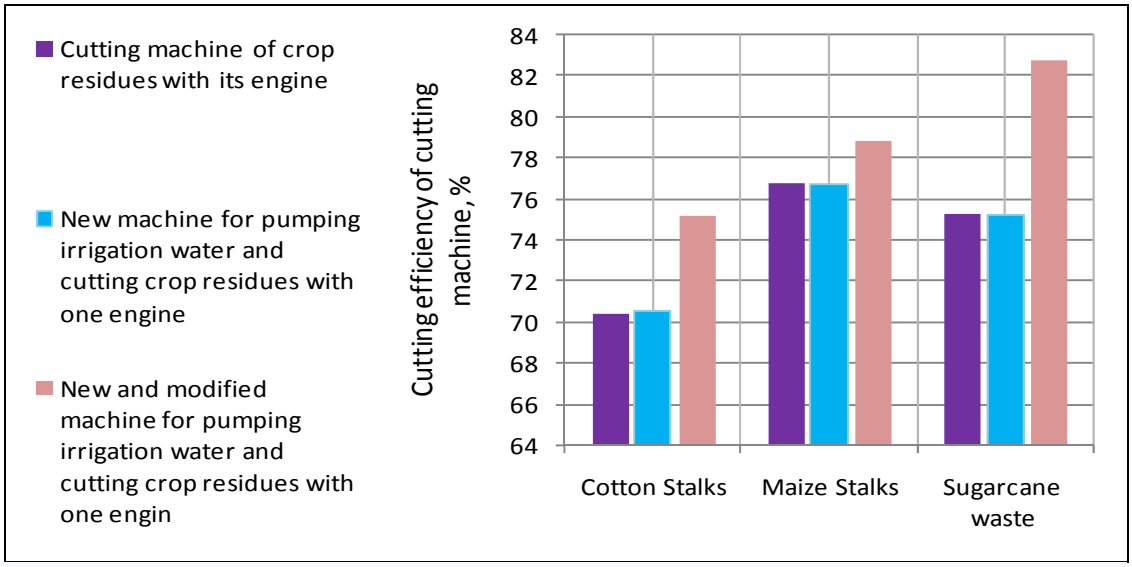


Fig. 10 : Stability of cutting efficiency of cutting machine of crop residues for both engine cutting machine of crop residues and new machine for irrigation pump and cutting machine of crop residues while increasing cutting efficiency with new advanced machine for irrigation pump and crop residue shredder

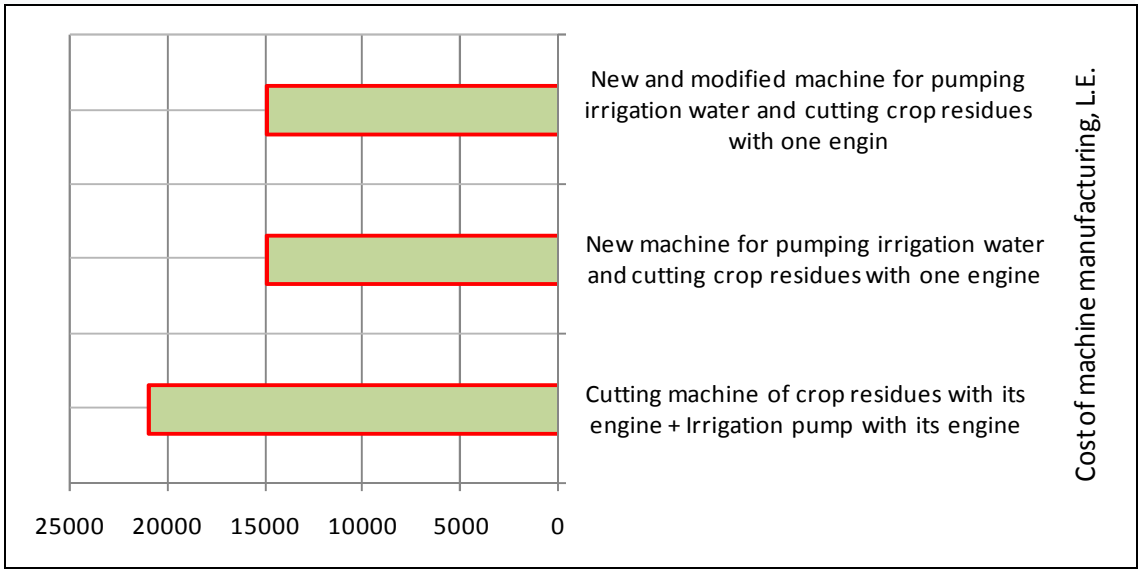


Fig. 11 : Stability of cost of machine manufacturing for both cutting machine of crop residues and new machine for irrigation pump and cutting machine of crop residues while increasing cutting efficiency with new advanced machine for irrigation pump and cutting machine of crop residues

Table 5 : Comparative study between using new machine and new and modified machine for pumping irrigation water and cutting crop residues with one engine and between separated machines each one has engine.

Evaluation parameters	Type of crop residue	cutting machine of crop residues with its engine	Irrigation pump with its engine	New machine for pumping irrigation water and cutting crop residues with one engine		New and modified machine for pumping irrigation water and cutting crop residues with one engine	
				Crop shredder	Irrigation pump	Crop shredder	Irrigation pump
Water discharge of irrigation pump, m^3/hr			251		251		251
Fuel consumption, l/hr	Cotton Stalks	6.12	6.71	6.11	6.71	5.31	6.71
	Maize Stalks	4.56		4.52		4.11	
	Sugarcane waste	5.01		5.03		4.72	
Machine production of cutting crop residues, ton /hr	Cotton Stalks	0.62		0.61		0.78	
	Maize Stalks	0.66		0.65		0.85	
	Sugarcane waste	0.57		0.58		0.69	
Cutting efficiency of cutting crop residues, %	Cotton Stalks	70.4		70.5		75.2	
	Maize Stalks	76.8		76.7		82.8	
	Sugarcane waste	75.3		75.2		80.7	
Cost of machine manufacturing, L.E.		10000	11000	15000		15000	
		21000		**15000**		**15000**	

Total cost of the machine manufacturing process according to the prices of 2019

Conclusion

The modified and new machine achieved more than a positive result: (1) increasing the productivity and crop cutting efficiency,(2) low fuel consumption when cutting crop residues, (3) their disposal was equal to that of the irrigation pump prior to development, (4) lower their manufacturing price when compared to the total cost of both. The first is the possibility of using one engine for two agricultural machines, namely the irrigation pump and cutting crop residues, rather than the purchase of two machines, each with its own engine. The second reason is that the manufacturing of cutting machine of crop residues from local raw materials instead of foreign imports in hard currency. The opening of local manufacturing will increase employment opportunities for Egyptian youth and improve their economic and social conditions.

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