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PERFORMANCE CHARACTERISTICS OF THE RICE MILLING MACHINE

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ABSTRACT

The objective of this work is to study the effect of some operational factors on the performance of the rice milling machine. These factors are, feed rate, moisture content of paddy rice (raw material) and whitening roll speed on the power consumed, required torque, grain damage and unit energy per Kg of white rice (product) in the milling process. The samples of paddy rice Japanes variety used in the experimental work. From the experimental results the following conclusions are obtained:

1. Feed rate of (6.5 kg/min) is found to be an optimum value at M.C.= 13% and 450 R.P.M.
2. As the M.C. (moisture content) of paddy rice increases the grain damage decreases at all roller speeds.
3. As the feed rate increases the grain damage decreases until it reaches an optimum value and then increases.

INTRODUCTION

The objective of rice milling is to obtain the maximum possible yield of whole kernels of white rice for the least power consumption.

Milling is done in various kinds of equipment, ranging from simple mortars to modern equipment. Rice mills in general use can be divided into friction mills and shearing mills. In a friction mill, the kernels are exposed to high pressure of more than 20 KN/m^2, provided by a rotor with a peripheral speed of about 150 m/min, and the husks and bran are removed by a combination of the pressure and friction. In the shearing mill, the husks and bran are removed by cutting using a stationary abrasive and a rotating roller. The peripheral speed of the roll is usually more than 600 m/min, and the pressure on kernels is about 5 KN/m^2 [1 and 2].

Experimental tests were carried out using a friction rice mill in order to study the effect of some operational factors on the mill performance. These factors are, feed rate, moisture content (M.C.) of paddy rice and the roll speed on the power consumption, required torque, grain damage and unit energy consumed per Kg of white rice in the milling process.

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EQUIPMENTS AND MATERIALS

EQUIPMENTS

The rice milling machine which used in this study is shown in Fig.(1). This machine was designed and constructed in a special laboratory at the Faculty of Engineering and Technology, Menoufia University, Egypt. It consists of the following main parts:

- Whitening roller: The machine is equipped with a roll having 108 mm. diameter with six beaters, the roller and beaters are made from grey cast iron.
- Husker knief: used to separate the outer layer of the paddy grain out of the grain surface by the combination of the pressure and friction.
- Electric motor: the rice milling machine is equipped with an electric motor 15 HP, 1450 R.P.M., 3 phase and 50 C/S.
- Unit control box: used to avoid the over load that may occur during operation.
- Power transmisson system: the power is transmitted through a system composed of two pulleys and three V-belts 22 x 13.5 mm. cross-section and 230 mm^2. Cross sectional area for each. The driving pulleys can be changed to obtain the required roller speed. The roller speeds of 300, 450 and 550 R.P.M. were considered. The other pertient dimensions are as indicated in Fig.(1). Paddy rice was cleaned through the following cleaning equipments:

1. Sieve separator: used to separate straws, mud balls, sand and foreign seeds from the paddy rice.
2. Air aspiration: used to separate dust, small straws, light grains and other light particles.
3. Magnet: used to separate the metal parts from the paddy rice.

MATERIALS

A samples of paddy rice used in this work was taken from the rice japanese variety. It was obtained from the Provience of Agriculture Behera Governorate, Egypt.

MEASURING DEVICES

The following measuring devices as that shown in Figs.(2-a) and (2-b) were used in the present work:

1. Wattmeter: to measure the power consumption, its range from 0-375 watt and its accuracy 2.5 watt.
2. Current transformer: to reduce the input current to the wattmeter (type ONF 040099).
3. Portable digital tachometer: for measuring the number of revolutions of the machine (type PR 9131/00). It is speed range 1 : 9999 R.P.M. and accuracy $\pm$ 0.2% digit.
4. Calibrated torque transducer: to measure the required torque-PHILIPS type (PR 9380 R/50).
5. Multi-channel recorder- PHILIPS type (PR 9034).
6. Stopwatch: to measure the time period.

EXPERIMENTAL PROCEDURE

a. A quantity, W, kg of paddy rice was taken and put in the feed hopper to be fed in order to keep the feed rate is a constant as possible. The time during which the above quantity is fed was measured using a stopwatch

Then,

The feed rate, R_f, = $\frac{W}{T}$ Kg/min

b. During the experiments, the machine speed, the power consumed and the required torque were measured using a digital tachometer, wattmeter and calibrated torque transducer respectively.

c. Ten samples, each between 30-70 grains, of white rice (product) were taken at random to determine the visible grain damage percent as follows:

Visible damage percent = $n_d/n_t \times 100$

Where,

n_d = the number of damaged grains;

n_t = the total number of sample grains.

d. The whitening roller speed was changed using different reduction ratios of power transmission.

e. The above steps were repeated at each speed and moisture content (M.C.).

RESULTS AND DISCUSSION

MACHINE PERFORMANCE AT SPEE OF 450 R.P.M. AND MOISTURE CONTENTS 13% AND 15.6% (w.b.)

In Figs.(3), (4), and (5), the relations between the Machine performance parameters (power consumption, P_m, required torque, T_R, and grain damage G.D.) and the feed rate, R_f, at different moisture contents are given. It is shown in Fig.(3), that the power consumption at no load is given as 2 Kw. It can be also seen that the consumed power increases with the increase in the feed rate. It is thought that the increase of power consumption is logically accompanied by an increase in the feed rate. The relationship between the feed rate, R_f, and the machine performance parameters(required torque, T_R, and roller speed, N_R) were found statistically from the experimental results as follows:

$$T_R = 4.91\ e^{0.155R_f} \qquad \text{Kg.m.} \qquad (1)$$

$$N_R = 449.12 - 2.794\ R_f \qquad \text{R.P.M.} \qquad (2)$$

The above relations are given at M.C. = 13%, however at M.C. = 15.6% the relations will be given as:

$$T_R = 4.91\ e^{0.1625\ R_f} \qquad \text{Kg.m.} \qquad (3)$$

$$N_R = 449.24 - 2.818\ R_f \qquad \text{R.P.M.} \qquad (4)$$

As indicated in eqs.(1) and (3), the torque of 4.91 Kg.m at no load. It can also be given by the vertical value of Fig.(3) at R_f = 0. It is clear that the required torque increases exponentially with the increase in the feed rate. Also, it can be seen that the increase in the required torque is greater at 15.6% M.C. than that at 13% M.C. It is logically that the increase in the feed rate and a decrease in the moisture content M.C.

As indicated in eqs.(2) and (4), it is clear that the whitening roller speed decreases with the increase in the feed rate. Also, it can be noticed that the rate of decrease in the roller speed is greater at 15.6% M.C. than that at 13% M.C.

With regard to the visible grain damage, Fig. (4) shows that when the M.C.= 13% the grain damage percent generally decreases with the increase in the feed rate until it reaches a minimum value of (17%) at R_f = 6.4 Kg/min whereas when the M.C. = 15.6%, it reaches a minimum value of (16.4%) at R_f = 6.67 Kg/min. For both moisture contents, the grain damage increases with a further increase in feed rate. From the same figure it can be seen that the values of the grain damage percent are greater at M.C. = 13% than those at M.C. = 15.6%. This may be attributed to the fact that the drier grains are more brittle at M.C. = 13% than those at M.C.= 15.6%.

One of the most important performance parameters is the energy required per unit weight of rice. This parameter may be termed "Unit energy" (U) hence,

$$U = \frac{P_m}{R_f}$$

where,

P_m = motor power consumed kw.

As shown in Fig.(5), the relation between the feed rate and the unit energy consumed at M.C. of 13% decreases rapidly at first until it reaches a minimum value (optimum value) of 5700 Kg.m/Kg (0.018 Kw/Kg) at feed rate of 6.6 Kg/min. Also, at M.C. = 15.6%, the optimum feed rate R_{fop} as 6.1 Kg/min has been graphically determined from Fig.(4) at the unit energy (U) as 5040 Kg.m/Kg (0.0137 Kw/Kg). The values of unit energy are greater at M.C. = 15.6% than those at M.C. = 13%. This may be attributed to the increase of power consumption which is greater at M.C. = 15.6% than that at M.C. = 13%.

MACHINE PERFORMANCE AT SPEEDS OF 350 AND 550 R.P.M., AND M.C. OF 13%

The relationship between the feed rate, R_f, and the machine performance parameters (required torque, T_R, and roller speed, N_R) were found statistically from the experimental results as follows:

$$T_R = 5.403 \ e^{0.171 R_f} \qquad \text{Kg.m.} \qquad (5)$$

$$N_R = 348.82 - 2.586 R_f \qquad \text{R.P.M.} \qquad (6)$$

The above relations at speed of 350 R.P.M., however at speed of 550 R.P.M., the relations will be:

$$T_R = 4.01 \ e^{0.178 R_f} \qquad \text{Kg.m.} \qquad (7)$$

$$N_R = 548.01 - 2.826 R_f \qquad \text{R.P.M.} \qquad (8)$$

Eqs.(5) and (7) are presented in Fig.(6). It is clear that the required torque increases exponentially with an increase in the feed rate. Also, it can be seen that the rate of increase in the required torque is greater at speed of 350 R.P.M. than that at speed of 550 R.P.M.

Fig.(7) shows the relation between the feed rate and the unit energy consumed. From this figure it is clear that the values of unit energy are greater at speed of 550 R.P.M. than those at 350 R.P.M. Also, the optimum feed rate (R_{fopt} = 6.1 Kg/min) at speed of 350 R.P.M. has been graphically determined from Fig.(7), at which the unit energy (U) as 5060 Kg.m/Kg (0.014 Kw/Kg), compared with the value of (R_{fopt} = 6.85 Kg/min) at speed of 550 R.P.M., and the unit energy, U, was found to be 6400 Kg.m/Kg (0.0174 Kw/Kg).

Fig.(8) shows the relation between the feed rate and the grain damage percent. From this figure it is clear that the values of grain damage percent are greater at speed of 550 R.P.M., than those at 350 R.P.M. This may be attributed to the impact between the grains and the roller surface is greater at speed of 550 R.P.M., than that at 350 R.P.M.,Also, this figure shows that

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when N_R = 350 R.P.M., the grain damage percent decreases with the increase in the feed rate until it reaches a minimum value of (16.2%) at R_f = 17 Kg/min, whereas when N_R = 550 R.P.M., it reaches a minimum value of (22.2%) at R_f = 6.67 Kg/min.

INTERACTION OF FACTORS AFFECTING PERFORMANCE

The factors Affecting performance are, feed rate, R_f, whitening roller speed, N_R and moisture content, M.C. The performance parameters are the power consumption, P_m, required torque, T_R, grain damage, G.D., and the unit energy consumed, U,. The effect of these factors will be considered in collaboration with other factors on each of the performance parameters.

Unit Energy

The unit energy consumed may be considered as a decisive factor in operation. It is affected by many factors. The prominent of which are the factors considered in this work, R_f, N_R and M.C. It is to decrease rapidly at first level of feed rate and then increases. It is indicated from this figure that the values of unit energy are great at high speeds at 13% M.C. The same argument holds true at 15.6% M.C.

With regard to the optimum feed rate, it is affected by the factors affecting unit energy. As for the roller speed, N_R, it is shown from Fig.(7) that the optimum feed rate is great at low value of moisture content.

Grain Damage

Grain damage may be considered an important performance parameter. It is affected by many factors, the prominent of which are the factors considered in this work, R_f, N_R, and M.C. Fig.(8) shows the relation between the feed rate, R_f, and the grain damage, G.D. From this figure, it is clear that the grain damage generally decreases as the feed rate increases until it reaches a minimum value at an optimum value of feed rate and then increases. Also, this figure indicates that the values of grain damage are greater at high roller speeds. This may be attributed to the great impact between the grains and the roller surface at high speeds. Also, Fig.(8) shows that the values of grain damage are greater at low value of moisture content. This may be attributed to the fact that the dry grains are more brittle than the wet ones grains.

CONCLUSIONS

From the experimental results the following conclusions may be drawn:

1. The unit energy decreases as the feed rate increases until it reaches an optimum value (minimum value) and then increases.
2. The values of unit energy consumed is always high at high speeds and low moisture contents.
3. As the feed rate increases the grain damage decreases until it reaches an optimum value and then increases.
4. As the moisture content (M.C.) of paddy rice (raw material) increases the grain damage, G.D., decreases at all roller speeds.
5. The values of grain damage is always high at low moisture content.
6. The optimum value of roller speed for whitening process is found to be 450 R.P.M., at M.C. = 13%.
7. Feed rate of (6.5 Kg/min) is found to be an optimum value at M.C. = 13% and 450 R.P.M.

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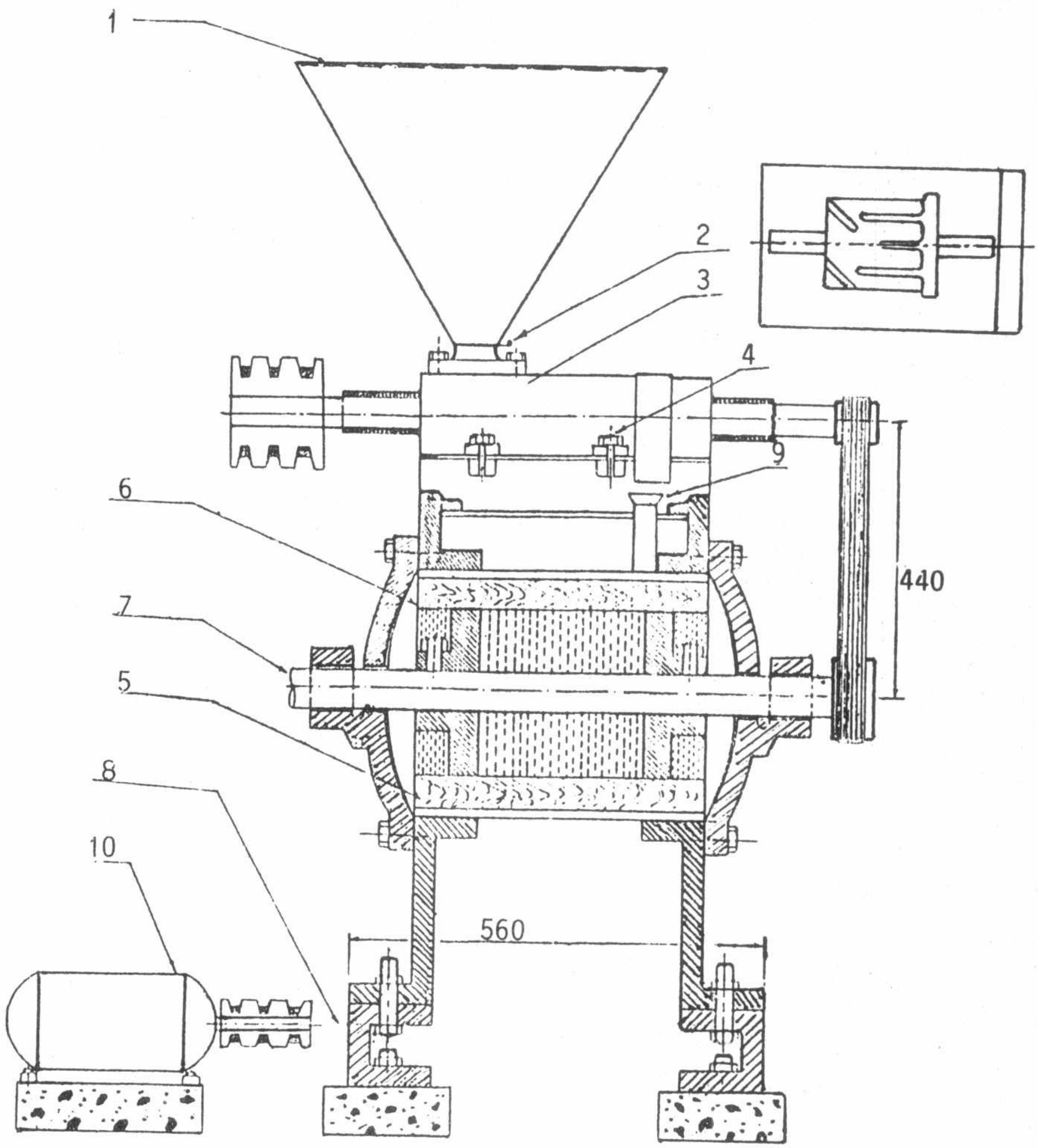

10. Electric Motor 9. Husked Rice Hopper 8. Frame 7. Brush Shaft
6. Perforated Crib 5. Brushed Roller 4. Husked Knief
3. Husked Roller 2. Feed Regulator 1. Feed Hopper

Fig.(1) Sectional elevation through the rice Milling M/C.

DIM. IN MM

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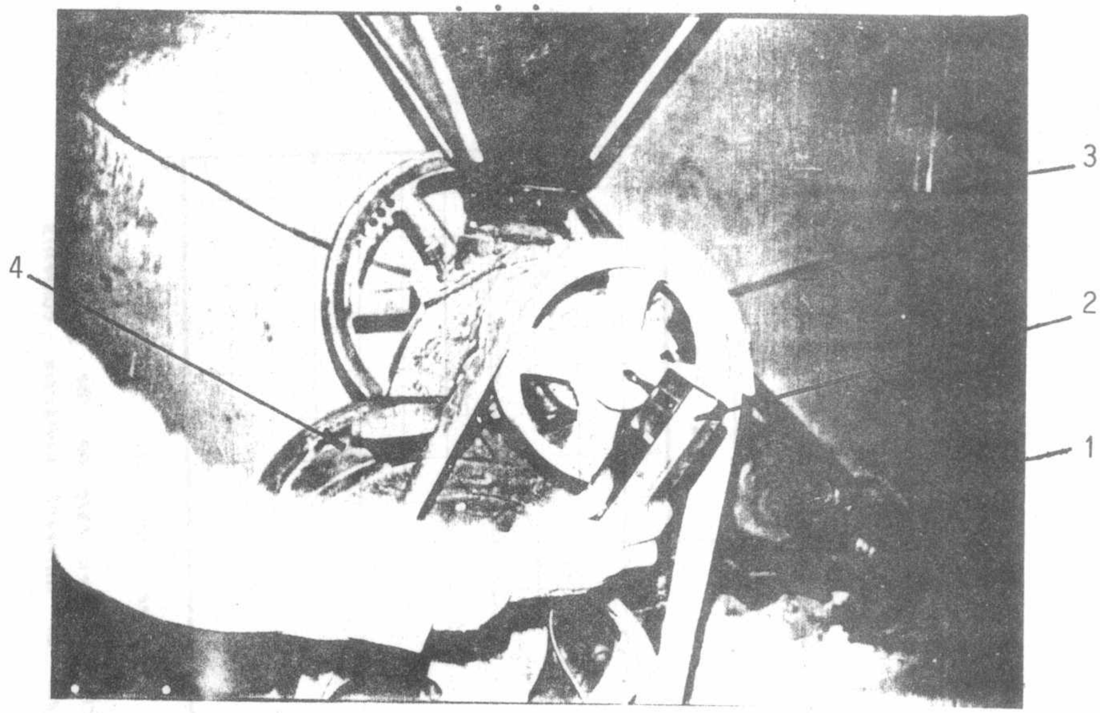
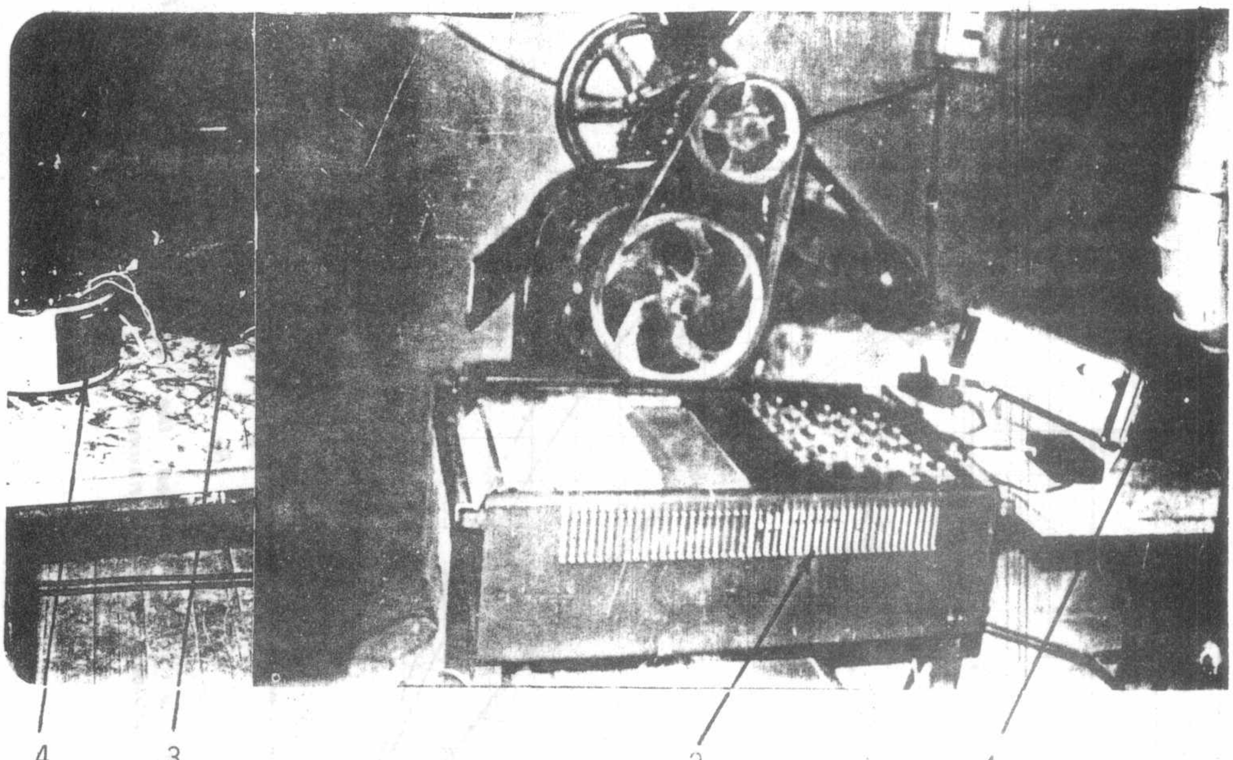


a

1. Torque transducer 2. Tachometer. 3.Unit control box.
4. The rice milling machine.



b

1.Frequency bridge 2. Multi-channel recorder. 3. Wattmeter
4. Current transformer.

Fig.(2-a,b) Experimental set-up

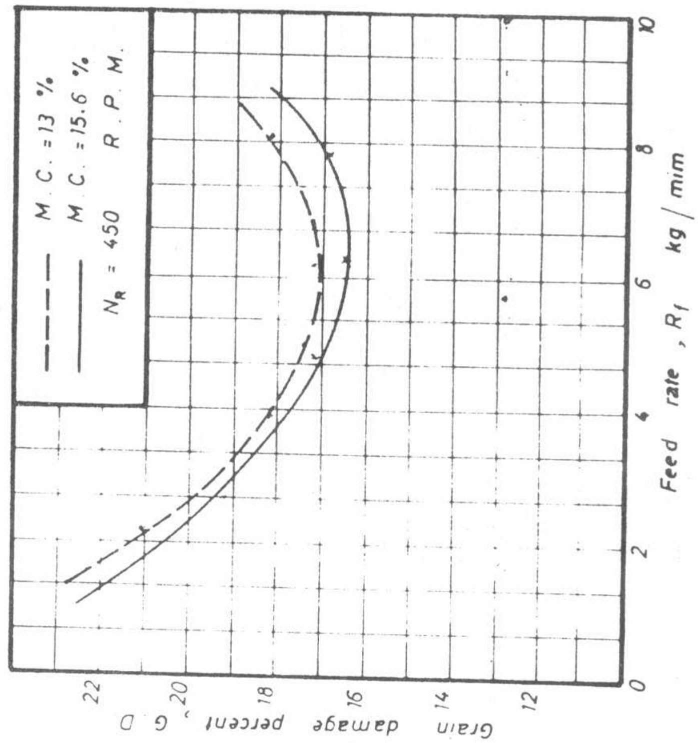


Fig.(4) Effect of feed rate on the grain damage percent at different moisture contents.

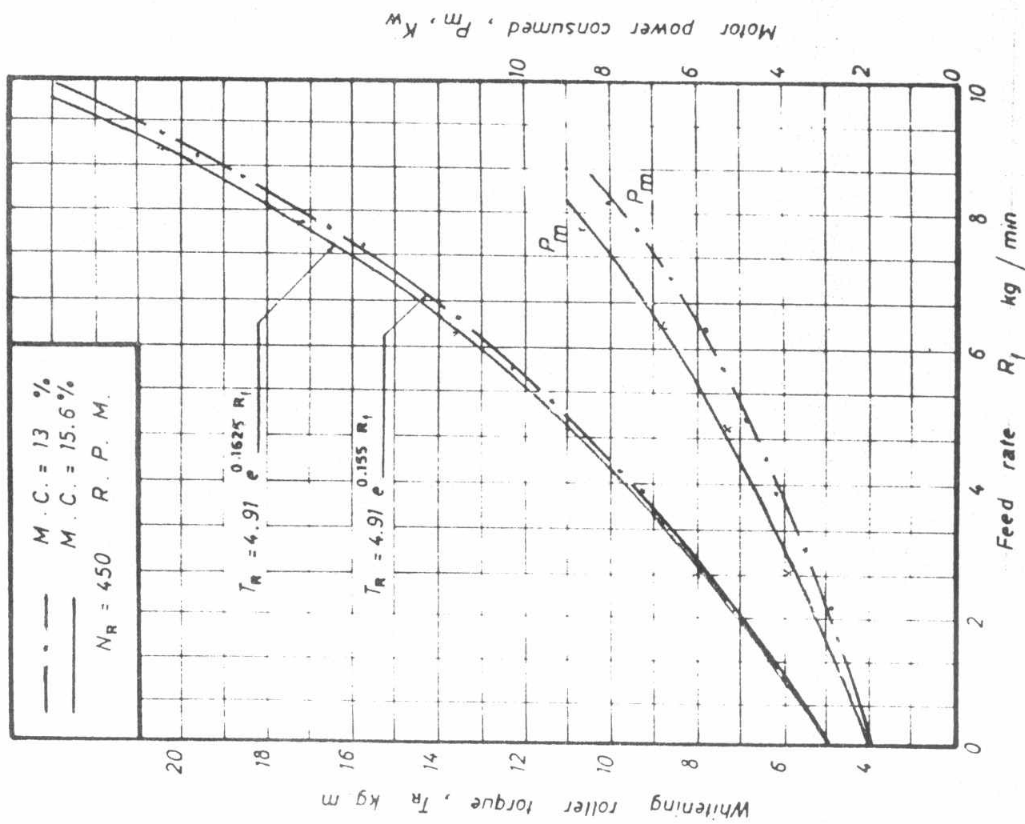


Fig.(3) Effect of feed rate on the required torque and motor power consumed.

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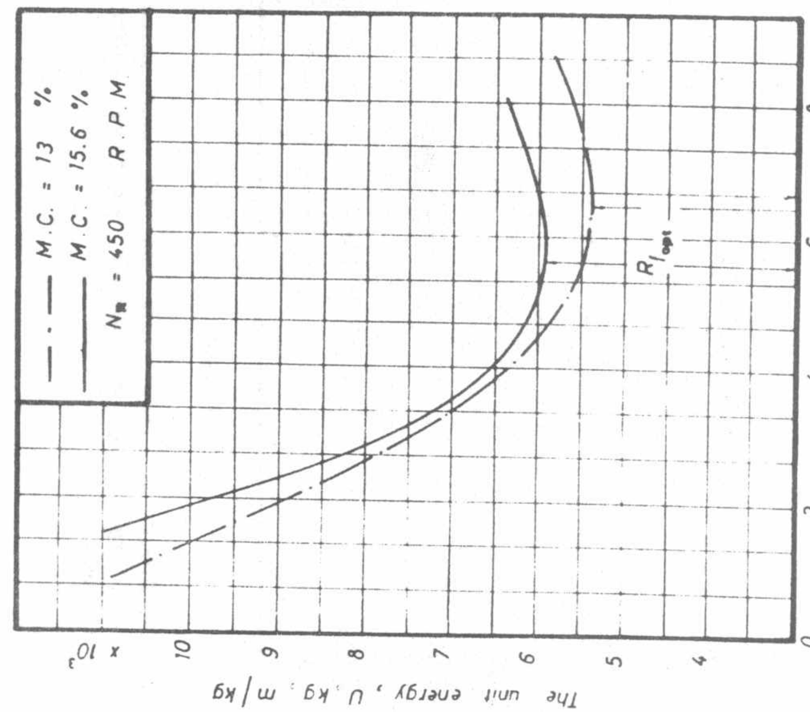

Fig.(5) Effect of feed rate on the unit energy consumed at M.C. = 13 % and 15.6 %.

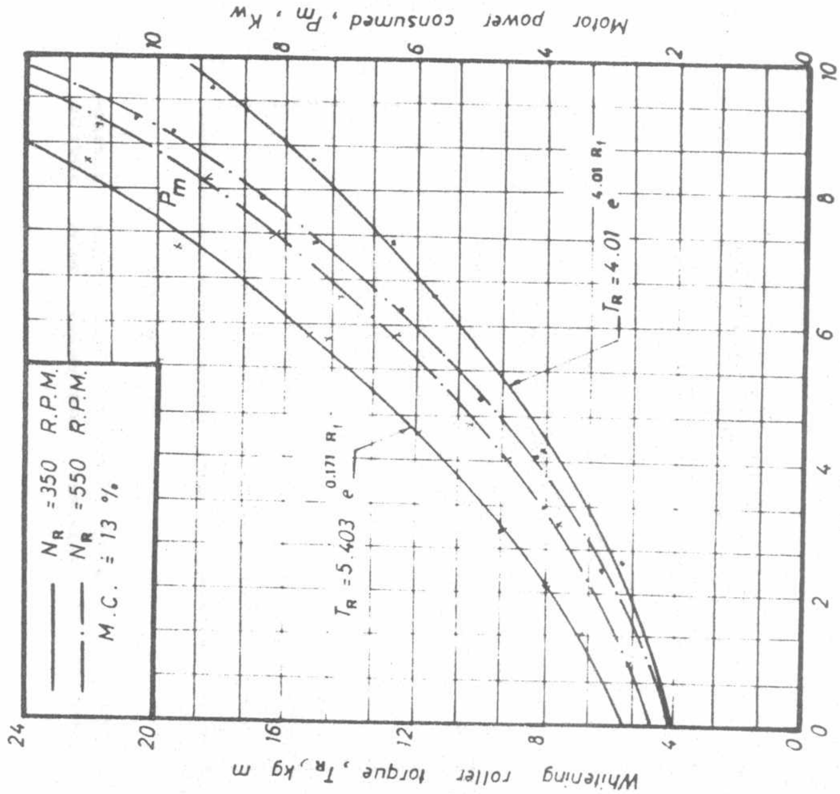

Fig.(6) Effect of feed rate on the required torque and motor power consumed.

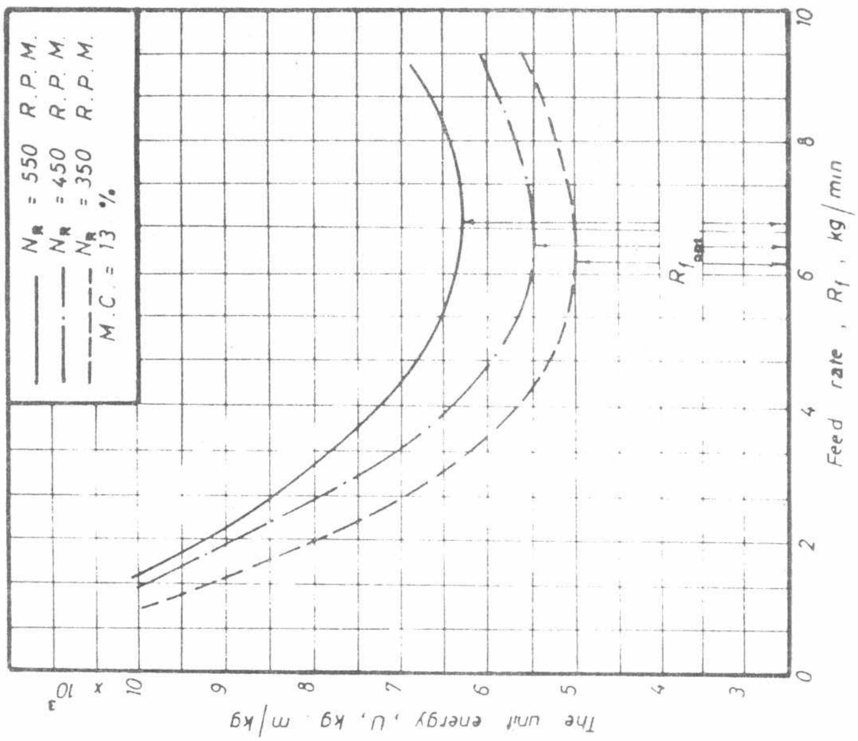

Fig.(7) Effect of feed rate on the unit energy, U, kg . m/kg at different whitening roller speeds.

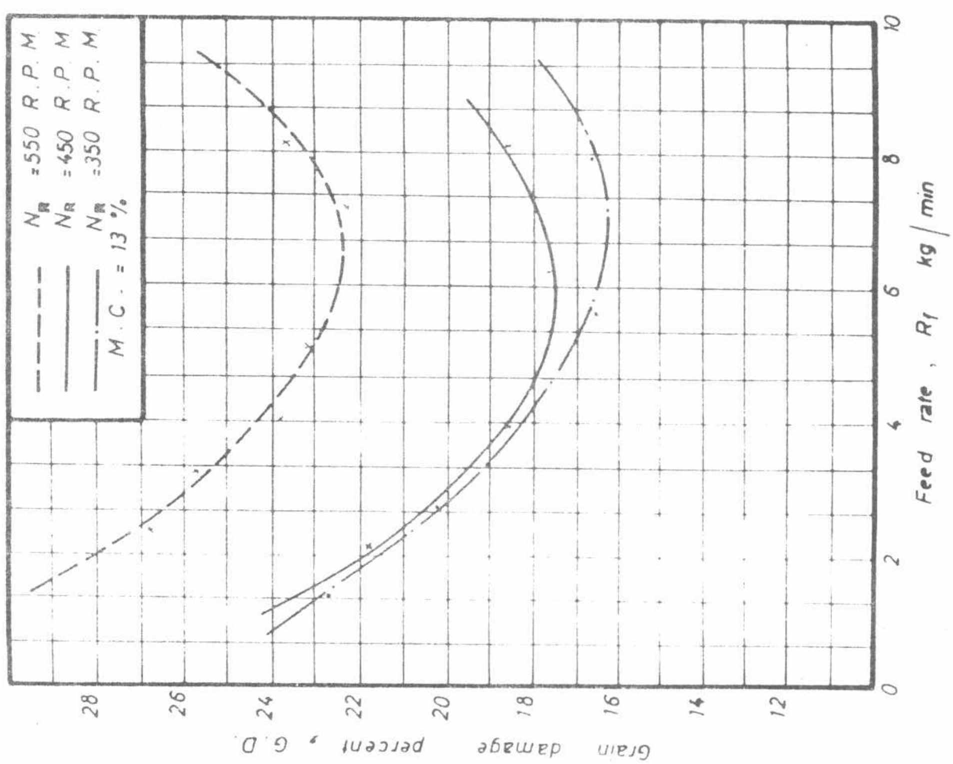

Fig.(8) Effect of feed rate on the grain damage percent at different whitening roller speeds.