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ANALYZING THE IMPACT OF COMPENSATING WINDING REMOVAL ON STARTING TORQUE IN UNIVERSAL MOTORS FOR PALM OIL MILLING MACHINES

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Abstract: This study investigates the effect of removing compensating windings on the starting torque performance of industrial palm oil milling machines using a universal machine model. Palm oil milling machines are essential in the processing of palm fruits, performing critical operations such as raw material reception, sterilization, threshing, digestion, pressing, clarification, and drying to produce refined palm oil. A key component in the reliable operation of these machines, especially under varying and heavy load conditions, is the presence of compensating windings. These windings are embedded in the field pole faces of electrical machines to counteract the armature reaction by carrying armature current, thereby minimizing magnetic field distortion.
The removal of compensating windings can result in increased brush arcing and erosion, particularly in machines subjected to weak fields, high torque demands, and frequent load variations or reversals. This is of particular concern in palm oil milling, where mechanical stress and operational reliability are critical for consistent production output. Our findings suggest that uncompensated machines exhibit decreased starting torque and higher maintenance issues due to electrical noise and brush wear, leading to potential threats in production efficiency and equipment lifespan. The study emphasizes the need to maintain or improve compensation mechanisms in motor design for industrial applications in the palm oil sector.

Keywords: Compensating Windings, Palm Oil Milling, Universal Machine, Starting Torque, Armature Reaction

1.0 INTRODUCTION

Industrial palm oil milling machines starting torque effect of removing compensating winding using universal machine is presented. The palm oil milling plant machine is an equipment use for processing of raw material reception, sterilizing, threshing, digesting, pressing, clarifying, drying and the output product is palm oil. [1, 4, 5]
Compensation machine windings are winding in the field pole face plate that carries armature current to reduce stator field distortion. [3, 7, 8] It reduce brush arcing and erosion in machine that are operates with weak fields, variable heavy loads and reversing operations. Uncompensated windings of industrial palm oil milling machines have received negative threat in oil production.

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The starting torque of universal machine is determined by the current that flows through the armature and field windings. [3, 10] The inductive reactance of these windings, the alternating current (AC) starting current is always less than that of direct current (DC) starting current. [4, 9]. Thus, the starting torque on AC power will be lower than that of starting torque on DC power. The compensating winding has a very great important role to play of reducing the overall reactance of the machine. The compensating windings also has the ability of opposing armature reaction, thereby improves commutation. [2, 6, 8]. The universal machine that is not compensated has the ability to lose most of its power and worsen brushes sparking. [5, 6, 7]

2.0 Laboratory Investigation on Industrial Palm Oil Milling Universal Machines

A laboratory experiment was carried out in the standard research UNIPORT laboratory to investigate the industrial palm oil milling machines starting torque effect of removing compensating winding using universal machine.

The materials, instruments and components used are: (1) Universal Machine, (2) Power Supply, (3) Electro-dynamometer, (4) AC Metering current module (2.5A, -8.0A), (5) AC Metering voltmeter module (100V-250V), (6) DC Metering Volt-Amps (200V, 2.5-5A), (7) Hand Tachometer, (8) Connecting leads and (9) Timing belt. The course of carrying out the investigation on industrial palm oil milling universal machines starting torque effect of removing compensating winding using universal machine. A high-level peculation was observed at every laboratory experiment as high voltage was present in the laboratory. No connection was made with power 'ON' at every experimental connection, and power must be switch 'OFF' after connecting each individual experimental connection.

3.0 Industrial Palm Oil Milling Universal Machines Starting Torque for DC operation

Using the materials, instruments and components as stated above, the industrial palm oil milling universal machine connection for DC operation is shown in figure1. The power was turn 'ON' after connection and it was adjusted to 30V using the control knob on the power supply. At the 30V power supply the line current was less than 1.0ampere and the compensating winding was producing flux in the same direction as the armature thereby increasing the inductance and reactance. It was also observed that the armature revolves and the brushes were not at exactly neutral position. As a result of this, an interchanged of the lead to armature winding was made and the system normalized and the line current was measured and recorded as 3.5A ac.

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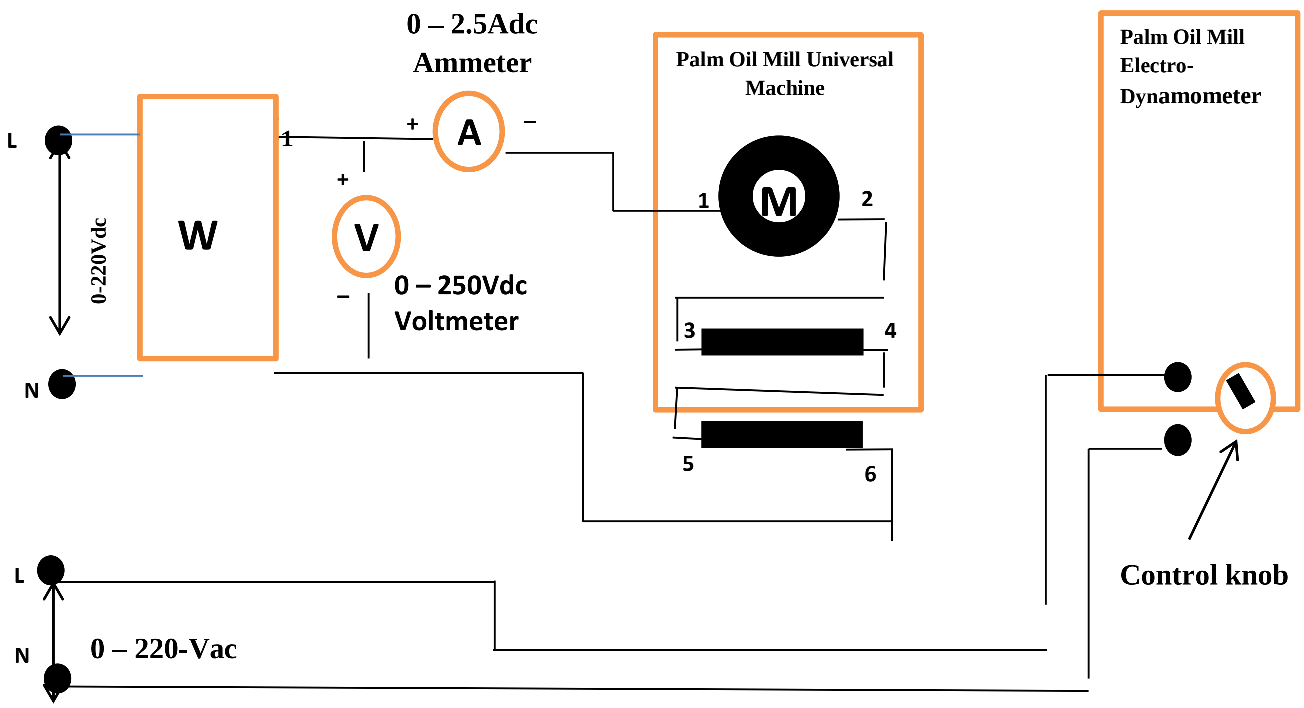

Figure1: Circuit diagram of industrial palm oil milling universal machine for DC operation

The electro-dynamometer was coupled to the industrial palm oil milling universal machine with timing belt. The input terminal of the electro-dynamometer was connected to 220 Vac terminal 1 and Neutral (N). The electro-dynamometer was adjusted to its full clockwise position to provide a maximum starting load for industrial palm oil milling universal machine and brushes were set to their neutral position. The machine was turned 'ON' and an adjustment was made as indicated on the voltmeter to 30V supply to industrial palm oil milling universal machine windings. The industrial palm oil milling universal machine current and the torque developed were recorded as current (I) = 3.7Amps dc and torque =16Ibf.in. The voltage was returned to zero and the power was turn 'OFF.

4.0 Industrial Palm Oil Milling Universal Machine for AC Operation

Using the materials, instruments and components, the industrial palm oil milling universal machine connection was reconnected for AC operation is shown in figure2. The power was turn 'ON' after connection and it was adjusted to 30V using the control knob on the power supply. The industrial palm oil milling universal machine current and the torque developed were recorded as current (I) = 1.4Amps ac and torque =1.6Ibf.in. The voltage was returned to zero and the power was turn 'OFF. It was observed from the result that the inductive reactance of the armature and field windings limits field current during AC operation. This reduced the AC starting torque drastically below the starting torque.

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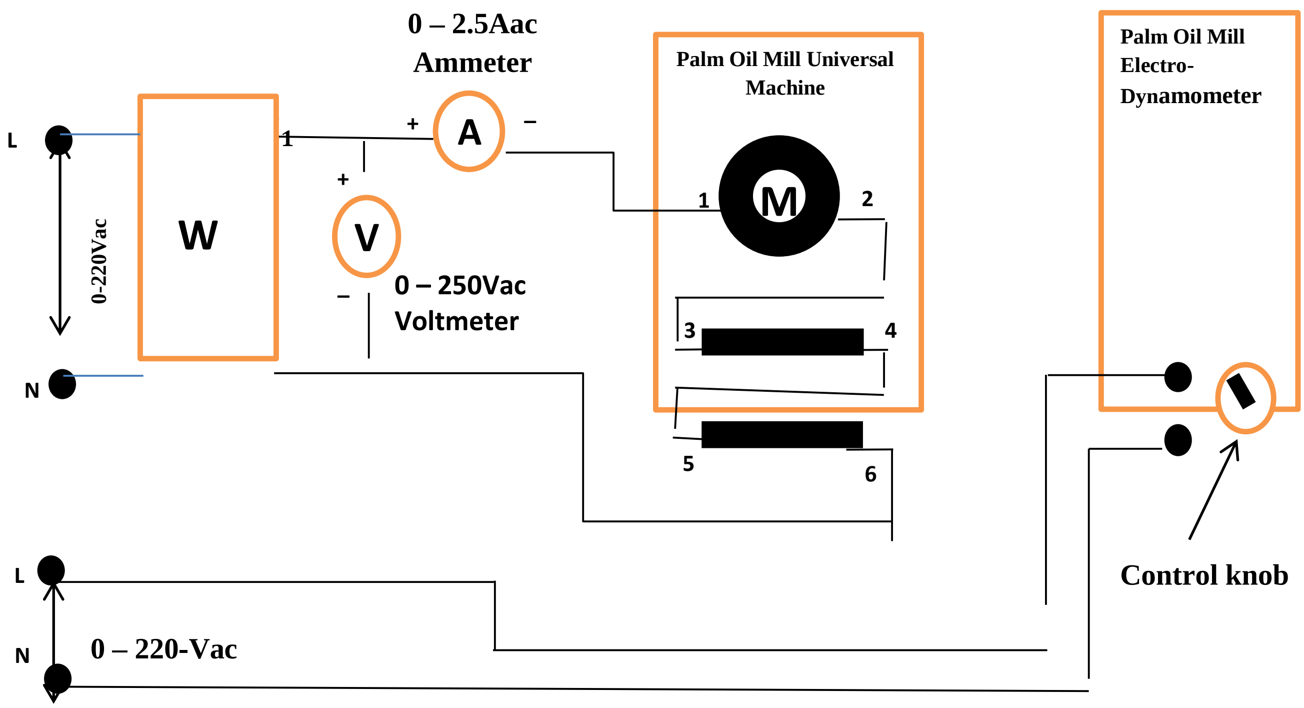

Figure2: Circuit diagram of industrial palm oil milling universal machine for AC operation

5.0 Industrial Palm Oil Milling Universal Machine for Uncompensated for AC Operation

Using the materials, instruments and components, the industrial palm oil milling universal machine connection was reconnected for uncompensated windings for AC operation by eliminating the compensating coil winding as shown in figure 3. The power was turn 'ON' after connection and it was adjusted to 220Vac using the control knob on the power supply and the electro-dynamometer to 3Ibf.in of the torque. The industrial palm oil milling universal machine for uncompensated operation the current and speed was recorded as current (I) = 2.4Aac and AC speed = 230rev/min.

The current is almost the same but the speed is much slower. Without the compensated windings for the industrial palm oil milling universal machine, the universal machine produces less power and more sparking at the brushes

7.0 Mathematical Model

The three main components of palm oil mill universal machine torque are: reluctance torque, Synchronous torque, Excitation torque. [3, 4, 7]

Palm oil milling universal machine *torque*

$$T_{em} = 1.5\,p\,(\lambda_d\, i_q - \lambda_q\, i_d) \qquad (1)$$

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Palm oil milling universal machine Reluctance Torque

$T_r = 1.5\, P\, (L_d - L_q) i_d i_q$ (2)

Palm oil milling universal machine *Synchronous Torque*

T_{syn} = 1.5 P ($L_{md}\, i_{kd} i_q$ - $L_{mq}\, i_{kq} i_q$) (3)

Palm oil milling universal machine *Excitation Torque*

T_{ex} = 1.5 P $L_{md}\, i_{fm} i_q$ (4)

Where P are pole pairs, assumed the line voltage are balanced,

The d-q voltages in terms of the load angle become,

$V_d = -V \sin\delta$ (5)

$V_d = V \cos\delta$ (6)

Stator phase current is related to the d-q currents [3, 9].

$i_{ax} = i_q$ (7)

$i_{bx} = -\frac{1}{2} i_q - \frac{1}{\sqrt{3}} i_d$ (8)

$i_{cx} = -\frac{1}{2} i_q + \frac{1}{\sqrt{3}} i_d$ (9)

8.0 Mechanical Model

The mechanical model of the palm oil mill universal machine which allows the inertia and Mechanical load torque to be incorporated, [1, 5, 7] swing equation equations (10-11),

$\dot{\delta} = \omega_b - \omega_r$ (10)

$\dot{\omega_r} = \frac{p}{jm} (T_{em} - T_L)$ (11)

$J_m \frac{d^2\theta_m}{dt^2} = T_c - T_L$ (12)

Decomposing equation (12) into two first order differential equation gives,

Pθ_m=ωm (13)

J_m (P ωm) = $T_c - T_L$ (14)

P ωm = $\frac{1}{J_m} (T_c - T_L)$ (15)

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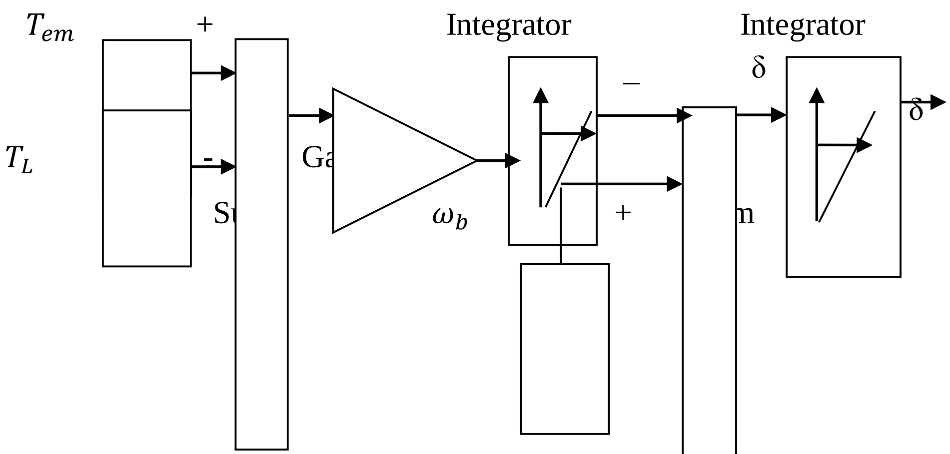

Figure 5: Mechanical model block diagram of Palm oil mill universal machine **Control**

Table 1: Laboratory Investigation Results on Industrial Palm Oil Milling Universal Machine for Compensated Operation.

S/NO.	CURRENT(I)	VA	P(WATTS)	SPEED (r/min)	HORSE POWER(hp)	TORQUE (Ibf.in)
1	1.8	226	208	3448	0	0
2	2.2	274	243	2548	0.120	3
3	2.8	246	288	1858	0.175	6
4	3.3	406	323	1388	0.188	9

Table2: Laboratory Investigation Results on Industrial Palm Oil Milling Universal Machine for Uncompensated Operation.

S/NO.	CURRENT(I)	P(WATTS)	SPEED (r/min)	HORSE POWER(hp)	TORQUE (Ibf.in)
1	1.5	238	4148	0	0
2	1.8	288	3298	0.155	3
3	2.3	358	2598	0.246	6
4	2.7	388	2198	0.313	9

Table 3: Industrial Palm Oil Milling Universal Machine Parameters in simulation

d-axis inductance,L_d	1.4Mh
q-axis inductance, L_q	2.8mH (1.4mH)
Stator windings R_s	0.6 Ω (1.2 Ω)

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Induced flux by magnet	0.12Wb
Number of poles, P	2
Rated Voltage, V	250 V
Rated frequency, f	50Hz
Combined rotor and load inertia, J_m	0.83Kgm^2
Shaft mechanical torque, T_l	3.2Nm

Source: [3, 5, 6, 7]

11.0 CONCLUSION

The DC and AC industrial palm oil milling universal machine for inductive compensation operation does not work at the same level of operation. The inductive compensation is effective only when the current is alternating. The performance is the same with compensating winding shorted as when it is open. While on the DC, the industrial palm oil milling universal machine draw more current and have severe sparking at the brushes.

At the 30V power supply, the line current was less than 1.0ampere and the compensating winding were producing flux in the same direction as the armature thereby increasing the inductance and reactance. The armature revolves and the brushes were not at exactly neutral position. As a result of this, an interchanged of the lead to armature winding was made and the system normalized and the line current was measured and recorded as 3.5A ac. When coupled to electro-dynamometer, the machine current and the torque developed were recorded as I=3.7Amps dc and torque =16Ibf.in

The industrial palm oil milling universal machine for uncompensated for AC operation the current and speed was recorded as current (I) = 2.4Aac and AC speed = 230rev/min.

Without the compensated windings for the industrial palm oil milling universal machine, the universal machine produces less power and more sparking at the brushes. While the industrial palm oil milling universal machine for uncompensated for DC operation the current and speed was recorded as current (I) = 2.5Aac and AC speed = 2680rev/min.

When the industrial palm oil universal machine was loaded up to 9Ibf.in for inductive compensation operation the current, speed and torque was recorded as current (I) = 2.4Aac, AC speed = 1430rev/min and AC torque = 9Ibf.in. It was observed that the sparking was the same when the industrial palm oil milling universal machine was conductively compensated. While the machine was on operation, the shorted compensating coil was removed by holding the wire with insulating material as a precaution. Industrial palm oil milling universal machine stalled as soon as the short was removed. The full power cannot develop when it is uncompensated. While for the industrial palm oil milling universal machine for inductive compensation for DC operation, the current, speed and torque was recorded as current (I) = 4.1Adc, DC speed = 2400rev/min and AC torque = 9Ibf.in. and there was no changed when the short was removed. This recommended for machines designers and operators of industries of Palm oil milling, fans and blowers, hair dryers, electric shavers, electric heir clippers,

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can openers, sewing machines, vibrators, coffee grinders, power screwdrivers, nut drivers, sabre saws, and hedge clippers.

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