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Performance Evaluation of Friction Belt Apparatus Using Indigenous Materials

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Abstract: *This project presents performance evaluation of a designed and constructed friction belt apparatus, using locally available materials. The aim is to explore the possibility of producing cheaper alternative testing apparatus for quality control laboratories and institutions in Nigeria. The locally produced friction belt apparatus has the main body frame ; pulley ; bearing ; stud ; hangers ; masses; Tommy bar ; and belts as components. The apparatus was tested with V-belt and flat belt with constant load as T_1 (kg) and varying load masses as T_2(kg) at different angles of wrap and thereafter compared with results using similar procedures on fabricated apparatus and standard imported friction belt apparatus. The comparisons were done, using graphical presentation to study the trend and t-Test was used to investigate the significant difference in the results. t-Test shows that, for flat belt experiment, t-Stat value (1.378189195303) is lesser than the critical value (2.17898812792408) and also for V-belt experiment, t-Stat value (1.06852895427649) is lesser than the critical value (2.17881279240828), for two tail analysis. These confirmed that there is no significant difference between the two results. (t-stat value < critical value). It was established that the result of the friction belt apparatus obtained for all the experiments carried out using standard imported apparatus and locally produced apparatus have no significant difference at 95% confidence limit. The production cost of the locally produced apparatus is ₦33,520.00k, as against the sum of $960.00 for the purchase of standard imported apparatus.*

Keywords: *Friction, belt, performance evaluation, Analysis of variance and t-test.*

I. Introduction and Concept

Man's quest for a better life has led him to various technological breakthroughs**.** Some of these breakthroughs are recorded in machine design, particularly in the area of power transmission in engines. Power transmission is a function of belt tension. Fatigue, more so than abrasion, is the culprit for most belt problems, due to stress from rolling around the pulleys. High belt tension, excessive slippage, adverse environmental conditions and belt overloads caused by shock, Vibration or belt slapping, all contribute to belt fatigue. (Attaway et al 1999). In some cases in machine design, in the past, belt tension with respect to the pulley diameter and surface on which the belt moves were not taken into cognizance therefore slip occurred and therefore maximum power transmission could not be achieved. Belt tension should be adjusted to belt type, size, and speed and pulley diameter. The equation that describes the relationship between tension ratio and angle of wrap is given as:

$$\mu = \frac{\ln(T_1/T_2)}{\theta}$$

Where μ describes the coefficient of friction, T_1 is the initial tension, while T_2 is that required to overcome friction, θ is the angle of wrap and μ is the coefficient of friction. It has been reported that for technological development in Nigeria to succeed, development and manufacture of most of the needed equipment and machines must be based on indigenous designs. (Charles – Owaba, 2009; Ismaila, 2008 and Akintayo, 2009). These will ensure conservation of foreign exchange earnings, maintainability and affordability to average Nigerians. In view of importance of the control of the friction between belts and pulley at various angles of wrap, to optimum power transmission of machine in Nigeria, it is therefore pertinent to explain the possibility of constructing an equipment to measure the tension require to overcome the coefficient of friction of different angels of wrap, using different types of belt such as Flat belt and V-belt. With the availability of this apparatus in the laboratories on large scales, Engineer will be equipped with the right information before lunching to go into the field of construction as properties of different belt at different angles of wrap with respect to apply tension would be known. This project present the performance evaluation of locally produced friction belt apparatus for the purpose of laboratory teaching aids and industrial application using indigenous materials in the Department of Mechanical Engineering, Ladoke Akintola university of technology, Ogbomoso. The apparatus was tested using two different belts viz: flat belt and V-belt.

Belt Theory

A change in belt tension due to friction forces will cause the belt to elongate or contract and move relative to the surface of the pulley. This motion is caused by elastic creep and is associated with static friction as opposed to static friction. The action at the driving pulley, through that portion of the angle of contact that is actually transmitting power is just that the belt moves slowly than the surface speed of the pulley because of the elastic creep Firbank et al (2001).

Belt Tension

In practice a spring loaded wheel pushing against the belt is used to tension the belt. The tension will be the same along its whole length and equal to F. When transmitting power, the driven wheel will be reluctant to turn and the driving wheel has to pull it and exert a torque on it. Consequently, the tension in the side pulling will increase to T_1 but the tension in the other side will decrease to T_2. The increase in tension on the tight side of the belt is equal to decrease on the slack side so the sum of the tensions remains the same (http://www.freestudy.co.uk).

Maximum Power Transmitted in Pulleys

The (tension) in a pulley belt increases with torque and power. The maximum power that a pulley system can transmit is ultimately limited by the strength of the belt material. If this is a problem then more than one belt should be used to share the load. If the belt does not break then t he possibility of the belt slipping exists and this depends upon the angle of lap and the coefficients of friction is the same on both wheels, then slippage will occur first on the smaller wheel. The power at which the belt slips is not the absolute maximum power that can be transmitted as more power can be transmitted with slippage occurring by using higher wheel speed.

The friction between the belt and the wheel is further affected by centrifugal force which tends to lift the belt off the wheel. This increases the likelihood of slippage. The friction between the belt and the wheel may be increased by the shape of the belt. A V-section or round section belt in a V-groove will grip better than a flat belt and is less likely to slip.

II. Materials and Methods

2.1 Material Selection

The materials used for the fabrication of the apparatus for measuring the friction belt apparatus were sourced locally. This is aimed at producing the machine at affordable and economic price, to make it readily available to Nigerians for quality control. The materials were selected based on the following factors: strength, availability, cost and comfort. The frame work of the apparatus is as shown in Figures 1.0.

2.2 Pulley

The construction of the pulley of the friction belt apparatus, mild steel was used which is readily available, even at cheaper cost. It has two machined grooves to suit a flat or V-belt and a rope. The pulley was made of diameter 150mm from mild-steel of a cylindrical pipe which also has thickness of 5mm. It has grooves for Flat belt and V-belt cut on it. At the centre was also cut a slot of15mm inside which the bearing was tightly fitted.

2.3 Bearing

They are manufactured to take pure radial loads, pure thrust loads, or a combination of two kinds of loads. A ball bearing is a type of rolling element bearing that uses balls to maintain the separation between the moving parts of the bearing. The purpose of ball bearing is to reduce friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. McGraw-Hill (2002),

2.4 Belt

This is a band of flexible material used in machinery to transmit motion or power. Flat belt and V-belt were used.

2.5 Hanger

The hanger which is made of mild-steel was fabricated using a cylindrical rod and sheet metal. This cylindrical rod was cut size to size and bents into shape of hanger to the top.

2.6 Beam

The beam of the apparatus was fabricated by welding cut-to-size sheet of the mild-steel. The length is 227mm, breadth 226mm and the width 60mm. The base is rectangular in shape, with specification of 227 x 226 x 60mm. A slot of 7mm was cut at the centre to accommodate the shaft force fitted into the pulley bearing.

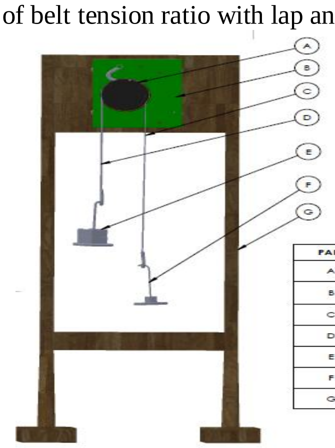
2.7 Frame

This was made of wood where the apparatus was mounted. The apparatus was bolted to the top of the frame to carry the apparatus to be tested. The masses which are the weight to be placed on the beam were purchased and was used in its original form and not fabricated.

2.8 Experimental Methods

The apparatus was subjected to various testing condition in the laboratory using different belts such as Flat belt and V-belt separately. A constant load T_1 was loaded on the side of the apparatus and varying mass T_2 was loaded on the hanger on the other side of the apparatus gradually until the exact mass that will overcome friction posed by constant mass 15 kg hanging on the belt against the pulley. The procedure was repeated five times for each angle of wrap such as 30°, 60°, 90°, 120°, 150°, 180°, and 210° respectively.

All the procedures adopted for the fabricated apparatus were repeated for the standard apparatus. The results of standard apparatus and fabricated apparatus were compared using t-Test to indicate if there is significant difference between the results. This apparatus consists of a wall mounted fixed pulley with a loaded belt. The equipment is part of a range design to both demonstrate and experimentally confirm basic engineering principles. It is used to carry out experiments which help to investigate: the ratio of belt tension when a rope passes over pulleys of different V-angles, to determine the coefficient of friction between the pulley and cotton rope, and to assess the variation of belt tension ratio with lap angle.



PART	DESCRIPTION
A	BLINDED PULLEY WITH TWO BEARINGS
B	SLOT
C	STRING
D	BELT
E	SLOTTED WEIGHT
F	HANGER
G	FRAME

Figure 1.0 Experimental set-up of friction belt apparatus

III. Result And Discussion

Five consecutive experiments were done for each angles of wrap using 15kg as constant mass T_1 and values for T_2 were obtained for Flat belt as indicated in Figure 2.0 for the standard apparatus and Figure 3.0 for the fabricated apparatus. Figure 2.0 and 3.0 show that effect of angle of wrap, θ on the overcoming tension T2 of a flat belt, it shows that increase in the angle of wrap from 30^o to 210^o reduces the overcoming tension in both apparatus.

The results obtained on the two apparatus using V-belt are shown in characteristics profile in Figure 4.0 for the standard apparatus and Figure 5.0 for the fabricated apparatus. It is evident that overcoming tension T_2 is inversely proportional to the angle of wrap, θ that is increase in angle of wrap yields decrease in overcoming tension in the pulley for V-belt.

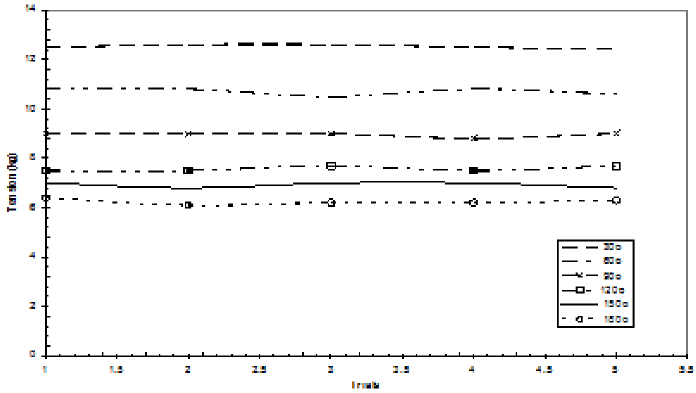


Figure 2.0 Plot of varying angles of rap and tension in flat belt of the standard apparatus

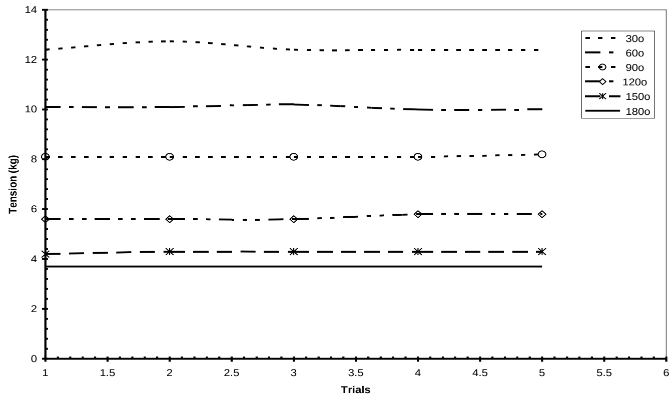


Figure 3.0 Plot of varying angles of rap and tension in flat belt of the fabricated apparatus

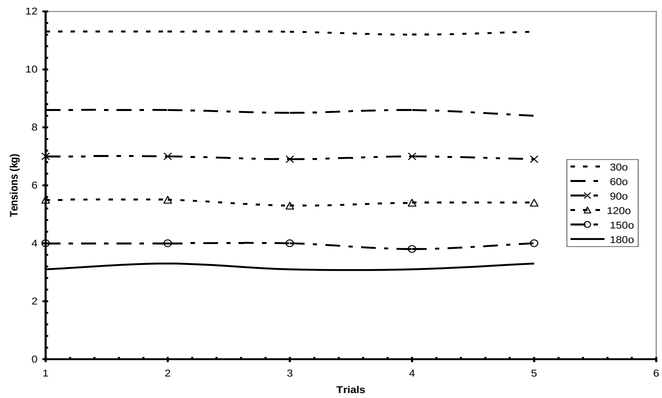


Figure 4.0 Plot of varying angles of rap and tension in V - belt of the standard apparatus

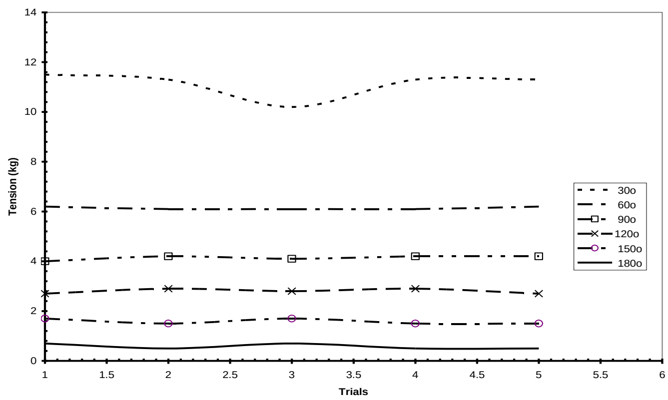


Figure 5.0 Plot of varying angles of rap and tension in V - belt of the fabricated apparatus

The natural logarithms for the tension ratio for each angle of wrap were obtained on the apparatus (imported and locally fabricated) using flat and V -belt. The results are presented in Figure 6.0 and Figure 7.0. Figure 6.0 shows graphical comparison of $\ln(T_1/T_2)$ for standard apparatus and fabricated apparatus results using flat belt. Figure 7.0 shows graphical comparison of $\ln(T_1/T_2)$ for standard apparatus and fabricated apparatus results using V belt. The two figures show characteristics performance profile for both imported apparatus and locally fabricated apparatus using flat belt and V belt has the same trend pattern. The results were further subjected to statistical test to affirm if there is any significant difference in the results obtained in locally fabricated and imported apparatus as shown in Table 1.0 and Table 2.0.

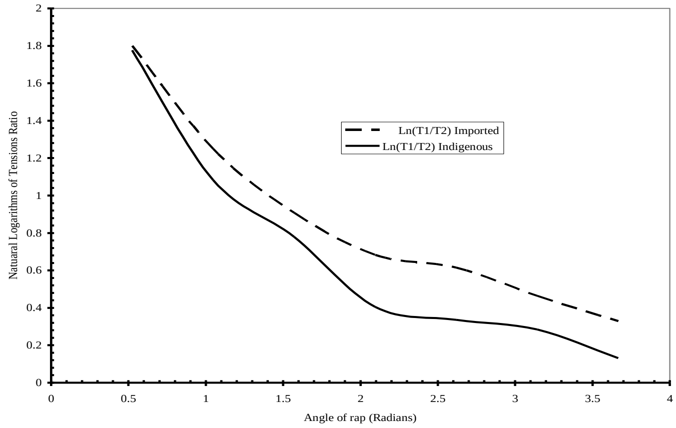


Figure 6.0 Plot of natural logarithms of the tension ratio against angle of wrap using flat belt

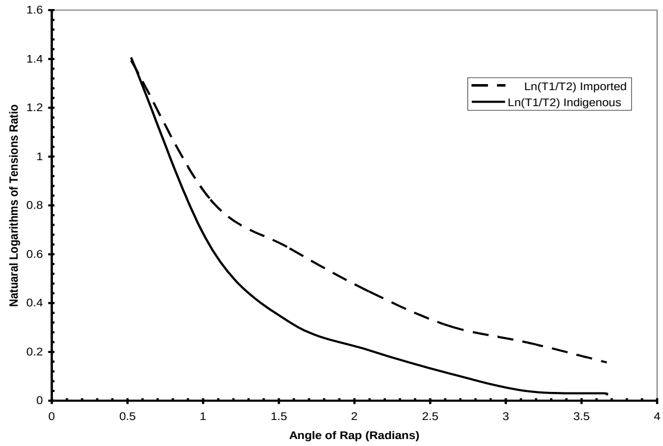


Figure 7.0 Plot of natural logarithms of the tension ratio against angle of wrap using V belt

Table 1.0 shows t-test result analysis for comparing of $\ln(T_1/T_2)$ obtained on the two apparatus using flat belt at 95% confidence limit and Table 2.0 shows t-test result analysis for comparing $\ln(T_1/T_2)$ obtained on the two apparatus using V belt at 95% confidence limit

Table 1.0: t – Test Analysis Results Obtained for Flat Belt Experiment

	Imported	*Indigenous*
Mean	0.864142857	0.685
Variance	0.26133581	0.337671
Observations	7	7
Hypothesized Mean Difference	0	

Df	12
t Stat	0.612396411
P(T<=t) one-tail	0.275851878
t Critical one-tail	1.782287548
P(T<=t) two-tail	0.551703756
t Critical two-tail	2.178812827

Table 1.0 shows that the values of t-Stat Calculated, 1.378189195303 is less than the critical values 1.782286744856 and 2.17898812792408 for both one tail and two tails respectively. This implies that there is no significant difference in the results of natural logarithms of the tension ratio for varying angle of wrap on the two apparatuses (imported and locally fabricated) using flat belt.

Table 2.0: t–Test Analysis Results Obtained for V-Belt Experiment

	Imported	*Indigeous*
Mean	0.518625	0.346375
Variance	0.180101125	0.225523125
Observations	8	8
Hypothesized Mean Difference	0	
Df	14	
t Stat	0.764966239	
P(T<=t) one-tail	0.228496832	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.456993663	
t Critical two-tail	2.144786681	

Table 2.0 shows that the values of t-Stat calculated 1.06852895427649 is less than the critical values 1.78228674485581 and 2.17881279240828 for one tail and two tails respectively. This implies that there is no significant difference in the results of natural logarithms of the tension ratio for varying angle of wrap on the two apparatuses (imported and locally fabricated) using flat belt at 5% significant level.

The coefficients of friction for varying angle of wrap were determined on the two apparatuses (imported and locally fabricated) using flat and V -belt. The results are presented in Figure 8.0 and Figure 9.0. Figure 8.0 shows graphical comparison of coefficients of friction for varying angle of wrap on standard apparatus and fabricated apparatus results using flat belt. Figure 9.0 shows graphical comparison of coefficients of friction for varying angle of wrap on standard apparatus and fabricated apparatus results using V belt. The two figures show characteristics performance profile for both imported apparatus and locally fabricated apparatus using flat belt and V belt has the same trend pattern. The results were further subjected to statistical test to affirm if there is any significant difference in the results obtained in locally fabricated and imported apparatus as shown in Table 3.0 and Table 4.0.

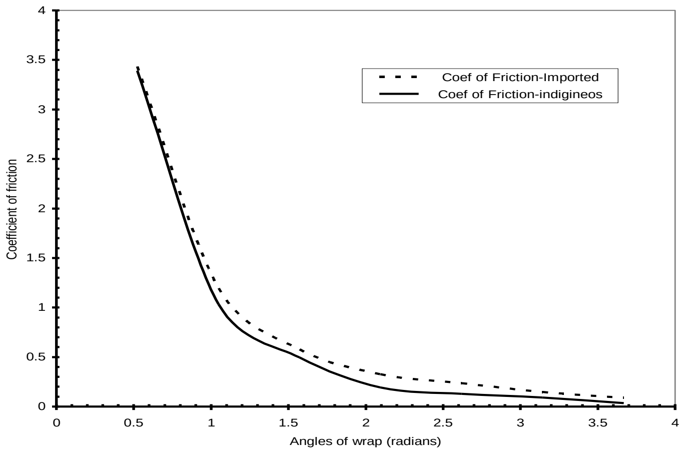


Figure 8.0 Plot of Coefficient of friction versus varying angles of wrap for flat belt

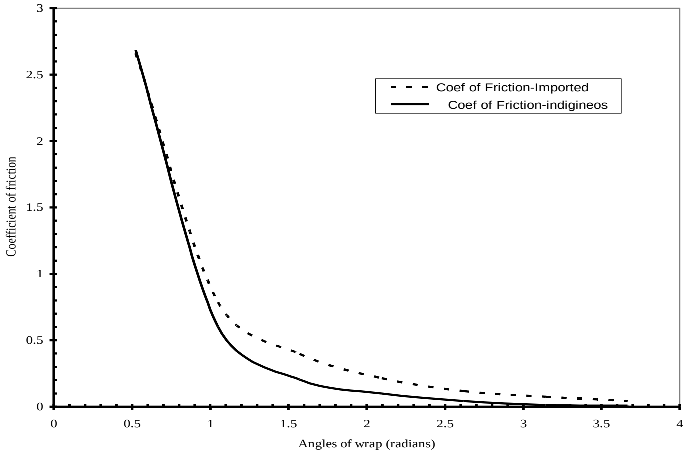


Figure 9.0 Plot of coefficient of friction versus varying angles of wrap using V belt

Table 3.0 shows t-test result analysis for comparing of coefficient of friction obtained on the two apparatus using flat belt at 95% confidence limit and Table 2.0 shows t-test result analysis for comparing coefficient of friction obtained on the two apparatus using V belt at 95% confidence limit

Table 3.0: t – Test Analysis of coefficient of friction Results Obtained for Flat Belt Experiment

	Imported	*Indigenous*
Mean	0.857717707	0.766791288
Variance	1.433038168	1.45995789
Observations	7	7
Hypothesized Mean Difference	0	
Df	12	
t Stat	0.1414377	
P(T<=t) one-tail	0.444935432	
t Critical one-tail	1.782287548	
P(T<=t) two-tail	0.889870865	
t Critical two-tail	2.178812827	

Table 3.0 shows that the values of t-Stat Calculated, 0.1414377 is less than the critical values 1.782287548 and 2.178812827for both one tail and two tails respectively. This implies that there is no significant difference in the coefficient of friction for varying angle of wrap on the two apparatuses (imported and locally fabricated) using flat belt.

Table 4.0: t – Test Analysis of coefficient of friction Results Obtained for V Belt Experiment

	Imported	*Indigenous*
Mean	0.542022416	0.457470814
Variance	0.795965552	0.848989142
Observations	8	8
Hypothesized Mean Difference	0	
Df	14	
t Stat	0.186461796	
P(T<=t) one-tail	0.427378777	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.854757554	
t Critical two-tail	2.144786681	

Table 2.0 shows that the values of t-Stat calculated 0.186461796 is less than the critical values 1.761310115 and 2.144786681 for one tail and two tails respectively. This implies that there is no significant difference in the coefficient of friction for varying angle of wrap on the two apparatuses (imported and locally fabricated) using V belt at 5% significant level.

Table: 5.0 Bill of Engineering Measurement and Evaluation for the Apparatus as at 04 05 2012

S/N	Description	Quantity	Unit Cost (₦)	Cost (₦)
1	Pulley	1	7000	7000
2	Bearing	1	500	500
3	Shaft	1	200	200
4	Plate	2	1,250	2,500
5	Frame	1	2,000	2,000
6	Painting			500
7	Belt			1,800
	Contingency			1,450
	Overhauling			1,550
	Workmanship			2,000
	Total Cost			**₦19, 500.00k**

IV. Conclusions

It has been established that the results of friction of belt obtained when using standard imported apparatus and locally fabricated apparatus with indigenous materials have the same characteristic performance profile trend pattern and there is no significant difference in the results from the two apparatuses at 95% confidence limit, for all experiments carried out. Hence the locally fabricated apparatus is reliable.

The economic feasibility of fabricated apparatus with indigenous available materials is better compared to the exorbitant cost of standard foreign apparatus which many Nigerians cannot afford. The fabricated apparatus with indigenous material is affordable to an average Nigeria at the production cost of ₦19,500.00k compared to the cost of standard apparatus which sells for $ 960, approximately ₦144,000. It does not include the cost of importation.

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