Design and Development of a testing machine for manufacturing laboratories

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DESIGN AND DEVELOPMENT OF A WEAR TESTING MACHINE FOR MANUFACTURING LABORATORIES

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ABSTRACT

Wear of parts during manufacturing processes is inevitable but controllable. Therefore, the critical study of wear in engineering components is vital because failure of components due to wear has resulted in loss of a great deal of fortune. This study was therefore an attempt to design and fabricate a wear testing machine, evaluate the performance of the machine and compare data obtained with existing ones. Materials for the various parts were carefully selected based on desirable properties and availability. Design calculations were made for the main shaft, compression spring, belt, pulley and electric motor. The post fabrication test was carried out on the machine to evaluate the performance of the machine and results gotten reported.
Keywords: Fabricated; Design; Discs; Material; Wear;

1.0 INTRODUCTION

Wear is the progressive loss of substance from the operating surface of a body. This occurs as a result of the physical contact between the bodies involved in the rubbing, sliding, meshing and grinding (Hasim and Nihat, 2002). Wear is often viewed as a setback because the service life of a machine or structure depends on the rate of wear of the materials used, hence the need to ascertain the pattern of wear of engineering components before usage.

Wear which is a result of friction, corrosion or abrasion independently or collectively, can occur to the hardest of materials and on any of the surfaces, bore rings, grooves, valve trains and the extent of the damage will depend on the running conditions (Hareesha and Jeevan, 2014). Despite the consequences and effect of wear, it is inevitable and can only be controlled but cannot be completely removed since all mechanical components gradually wear out in the course of usage leading to an eventual failure. Wear and corrosion are principal causes of failure of a large percentage of industrial equipment and machines such as valves and pumps where lubricants cannot be used and a process stream may be the only fluid present. (Aksakal *et al*, 2004; Foroulis, 1993). There are many types of wear that are of concern to the user of coatings some of which are abrasive wear, adhesive wear, erosive wear and fretting wear (Ohkubo *et al.*, 2003; Hareesha and Jeevan, 2014). Materials behave differently in friction state so it may be important to perform mechanical tests which simulate the condition the material will experience in actual use (Nasser and Nasser, 2011). The critical study of wear in engineering components is vital because failure of components due to wear has resulted into quite a great deal of money. Materials wear out differently as a result of their different structural components, chemical composition and mechanical properties even when subjected to the same conditions. Wear testing is therefore necessary to ascertain the life span of materials/components used in engineering structures. This work is therefore a study to design, fabricate and evaluate the performance of a wear testing machine, comparing the results with existing data to validate results.

2.0 METHODOLOGY

2.1 Material Selection

The availability of the material used for the machine is very critical in design. Mild steel, brass and copper are manufactured locally within the country are therefore available in the market for purchase. Table 1.0 describes the various materials selected for each part of the machine and their desirable properties

Table 1.0: Desirable properties of materials selected for design of parts

S/N	Part name	Desired mechanical properties	Material selected
1.	Main Shaft	Strength, Hardness, Toughness, Fatigue and Creep	Mild Steel
2.	Compression Ring	Toughness, Ductility, Hardness, Resilience	Alloy/ Carbon Steel
3.	Belt	Toughness, Elasticity and Durability	Leather
4.	Disc 1 & 2	Varying Wear rate	Brass and Copper
5.	Speedometer	Durability and longevity	Depends on Manufacturer
6.	Electric Motor	Durability and longevity and high speed	Depends on Manufacturer
7.	Electric Chord	Conductivity and Longevity	Copper and Rubber
8.	Pulley	Hardness and Strength	Wood and Iron
9.	Bolt and Nut	Hardness and Durability	Alloy Steel
10.	Metallic Base	Strength and Resilience	Cast Iron
11.	Spring Loaded screw (pin)	Strength, Hardness and Toughness	Mild Steel

2.2 Design Process And Calculation

2.2.1 Belt design

The belt was used to transmit power from the electric motor to the main shaft on which the brass and copper discs are mounted. The schematic shown (Fig. 1) was used to determine the angle of contact and velocity of belt (assuming there was no slip). From Electric Motor Specification

N_1 = 2700rpm, N_2 = Unknown, D_1 = 50mm, D_2 = 150mm and x = 400mm

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The number of revolutions per minutes of pulley and velocity of belt were determined using equation 1, 2 and 3

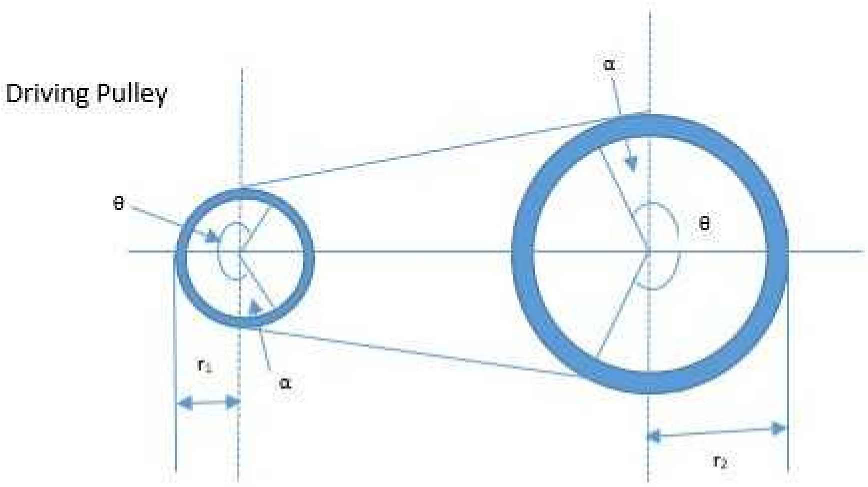

Figure 1: Schematic for Belt Design (Open Belt Pulley)

$$\frac{N1}{N2} = \frac{D1}{D2} \quad (1)$$

$$\Theta = 180 - 2\alpha \quad (2)$$

$$V_1 = \frac{\pi D1N1}{60} \quad (3)$$

Where,

N_1 = number of revolutions per minutes of electric motor pulley
N_2 = number of revolutions per minutes of the pulley
D_1 = diameter of electric motor pulley
D_2 = diameter of pulley
X = distance between the two pulley centres
Θ= angle of contact
V = velocity of belt

2.2.2 Shaft design

A mild steel bar was used as shaft for the design with steps created on it to accommodate shoulders for locating gears, pulleys, bearings and other attached or contacting parts.
The Torsion, bending moment and power transmitted where determined using equations 4, 5 and 6.

$$\tau = \frac{16T}{\pi d^3} \quad (4)$$

$$\sigma = \frac{32M}{\pi d^3} \quad (5)$$

$$P = F.V \quad (6)$$

Where

$\tau = Maximum\ shear\ stress$ $\quad$ $\sigma = Maximum\ bending\ stress$
$T = Torque$ $\quad$ $d = diameter\ of\ shaft$

$M = Bending\ moment$ $P = Power\ transmitted$
$F = Force$

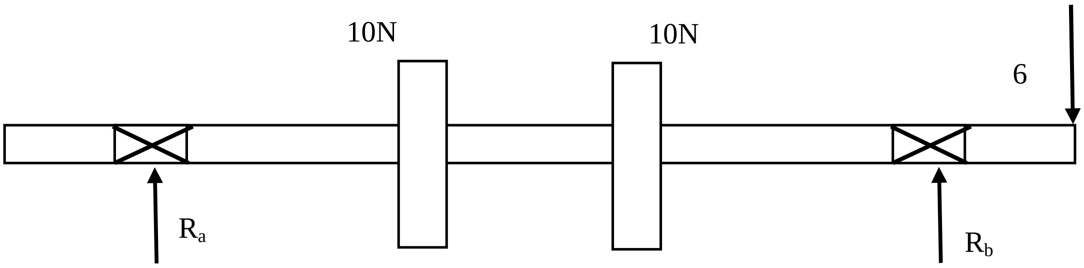

Fig. 2a

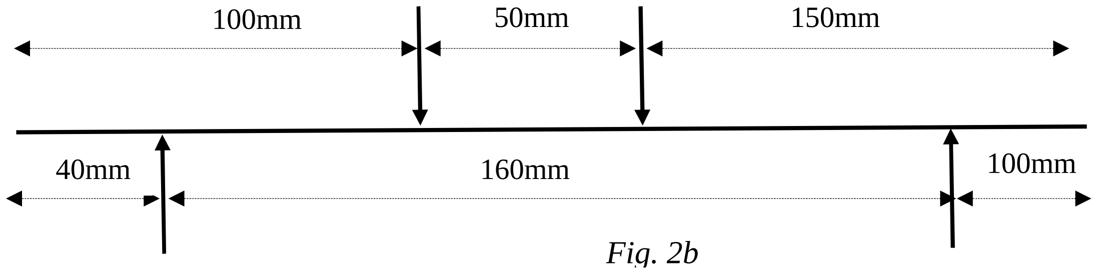

Fig. 2b

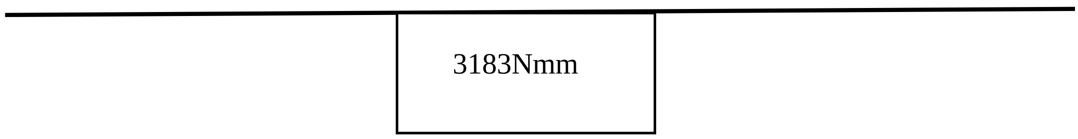

Fig. 2c

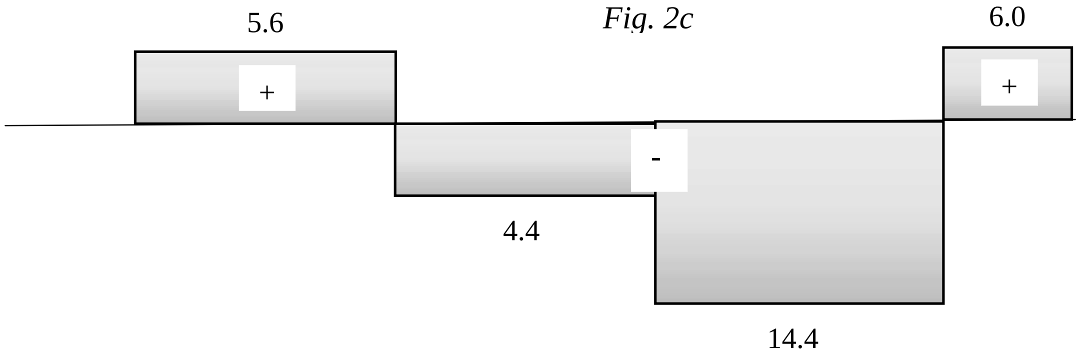

Fig. 2d

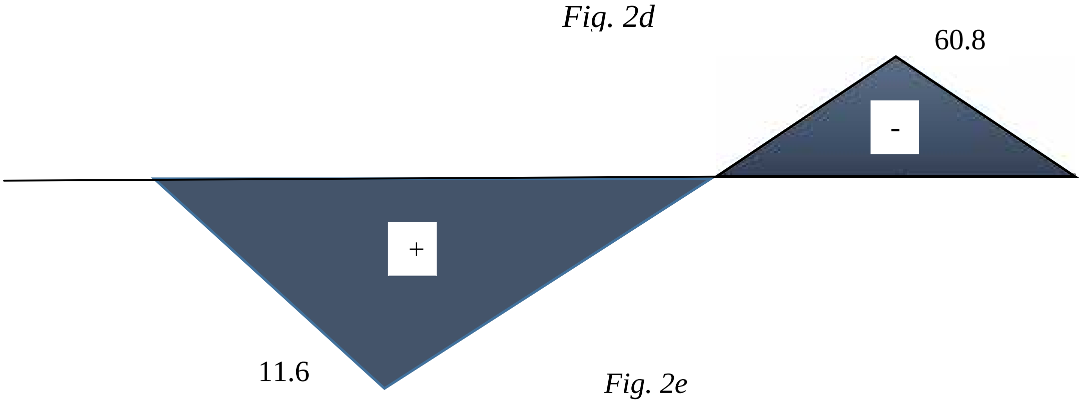

Fig. 2e

Figures 2: (a) Space Diagram (b) Free body diagram (c) Torque (d) Shear Force diagram (e) Bending Moment diagram

2.2.3 Spring design

The internal diameter of the spring to be used depends on the external diameter of the pin, the solid and free lengths of the springs were calculated using equations 7 and 8.

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$$L_s = n\ x\ d \quad (7)$$
$$L_f = nd + \delta_{max} + 0.15\,\delta_{max} \quad (8)$$

Where

L_s = solid length L_f = free length
n = total number of coils δ_{max} = maximum compression
d = diameter of wire

2.2.4 Transformer

A transformer is included in the wear-testing machine so as to enable the variation of speed, which is made possible using a variable selector switch. This gives the operator the opportunity to choose a desirable speed at which the shaft driving the brass and copper discs turns. A voltage range of 140V – 260V is used. The circuit diagram in Figure 3 illustrates this.

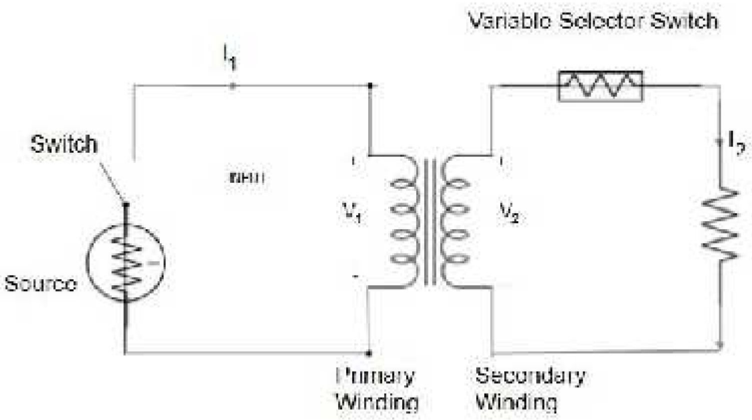

Figure 3: Electric Circuit diagram for 100-Watts Transformer

2.3 Fabrication and Assembly

The fabrication of the electric motor base was done using 1.5 inches square channel (angle iron), cut into two lengths of 170mm joined with 2 inches flat bar braces to form a rectangular shape with slots for bolts and nuts. Two clips were fabricated to hold the electric motor and prevent vibration during operation. The clip was formed using a length of 300mm from 1-inch flat bar with 17.5mm holes drilled to hold a 17mm diameter bolt and nut for proper tightening. The assembly of different parts and components of the wear-testing machine was carried out after the fabrication work was completed. The assembly has shown in Figure 6 was done in the following order

- Fix the bearing into shaft
- Fix the two discs into shaft
- Fix the second bearing into shaft
- Slightly tighten the bearings
- Fit the pulley into the shaft
- Mount the electric motor shaft
- Set the interface of the two pulleys to align

- Hold down the electric motor with the clip and tighten to the base
- Mount the transformer and hold tightly with clip
- Tighten the bearings
- Mount the cast iron (spring loaded) pin
- Perfect electric wire connection.

Figures 4 and 5 shows the schematic for the fabricated electric motor base and clip.

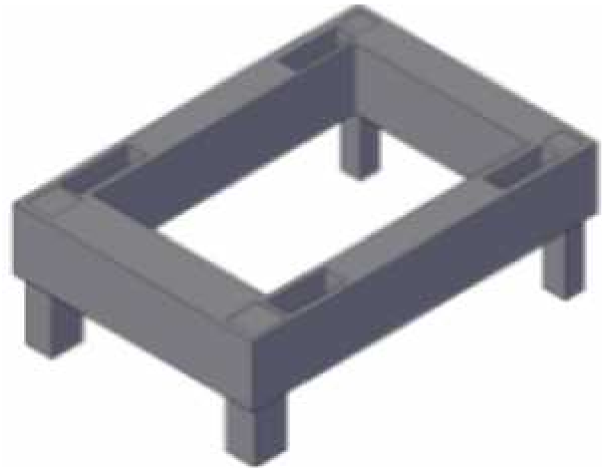

Figure 4: Schematic of fabricated electric motor base

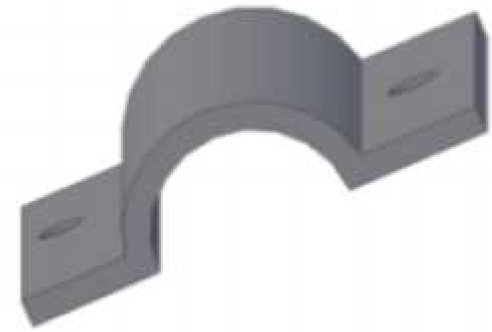

Figure 5: Schematic of fabricated electric motor clip

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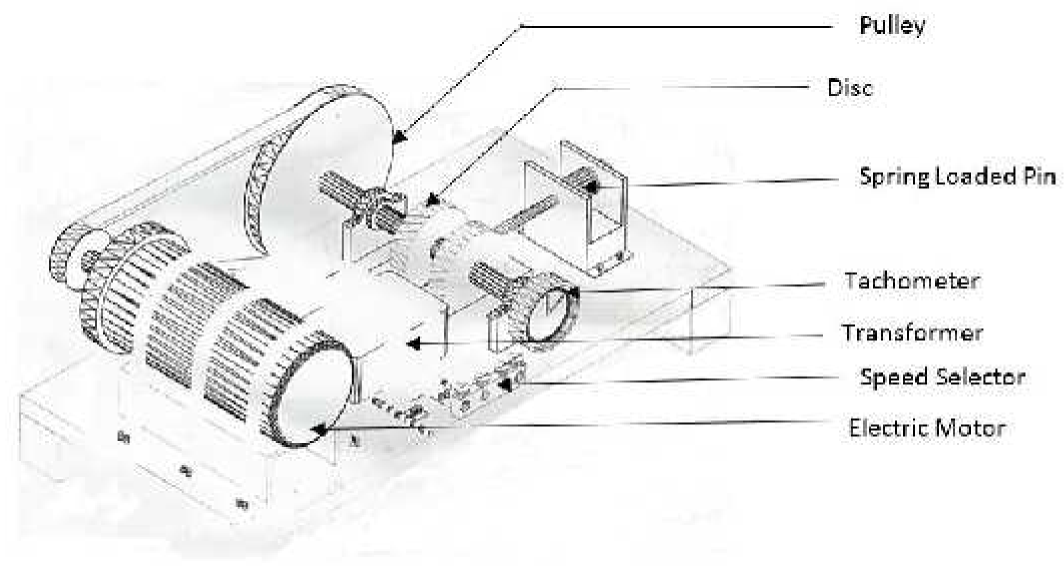

Figure 6: Isometric view of Developed Wear Testing Machine

2.4 Experimentation Procedure

The weights of the brass and copper discs where measured before and after the experimentation. The experimentation requires the subjection of the discs to wear through their direct contact with the cast iron pin for some amount of time after which the weights of both discs are measured and recorded again. A digital timer was used to control the duration of experiment. Wear rates was calculated using Archard's equation (John, 2007).

$$\text{Wear rate } W = \frac{\Delta w}{\rho t v A} \quad (9)$$

Where $\Delta w =$ change in weight of discs, t = duration of test, ρ = density and A = contact area

2.5 Reliability Test Procedure

The reliability of the fabrication was done to ascertain the effectiveness of the fabrication activities done on the developed machine.

2.5.1 Procedure

The discs (Brass and Copper) were weighed before experimentation, the discs were thereafter driven through the main shaft powered by the electric motor. The speed of the main shaft at different points using the speed selector switch was determined. The selector switch has four points (4-speed switch) and at each point, shaft speed was measured using a digital tachometer.

3.0 RESULTS AND DISCUSSION

The results gotten after the experimentation are as discussed below. As illustrated by Figure 7, the machine shaft did not rotate at point 1. This was due to high tension of the belt which was probably too much for the first speed. The speed at point 2 was 711.1 rpm, this increased to 786.1rpm and 794.4rpm at points 2 and 3 respectively. Whirling was observed on the shaft after the experimentation, this was due to the transmission of power via the shaft.

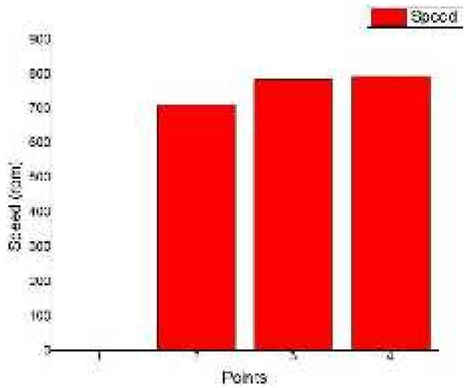

Figure 7: Speed of Machine at various Points

Table 2 shows the weight loss recorded during experimentation on the brass and copper discs. The weights of the disc after experimentation

Table 2: Weight Loss during Experimentation

Time	Weight Loss	
	Brass	Copper
180	0.041	0.034
240	0.065	0.052
300	0.092	0.081

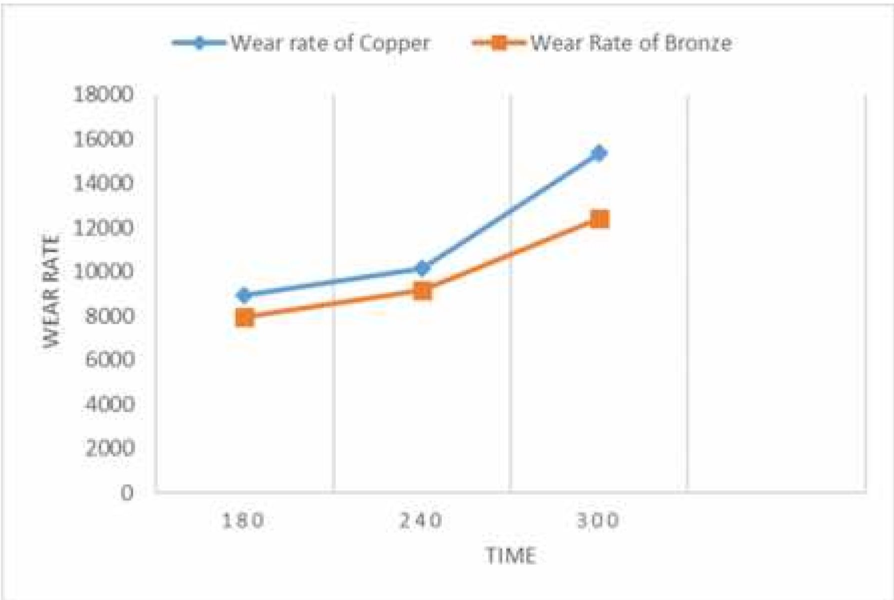

Figure 8: Wear rate of Copper and Brass discs

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The wear rate for brass and copper is as shown in Figure 8. It can be seen from the plots that there was a gradual increase in wear rate as pressure was applied on the two components over an increase in time. This trend agrees with Nasser and Nasser (2011) and Williams (2005). Copper however had a higher wear rate than Brass.

4.0 CONCLUSION

Results gotten from this experimentation shows that it is possible to use a locally designed and fabricated wear testing machine to determine the wear rate of engineering materials before they are used as components. It is therefore recommended that this be encouraged to reduce failure of engineering devices.

5.0 REFERENCES

Aksakal B., Yildirim Ö.S, and Gul H., Metallurgical Failure Analysis of Various Implant Materials Used in Orthopedic Applications, Journal of Failure Analysis and Prevention, Volume 4(3) June 2004, DOI: 10.1361/15477020419794.

Foroulis Z.A., (1993), The Role of Molybdenum as an alloy element in Adhesive wear resistance in specialty steel and hard materials (ed), Comins Press Ltd, England, p277.

Hareesha M., Jeevan T. P., Modification of Abrasive Wear Testing Machine and Testing of Materials, International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, Volume 3 Issue 10, October 2014.

Hasim P. and Nihat T., Effect of load and speed on the wear behavior of woven glass fabrics and aramid fibre-reinforced composites, Wear Volume 252, Issues 11–12, July 2002, Pages 979-984.

John M.T., A Proposal for the Calculation of Wear, 2007, p. 2-3, Available at: http://www.mkthompson.net/wp-content/uploads/2012/02/ansys-paper-2006-2.pdf

Nassar A.E. and Nassar E.E, “Design and Fabrication of a Wear Testing Machine”, Leonardo Electronic Journal of Practices and Technologies, Issue 19, pp. 39-48 July-December 2011.

Ohkubo C., Shimura I., Aoki T., Hanatani S., Hosoi T., Hattori M., Oda Y., Okabe T., Wear resistance of experimental Ti–Cu alloys, Biomaterials Volume 24, Issue 20 (2003), Pages 3377–3381.

Williams, Wear and wear Particles- Some fundamentals. Tribology International 2005, 38(10): p. 863-870.