EXPERIMENTAL INVESTIGATION OF WEAR BEHAVIOUR OF BRASS USING DUAL CONDITION PIN- ON- DISK WEAR TESTING MACHINE

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ABSTRACT

Surface wear measuring has being a fundamental feature in the operational and industrial set ups. In this paper, Design of Experiment (DOE) approach using dual condition pin-on-disc wear testing machine was used to analyse the wear behaviour of brass. The dual condition pin-on-disk machine was employed to carry out the wear tests. The load, sliding speed and time were independently varied to determine the influence of parameters on the brass wear rate. It was revealed that load was the most significant parameter which the wear rate of brass depend with respect to the rotating disc. Experiments were conducted on a numbers of pin specimens of 4mm and 6mm diameter under varied applied force of 5.0N and 8.0N, different time interval consideration and sliding speed of 0.158m/s and 0.197m/s. Considering the operational parameters, the wear rate was relatively high at higher speeds with increasing normal load/applied force.

Keywords *Pin-on-disk, wear rate, sliding speed*

1.0 INTRODUCTION

Brass is an alloy of Copper and Zinc, in proportions which can be varied to achieve varying mechanical and electrical properties. It is a substitution alloy with differing combinations of properties, including strength, machinability ductility, wear resistance, hardness, thermal conductivity and corrosion resistance (Dalgobind etal, 2013). This is commonly used in applications where less friction and corrosion resistance is required (Callister etal, 2010). These include bearings, valves, ammunition casings, hinges, gears, plumbing and electric plugs.

Wear is a dynamic and complex process which involves not only surface and material properties but operating conditions as well (Roland, J, 2014). The wears in engineering material include wearing of bolts and nuts experienced by machines and equipment used in workshop.

The dual condition pin-on-disc means the wear testing machine can used for testing wearing of both on dry and lubrication condition on pin. The machine components are rotating disc, experimental container, pin holder, pumping (pipe) mechanism, pulley, pulley arm, supporting base, two electric motors and industrial lubricating oil tank. The wear testing is possible by inserting pin on the pin holder at variable time while loading the pulley mechanism on the machine. The pin is subjected to varying load, time and sliding distance during experimental stages that is employed for testing surface wear behaviour of the brass. The weight loss is continuously measured and stored to calculate the wear rate.

THE EXPERIMENTAL SET UP

The experiment was conducted on brass pin. The study considers the diameter 4mm and 6mm for its wear analysis in both dry and wet surface wear testing analysis. The effects of sliding speed and applied force on the pin were also determined. The pin-on-disc wear testing machine which is shown below in Fig 1 is used for the investigation of the effects of normal load of 5N and 8N on brass alloy.

Figure 1: Dual Condition Pin-On-Disc Wear Testing Machine

2.0 MATERIALS AND METHOD

2.1 Materials

The materials used in carrying out the experimental analysis include:

i. Pins of 25mm long and diameters of 4mm and 6mm. The pin material is brass
ii. Disc size of diameter size 170mm, thickness of 10mm and surface wear track radius of 50mm and 40mm respectively.
iii. Applied force of 5N and 8N using laboratory dead weight of 0.51kg and 0.82kg
iv. Gear oil as anti-wear additives oil

2.2 Methods

The sliding wear tests are conducted for two different pin materials using the developed wear test machine. The pin material is brass. Each pin material is 25mm of height with diameters of 4mm and 6mm respectively. Using (Kutz .M, 2006), the surfaces of the pin samples was cleaned by emery paper, the surface of the disc was cleaned by acetone. Each pin was held against the counter face of disc mounted on rotating shaft with wear track diameter of 100 mm as the dead weights used are 0.51 kg and 0.82kg. The experiment was carried out at constant nominal speed of 0.158 m/s and 0.1975m/s at interval of 5 minutes (300s). The number of experiment carried out was average of 4 experiments on a pin material.

The following parameter is determined based on Windarta *et al.,* 2011 and Ndaliman et al., 2015:

Volume loss in $V_l = Ah_l$ (1)
Wear rate in mm^3/m, $\omega = V_l/x_s$ (2)
Wear resistance in m/mm^3 , $\omega_r = 1/\omega$ (3)
Specific wear rate in mm^3/Nm,$\omega_s = \omega/W_p$ (4)

Where:
h_l= Height loss by the pin in m
x_s =Sliding distance in m
A = πr^2 = Cross section area in m^2
$W_p =$ Pulley weight

3.0 RESULTS AND DISCUSSION

3.1 Experimental Result

The results are the average of two test of SWA of Brass pin diameter 4mm and 6mm. The original pin height was 25mm measured using programmed micro controller with Ultra sonic sensor after required period of time. The height loss $h_l(mm)$ was determined by subtracting the original height from initial wear height. The experiment was repeated twice and average of the surface wear test parameter is determined and tabulated in Tables below.

Table 1.1: Dry SWA of Brass's Diameter 4mm @ 0.158m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/mm^3	mm^3/Nm
300	47.4	0.81	10.1264	0.2136	4.6808	4.2727
600	94.8	0.85	10.7260	0.1131	8.8384	2.2629
900	142.2	0.91	11.4588	0.0806	12.4097	1.6116
1200	189.6	0.95	11.9918	0.0632	15.8108	1.2650

Table 1.2: Dry SWA of Brass Diameter 4mm @ 0.1975m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	59.25	0.93	11.7466	0.1983	5.0440	3.9651
600	118.5	0.99	12.4421	0.1050	9.5241	2.0999
900	177.75	1.06	13.2922	0.0748	13.3725	1.4956
1200	237	1.11	13.9105	0.0587	17.0375	1.1739

Table 1.3: Dry SWA of Brass's Diameter 4mm @ 0.158m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	47.4	1.13	14.1769	0.2991	3.3435	3.7386
600	94.8	1.19	15.0164	0.1584	6.3131	1.9800
900	142.2	1.28	16.0423	0.1128	8.8640	1.4102
1200	189.6	1.34	16.7885	0.0885	11.2935	1.1068

Table 1.4: Dry SWA of Brass's Diameter 4mm @ 0.1975m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	59.25	1.19	14.9871	0.2529	3.9534	3.1618
600	118.5	1.26	15.8745	0.1340	7.4648	1.6745
900	177.75	1.35	16.9590	0.0954	10.4811	1.1926
1200	237	1.41	17.7478	0.0749	13.3537	0.9361

Table 1.5: Dry SWA of Brass's Diameter 6mm @ 0.158m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	47.4	0.32	9.1097	0.1922	5.2032	3.8438
600	94.8	0.34	9.6491	0.1018	9.8247	2.0357
900	142.2	0.36	10.3084	0.0725	13.7946	1.4498
1200	189.6	0.38	10.7878	0.0569	17.5754	1.1380

Table 1.6: Dry SWA of Brass's Diameter 6mm @ 0.1975m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	59.25	0.45	12.6807	0.2140	4.6724	4.2804
600	118.5	0.48	13.4316	0.1133	8.8225	2.2669
900	177.75	0.51	14.3493	0.0807	12.3874	1.6145
1200	237	0.53	15.0167	0.0634	15.7825	1.2672

Table 1.7: Dry SWA of Brass's Diameter 6mm @ 0.158m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	47.4	0.45	12.7536	0.2691	3.7166	3.3633
600	94.8	0.48	13.5088	0.1425	7.0177	1.7812
900	142.2	0.51	14.4317	0.1015	9.8533	1.2686
1200	189.6	0.53	15.1030	0.0797	12.5538	0.9957

Table 1.8: Dry SWA of Brass's Diameter 6mm @ 0.1975m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	59.25	0.48	13.4824	0.2276	4.3946	2.8444
600	118.5	0.51	14.2807	0.1205	8.2979	1.5064
900	177.75	0.54	15.2564	0.0858	11.6509	1.0729
1200	237	0.56	15.9660	0.0674	14.8441	0.8421

Table 1.9: Wet SWA of Brass's Diameter 4mm @ 0.158m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/mm^3	mm^3/Nm
300	47.4	0.57	7.1897	0.1517	6.5927	3.0336
600	94.8	0.61	7.6154	0.0803	12.4484	1.6066
900	142.2	0.65	8.1358	0.0572	17.4784	1.1443
1200	189.6	0.68	8.5142	0.0449	22.2688	0.8981

Table 1.10: Wet SWA of Brass's Diameter 4mm @ 0.1975m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	59.25	0.66	8.3401	0.1408	7.1042	2.8152
600	118.5	0.70	8.8339	0.0745	13.4142	1.4910
900	177.75	0.75	9.4375	0.0531	18.8345	1.0619
1200	237	0.79	9.8764	0.0417	23.9965	0.8335

Table 1.11: Wet SWA of Brass's Diameter 4mm @ 0.158m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	Mm	mm^3	mm^3/m	m/ mm^3	mm^3/Nm
300	47.4	0.80	10.0656	0.2124	4.7091	2.6544
600	94.8	0.85	10.6616	0.1125	8.8917	1.4058
900	142.2	0.91	11.3901	0.0801	12.4846	1.0012
1200	189.6	0.95	11.9198	0.0629	15.9063	0.7859

Table 1.12: Wet SWA of Brass's Diameter 4mm @ 0.1975m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	mm	mm^3	mm^3/m	m/mm^3	mm^3/Nm
300	59.25	0.85	10.6408	0.1796	5.5682	2.2449
600	118.5	0.90	11.2709	0.0951	10.5138	1.1889
900	177.75	0.96	12.0409	0.0677	14.7622	0.8468
1200	237	1.00	12.6010	0.0532	18.8081	0.6646

Table 1.13: Wet SWA of Brass's Diameter 6mm @ 0.158m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	mm	mm^3	mm^3/m	m/mm^3	mm^3/Nm
300	47.4	0.23	6.4679	0.1365	7.3285	2.7291
600	94.8	0.24	6.8509	0.0723	13.8377	1.4453
900	142.2	0.26	7.3189	0.0515	19.4290	1.0294
1200	189.6	0.27	7.6594	0.0404	24.7540	0.8079

Table 1.14: Wet SWA of Brass's Diameter 6mm @ 0.1975m/s (5N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	mm	mm^3	mm^3/m	m/mm^3	mm^3/Nm
300	59.25	0.32	9.0033	0.1520	6.5809	3.0391
600	118.5	0.34	9.5364	0.0805	12.4261	1.6095
900	177.75	0.36	10.1880	0.0573	17.4470	1.1463
1200	237	0.38	10.6618	0.0450	22.2288	0.8997

Table 1.15: Wet SWA of Brass's Diameter 6mm @ 0.158m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	mm	mm^3	mm^3/m	m/mm^3	mm^3/Nm
300	47.4	0.32	9.0551	0.1910	5.2346	2.3879
600	94.8	0.34	9.5912	0.1012	9.8840	1.2647
900	142.2	0.36	10.2465	0.0721	13.8779	0.9007
1200	189.6	0.38	10.7231	0.0566	17.6814	0.7070

Table 1.16: Wet SWA of Brass's Diameter 6mm @ 0.1975m/s (8N)

t	x_s	h_l	V_l	ω	ω_r	$\omega_s \times 10^{-2}$
(s)	m	mm	mm^3	mm^3/m	m/mm^3	mm^3/Nm
300	59.25	0.34	9.5725	0.1616	6.1896	2.0195
600	118.5	0.36	10.1393	0.0856	11.6872	1.0695
900	177.75	0.38	10.8320	0.0609	16.4097	0.7617
1200	237	0.40	11.3359	0.0478	20.9071	0.5979

3.2 DISCUSSION

Effect of Sliding Speed and Applied Force

The constant sliding speed effect is considered on the Brass pin at varying applied force and varying diameter. Figures 2 and 3 illustrate the graph of wear rate (mm^3/m) and sliding distance (m) of Brass pin.

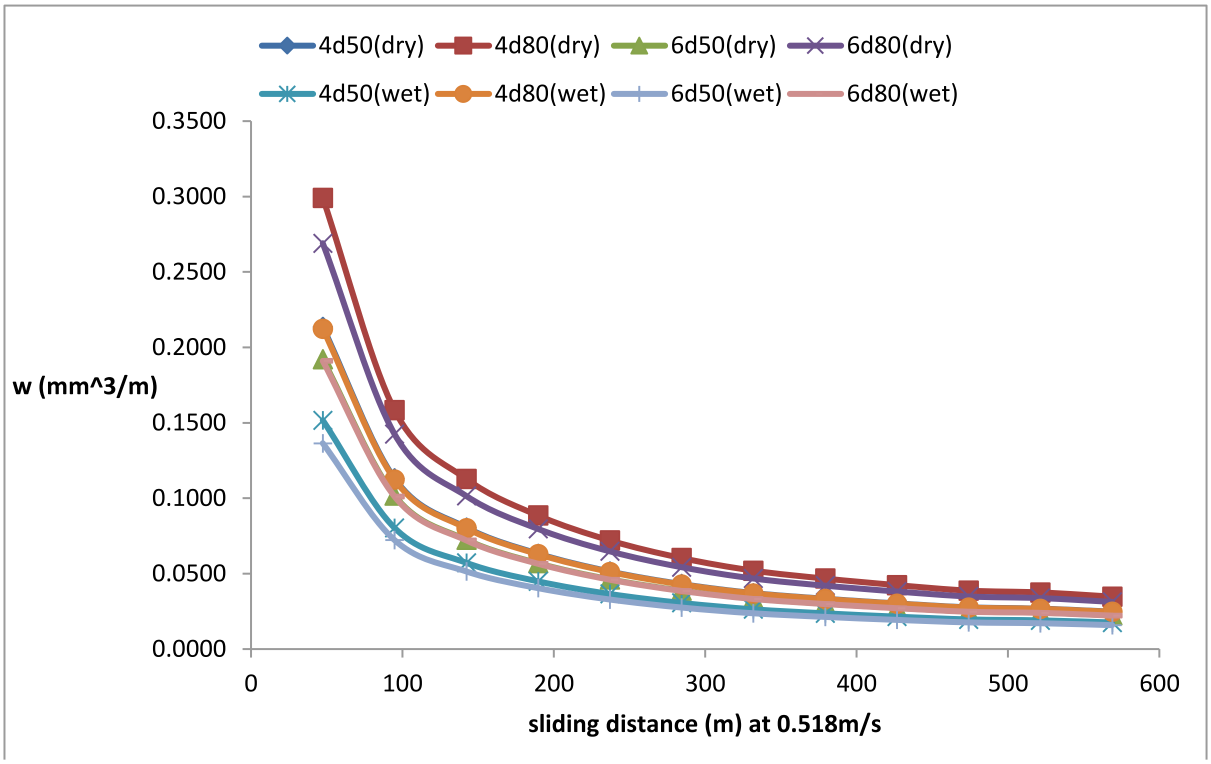

Figure 2: Effect of wear rate on Brass Pin at sliding velocity of 0.158 m/s

The graph of Figure 2 was in sliding speed of 0.158m/s, the wear rate was higher in Brass diameter 4mm pin "4d8(dry)" with 0.1128 mm^3/m under applied force of 8N without lubricating surface or at dry condition. This occurred at sliding distance of 142.2m covered at 900s and under the same condition the wear rate was lower to 0.0515 mm^3/m by Brass diameter 6mm pin "6d5(wet)". It was understood that increase in pin contact surface area due to increase pin diameter under lesser applied force of 5N and lubricated surface reduces wear rate to 54.34% condition.

There is instance of Brass diameter 4mm pin "4d5(dry)" under applied force of 5N without lubricating surface at sliding distance of 142.2m at 900s. The wear rate in this pin was 0.0806 mm^3/m and this reduced to 28.55 % in comparing with 4d8(dry) above. This is a result of reduce force on dry condition. The situation of changing the condition to lubricated surface of 4d8(dry) by 4d8(wet), the wear rate of 4d8(wet) was 0.0801 mm^3/m. This led to only 28.99% reduction of wear rate and this means wearing at surface is reduced using lubricating oil and tends to reduce more if with increase in surface contact area. Figure 3 shows the effect of wear rate on brass pin at sliding velocity of 0.1975m/s

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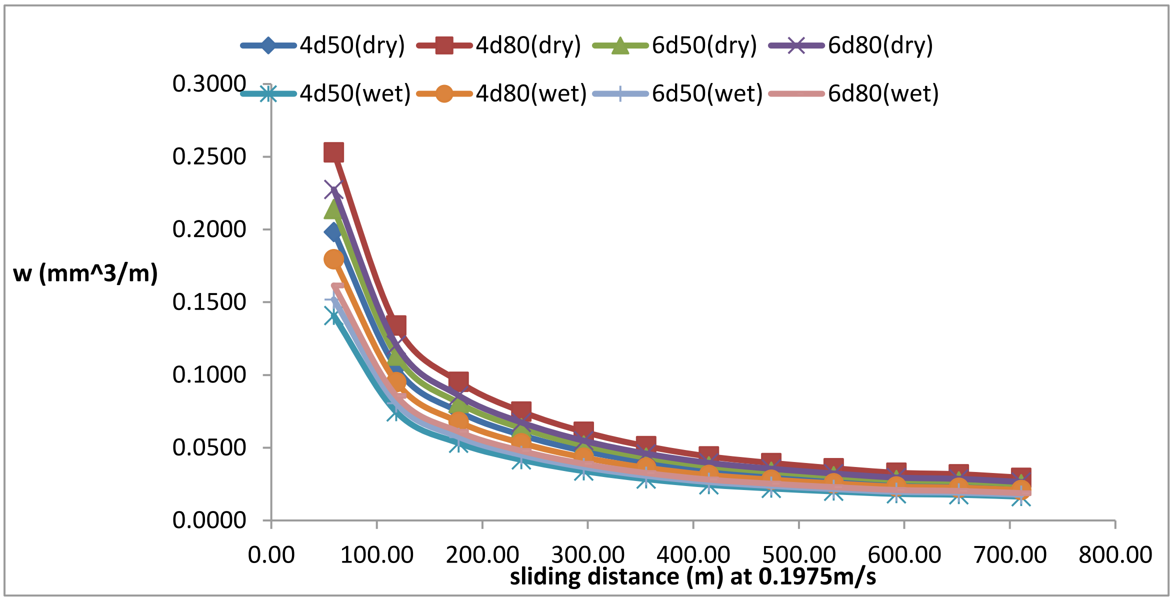

Figure 3: Effect of wear rate on Brass Pin at sliding velocity of 0.1975 m/s

Figure 3 on sliding speed of 0.1975m/s, the wear rate was more higher in Brass diameter 4mm pin "4d8(dry)" with 0.0954 mm^^{3}/m under applied force of 8N without lubricating surface or at dry condition. This occurred at sliding distance of 177.75m covered at 900s and under the same condition the wear rate was lower to 0.0531 mm^3/m by Brass diameter 4mm pin "4d5(wet)". This showed that the reduction of applied force to 5N on same diameter pin with lubricated surface will reduce wear rate to 44.34 % under same speed. The comparison of wear rate of 4d8(dry) by both sliding speed of 0.158m/s in Figure 4.7 and 0.1975 in Figure 3 it was understood that wear rate reduce to 15.43 % as result of increase in speed of the pin.

Specific wear rate

Figure 4 is the Brass diameter 6mm pin "6d5(wet) specific wear rate, this pin was selected as a result of lower wear rate in comparing to other condition considered.

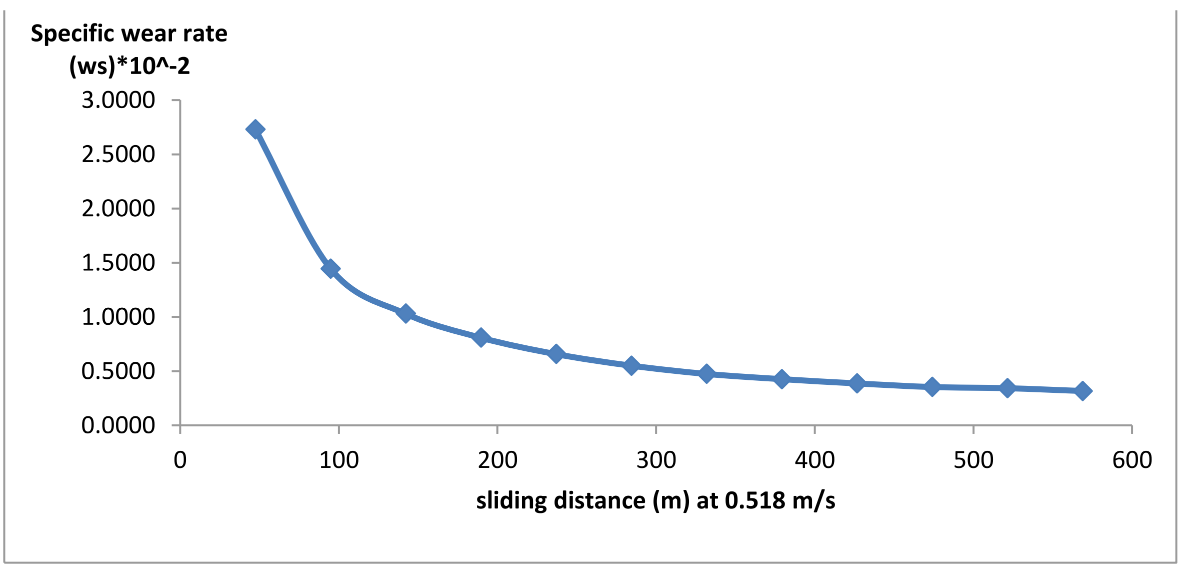

Figure 4: Specific wear rate of Brass

The specific wear rate of Al-Brass diameter 6mm pin with lubricated surface at speed 0.518m/s include 2.7291×10^{-2} mm^3/Nm, 1.0294×10^{-2} mm^3/Nm and $0.3172 \times 10^{-2} mm^3/Nm$ for 47.4m, 142.2m and 568.8m respectively. This means as sliding distance increase with decrease in specific wear of the pin.

CONCLUSIONS

The study was carried out with the aim of investigating the surface wear behaviour of the pin. The pins were subjected to variable parameters such as applied force of 5N and 8N, at interval of 300s and sliding of 0.518m/s and 0.1975m/s. From the results obtained, increase in force will increase wear rate at constant speed. The increase in speed will lead to reducing of wear rate. The increase in surface area of contact and using lubricated surface will lead to wear reduction rate as shown in the experimental analysis data. This can be used for wear prediction and wear behaviour of the brass under specified conditions.

REFERENCES

1. Callister Jr., W.D., and Rethwisch, D.G. (2010). *Material Science and Engineering An Introduction* (8^{th} Ed). New

2. Dalgobind, M and Anjani, K. (2013). Application of Reliability Centred Assessment in Improvement of Product quality and Productivity, Unpublished note, 12.

3. Kutz, M. (2006). *Mechanical Engineering Handbook, Material and Mechanical Design* (3^{rd}Ed). New Jersey, USA: John Wiley & Sons Incorporation.

4. Ndaliman, M. B., Bala, K. C., Khan, A. A., Ali, M. Y., Abdullahi, U. and Abdulmumin, A. A. (2015). The effects of Sliding Parameters on Dry Wear Characteristics of Ti-6Al-4V Alloy, Advanced Materials Research (AMR), 1115, 213-216.

5. Roland, J. D. (2014). Root Cause Investigation Best Practices Guide. US: Aerospace Report, Windara G and John, M.T. (2011). A Proposal for the Calculation of Wear (Unpublished Paper). London.