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Design And Manufacturing of a Pin-on-Disk wear Testing Apparatus

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ABSTRACT

The present work is about a design and manufacturing process of a pin-on-disk apparatus which is used as a test method for determining the wear of any two sliding materials. The aim of this paper is to give an information about the design steps and manufacturing procedure for the pin-on-disk apparatus and to discuss the problems follows the design and manufacturing process. It also gives information about wear testing process. Different types of experiments were done with several different test specimens to be able to make a comparison between wear test results of this work and that of another experiment found in literatures. It was concluded, that a pin-on-disk wear testing apparatus which is working properly is successfully designed and manufactured. The results of the wear testing obtained by the apparatus which have been designed and manufactured in this work shows that the wear of the test specimen increases as the speed (rpm) of the motor increases. And also, as the sliding distance increases,the wear decreases at constant load and speed.

Keywords: Design; Manufacturing; Pin-on-Disk apparatus

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تصميم وتصنيع جهاز أختبار ألبلى دبوس على قرص

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ألخلاصة:

العمل الحالي هو حول تصميم و عملية تصنيع جهاز دبوس على القرص الذي يستخدم كطريقة اختبار لتحديد ألبلى لأي اثنين من المواد المنزلقة. أن الهدف من هذا البحث هو إعطاء معلومات عن خطوات التصميم وطريقة تصنيع جهاز دبوس على القرص ومناقشة المشاكل التي تتبع عملية التصميم والتصنيع. كما أنه يعطي معلومات حول عملية اختبار البلى. وقد أجريت أنواع مختلفة من التجارب مع عدة عينات اختبار مختلفة لتكون قادرة على إجراء مقارنة بين نتائج اختبار ألبلى لهذا العمل وتجارب أخرى وجدت في البحوث. وخلص إلى أن جهاز اختبار ألبلى دبوس على القرص الذي يعمل بشكل صحيح تم تصميمها وتصنيعها بنجاح. وقد أظهرت نتائج اختبار ألبلى الذي تم الحصول عليها من قبل الجهاز والتي تم تصميمها وتصنيعها في هذا العمل أن بلى عينة الاختبار يزيد مع سرعة دوران (دورة/دقيقة) ألمحرك. وأيضا، مع زيادة مسافة ألأنزلاق، كما أن ألبلى يقل عند ثبوت الحمل والسرعة.

ألكلمات ألمفتاحية: تصميم؛ تصنيع؛ جهاز دبوس على قرص

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Abbreviation

a	Constant; distance (mm)
A	Area (mm^2)
b	Distance; width (mm)
c	Centroid (mm)
E	Modulus of elasticity (N/mm^2)
f	Static frictional force (N)
F	Force (N)
F.S.	Factor of safety (dimensionless)
g	Gravitational acceleration (m/sec^2)
h	Distance; height (mm)
I	Moment of inertia ($kg.m^2$)
l	Length of pin specimen (mm)
L	Length (mm)
L_e	Effective length (mm)
L/r	Slenderness ratio (dimensionless)
L_e/r	Effective slenderness ratio (dimensionless)
m	Mass; mass of pin specimen (g)
M	Moment (N.m)
n	Angular velocity (rpm)

N	Normal force (N)
P_{cr}	Critical force (N)
P	Minimum required power (watt)
r_p	Pin diameter (mm)
r	Radius of gyration; radius of pin touching line between disk and shaft (mm)
s	Sliding distance (mm)
S	Elastic section modulus (mm^3)
t	Time (sec)
T	Torque (N.m)
v	Speed (m/sec)
V	Shear (N/m^2)
W	Load (kg)
υ	Volume of beam (mm^3)
ρ	Density (kg/m^3)
f	Frequency (Hertz)
σ	Normal stress (N/m^2)
σ_{cr}	Critical stress (N/m^2)
σ_{all}	Allowable stress (N/m^2)
μ	Coefficient of friction (dimensionless)
ω	Angular velocity (rad/sec)

W_l Relative wear by length (mm)

W_m Relative wear by mass (gm)

Δ_l Change in length (mm)

Δ_m Change in mass (gm)

1. INTRODUCTION

Pin-on-disk wear test method covers a laboratory procedure for determining the wear of materials during sliding using a pin traveling on a rotating disk. As the name implies, such apparatus consists essentially of a pin in contact with a rotating disk. Either the pin or the disk can be the test piece of interest. The contact surface of the pin may be flat, spherical or indeed of any convenient geometry, including that of actual wear components[1].

The pin-on-disk apparatus consists of several components which help the apparatus to perform its functions properly. The main idea for the apparatus is that it should maintain test specimens such as pin and disk to contact each other at a variable revolution per minute which can be set from the controller[2]. For the pin-on-disk wear test, two specimens are required. One, a pin is positioned perpendicular to the other, usually a flat circular disk. A ball, rigidly held, is often used as the pin specimen. The test machine causes the disk specimen to revolve about the disk center. In this case, the sliding path is a circle on the disk surface. The plane of the disk is oriented horizontally. The pin specimen is pressed against the disk at a specified load usually by means of an arm or lever and attached weights. Wear results are usually obtained by conducting a test for a selected sliding distance, load and speed.

2. Design of Pin-on-Disk Apparatus

2.1 Chassis Design

The chassis of the apparatus is designed in such a way that its strength is maximized. The chassis of the apparatus is made by stainless steel profiles. Two types of profiles were used in the construction of the chassis. The dimension of the profiles used in this part is found by doing necessary calculations which is shown in the next section. The chassis of the apparatus was designed in a way that it will not be damaged or fail under the total weight of the upper part. Actually, the profile size used is higher than the required one, but these ones are preferred because in the future some modification might be done. In this work, a dry type wear testing is a adopted. Some factors that played a role in designing the chassis like the placement of the equipment's such as the DC motor.

2.2 Upper Part Design

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The upper part of the apparatus consists of a beam, pivot, counterweight and the pin holding part. According to the experiment method which is stated in the standard[3], pin should touch the disk and by putting several different weights on the pin, the amount of wear between pin and disk can be measured under various motor speeds. The design of the upper part is done exactly same as in the standard that is given to us, a counterweight is used to balance the level before placing the weight on top of the pin. A pivot is used to connect upper part with the chassis. A beam is used to hold the counterweight and the pin sides, and a very practical method is used for installing the pin on the beam.

2.3 Disk and Motor Connection Design

The DC motor and the disk were connected by a shaft. This shaft was attached to the motor with a keyway. Like in the pin holding method, a very simple design was made to connect the disk on to the shaft. The side of the shaft which will hold the disk was machined and threaded so that drilling a hole in the center of the disk and using a nut will be enough to make the connection between them.

3. Calculations and Analysis

In this section, the calculations for designing the apparatus will be discussed. For this purpose,the beam theory has been used[4]:

3.1 Beam Analysis

Calculations were made to find the dimensions of the beam which is going to be used in pin-on-disk apparatus. Steps of calculations are explained below and Figure

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3.1 shows the changeable parameters in a beam, while Figure 3.2 shows the dimensions.

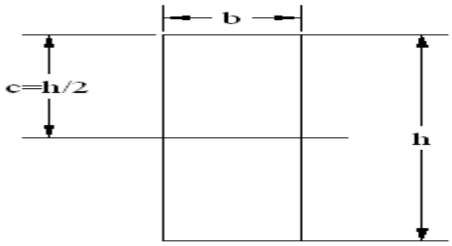

*Figure 3.1.*Changeable parameters in a beam

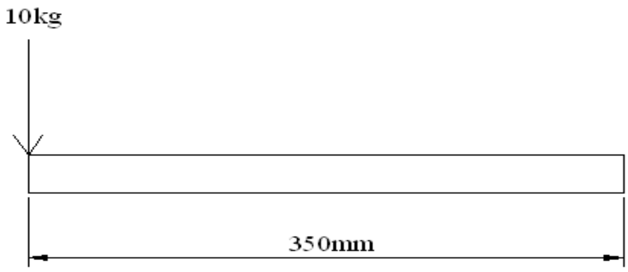

Figure 3.2. Length of the beam and the maximum amount of applicable load

$$I = \frac{bh^3}{12} \quad (1)$$

$$c = \frac{h}{2} \quad (2)$$

So,

$$\frac{I}{c} = \frac{bh^2}{6} \quad (3)$$

$$\frac{\sigma}{2} = \frac{Mc}{I} \quad [4] \quad (4)$$

$$\frac{200}{2} = \frac{10 \times 9.81 \times 350}{S} \Rightarrow S = 343.35mm^3$$

$$S = \frac{I}{c} = \frac{bh^2}{6} = 343.35mm^3$$

$$bh^2 = 343.35 \times 6 \qquad (5)$$

$$bh^2 = 2060.10mm^3$$

Take b as 10mm

$$h^2 = 206.01mm^2$$

$$h = \sqrt{206.01mm^2}$$

$$h = 14.35mm$$

Since the standard values have to be used for this part, “h” is taken as 20mm. Now, to find the weight of the slab which is going to be used to hold the pin, load,and counterweight,the following calculations are done:

3.2 Weight of Beam

To find the weight of the beam, it is necessary to determine the volume and density.

Volume of the beam:

v = 10mm×20mm×350mm

v = 70000mm3

Weight of the beam can be found by multiplying density with volume:

Weight = Density of Stainless Steel × Volume
(6)

$$w = \rho \times v = 7.8 \times 10^6 \times 70000mm^3$$

$$w = 0.546kg \cong 0.55kg$$

Similarly, weight of counterweight can be found as:

$$W = \rho \times \pi r^2 L$$
$$W = (8 \times 10^{-6}) \times \pi r^2 L$$

Where:

ρ is steel density which is equal to 8 kg/m3

Since the counterweight is going to be moveable, there are two choices to calculate its weight. In the first one, counterweight can be placed at the end of the beam. This makes the counterweight to have a distance of 95mm between the pivot and itself,as shown in the Figure 3.3below.

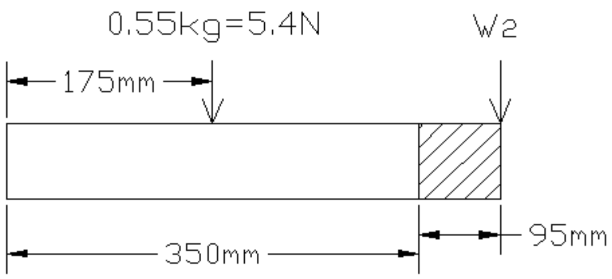

*Figure 3.3.*Free body diagram of the beam with the counterweight which is placed at the edge

By the moment analysis:

$$95w_2 = 5.4N \times 175mm$$
$$w_2 = 9.95N$$
$$w_2 = 1.015kg$$

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In the other option, counterweight can be placed closer to the pivot. This makes the counterweight to have a distance of 47.5mm between the pivot and itself,as shown in the Figure 3.4.

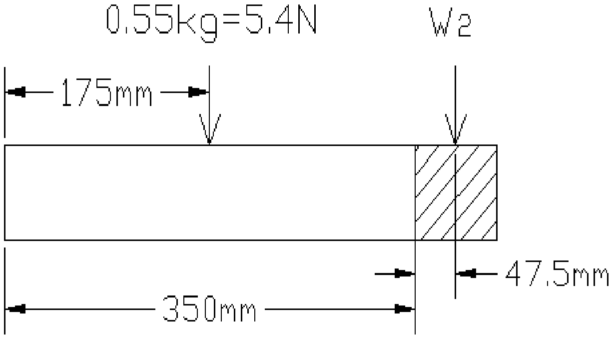

*Figure 3.4.*Free body diagram of the beam with the counterweight which is placed closer to the pivot

By the moment analysis:

$$47.5w_2 = 5.4N \times 175$$
$$w_2 = 19.9N$$
$$w_2 = \frac{19.9N}{9.81m/s^2} = 2.03kg$$

3.3 Counterweight Size

Dimensions of the counterweight have to be determined according to this weight range. The counterweight diameter is 50mm and its length is 100m.Weight can be calculated by using equation 6.

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$$W = \rho \times \pi r^2 L$$
$$W = (8\times10^{-6})\times \pi r^2 L$$
$$W = (8\times10^{-6})\times \pi (25mm)^2 \times 100mm$$
$$W = 1.57kg$$

Where:

ρ is steel density which is equal to 8 kg/m^3

By considering these dimensions, the weight of the counterweight becomes 1.57kg.

3.4 Power of DC Motor

To determine the power of the motor that is going to be used to rotate the shaft about the perpendicular axix to the disk, the torque must be calculated first. Information is gathered from the related book [5]. Figure 3.5 shows the disk and shaft assembly.

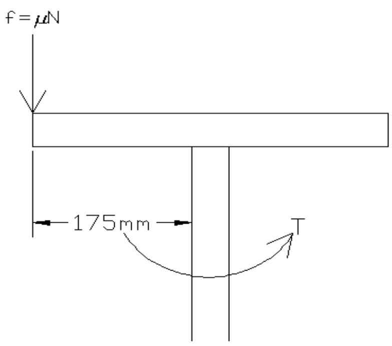

Figure 3.5. Disk and shaft assembly

To calculate the torque required, f value must be known. To find f, maximum amount of load that will be applied on the system is multiplied with the coefficient of friction (metal to metal). Coefficient of friction (μ) can be taken between 0.15-0.2;the value 0.2 has been selected.

$$f = 0.2\times(10kg\times 9.81m/s^2) = 19.62N \tag{7}$$

Then, torque can be calculated as shown below;

$$T = f \times 175mm$$
$$T = (19.62N) \times 0.175m \quad (8)$$
$$T = 3.44Nm$$

Finally, by using above values, power of the motor can be determined. Also, ω which is radian per second and should be taken as 17rad/s according to the related standard [4].

$$\omega = \frac{v}{r} = \frac{0.68m/s}{0.04m} = 17rad/\sec \quad (9)$$

$$P = T \times \omega$$
$$P = 3.44Nm \times 17rad/s = 58.48W \quad (10)$$

So the minimum required power of the motor is found to be 58.48 Watts.

In the above calculations, to determine the power of electrical motor, only the maximum size of the load that is going to be used for testing purpose is considered. The weight of the pin, beam, disk, and counterweight and some connections parts were neglected. Now, another way of calculating the motor power is possible. Firstly, weight of each component has to be determined.

Load:

$$W_1 = (10kg \times 9.81m/s^2) = 98.1N$$

Slab:

$$W_2 = (0.55kg \times 9.81m/s^2) = 5.4N$$

Counterweight:

$$W_3 = (2kg \times 9.81m/s^2) = 19.62N$$

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Disk:

$$W_4 = (0.5kg \times 9.81 m/s^2) = 4.9N$$

Pin and its connection components:

$$W_6 = (0.304kg \times 9.81 m/s^2) = 2.98N$$

Total value of W's is equal to 131 N (13.35kg).

Power of the motor can be recalculated by taking the total weight of the components, without neglecting any present part.

$$f = 0.2 \times (13.35kg \times 9.81 m/s^2) = 26.19N$$

$$T = f \times 175mm$$
$$T = (26.19N) \times 0.175m$$
$$T = 4.58Nm$$

$$\omega = \frac{v}{r} = \frac{0.68 m/s}{0.04m} = 17 rad/\sec$$

$$P = T \times \omega$$
$$P = 4.58Nm \times 17 rad/s = 77.86W$$

So, by follow this method, the minimum required power of the motor becomes 77.86 Watts.According to the power that is obtained from calculations, the type of the motor is chosen as EV030.00-56.

3.5 Speed Levels of RPM Adjusting Device

The motor drive of pin on disk apparatus test mechanism can rotate in several different speed levels up to 200 rpm. These levels can be adjusted according to the user's demand. As mentioned in the standard, rotating speeds are typically in the range of 0.3 to 3 rad/s. There are three possible speed levels.

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Highest speed:

It has to be equal to 0.68m/s which is = (40.8m/min).

$$2\pi f = 2\times 3.14\times 0.04 = 0.2512\,m/rev$$
$$(0.2512\,m/rev)\times(\omega_1 rev/\min) = 40.8\,m/\min$$
$$\omega_1 = 162.42\,rev/\min \qquad (11)$$
$$\omega_1 = (162.42\,rev/\min)\times\frac{2\pi}{60} = 17\,rad/\sec = 2.707\,rev/\sec$$

Where:

(17 *rad/sec*) / (2×3.14) = 2.707 *rev/sec*, and *f* is motor frequency= 0.04

There is another way of calculating the rpm value by using equation 9;

$$\omega_1 = \frac{v}{r} = \frac{0.68\,m/s}{0.04\,m} = 17\,rad/\sec$$

Medium speed:

It has to be 0.22m/s (13.2m/min). The same procedure in equation 11, angular velocity of medium speed can be found in the following:

$$2\pi f = 2\times 3.14\times 0.04 = 0.2512\,m/rev$$
$$(0.2512\,m/rev)\times(\omega_2 rev/\min) = 13.2\,m/\min$$
$$\omega_2 = 52.55\,rev/\min$$
$$\omega_2 = (52.55\,rev/\min)\times\frac{2\pi}{60} = 5.50\,rad/\sec = 0.875\,rev/\sec$$

There is another way of calculating the rpm value;

$$\omega_2 = \frac{v}{r} = \frac{0.22\,m/s}{0.04\,m} = 5.50\,rad/\sec$$

Lowest speed:

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It has to be 0.12m/s (7.2m/min). By using equation 11, angular velocity of lowest speed can be found as follow:

$$2\pi f = 2 \times 3.14 \times 0.04 = 0.2512 m/rev$$
$$(0.2512 m/rev) \times (\omega_3 rev/\min) = 7.2 m/\min$$
$$\omega_3 = 28.66\, rev/\min$$
$$\omega_3 = (28.66\, rev/\min) \times \frac{2\pi}{60} = 3 rad/\sec = 0.477 rev/\sec$$

There is another way of calculating the rpm value;

$$\omega_3 = \frac{v}{r} = \frac{0.12 m/s}{0.04 m} = 3 rad/\sec$$

3.6 Column Analysis of Square Profile

In this section, the selection of appropriate profile size is shown. These profiles are going to be used in the chassis construction of the pin-on-disk apparatus. In order to make the right selection, some calculations must be done to assure that under all circumstances, the chassis will not get damaged or cause any trouble. Figures 3.6 and 3.7 represent the dimensions of the profile that will be used in the following calculations.

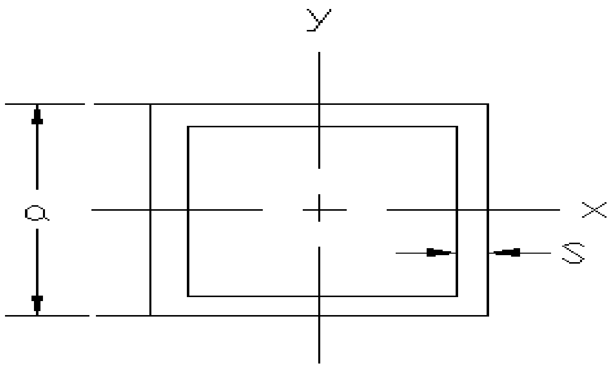

Figure 3.6. Changeable parameters in a square profile

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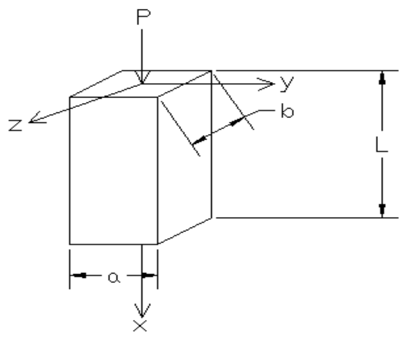

Figure 3.7. Isometric view of a square profile with changeable parameters

The best profile for the square column was obtained by using the following design steps.

<u>Step 1:</u>

These formulae will be used.

$$\sigma_{cr} = \frac{P_{cr}}{A} \quad (12)$$

$$P_{cr} = P \times (F.S) \quad (13)$$

$$P = m \times g = 50kg \times 9.81m/s^2 = 0.5kN \quad (14)$$

F.S represents the factor of safety.

$$P_{cr} = 0.5kN \times (2.5) = 1.25kN$$

$$\sigma_{cr} = \frac{\pi^2 E}{(Le/r)^2} \quad [4] \quad (15)$$

$$\frac{Le}{r} = \frac{2L}{b/\sqrt{12}} \quad (16)$$

Apply equation 16. Let, L = 900 mm = 0.9m and for steel E = 200 GPa

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$$\frac{Le}{r} = \frac{6.235}{b}$$

By using equation 15, critical stress can be found.

$$\sigma_{cr} = \frac{\pi^2 E}{(6.235/b)^2} = \frac{\pi^2 \times 200 \times 10^9 \times b^2}{(6.235)^2}$$

$$\sigma_{cr} = \frac{1.9719 \times 10^{12} \times b^2}{38.875} = 5.0724 \times 10^{10} \times b^2$$

$$\sigma_{cr} = 5.0724 \times 10^{10} \times b^2$$

$$\frac{1250}{A} = 5.0724 \times 10^{10} \times b^2 \qquad (17)$$

Value of A is changeable and some iteration must be done by using the values from Table 3.2, to reach the best result.

Table 3.2. **Square profile [4]**

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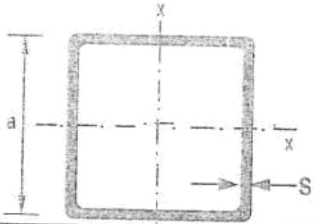
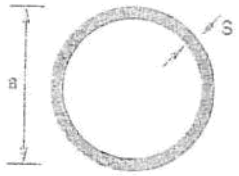
KARE PROFILLER



a mm	Et Kalınlığı mm	Köşe yarı çapı r mm	Kesit alanı F cm²	Ağırlık G Kg/m	Atalet momenti J cm⁴	Atalet yarıçapı i cm	Mukavemet moment w cm³
10	1.0	2	0.36	0.28	0.05	0.10	0.37
	1.0	2	0.56	0.44	0.18	0.24	0.57
15	1.2	2	0.66	0.52	0.21	0.28	0.56
	1.5	3	0.81	0.64	0.25	0.33	0.55
	1.0	2	0.76	0.60	0.46	0.46	0.78
20	1.2	2	0.90	0.71	0.53	0.53	0.77
	1.5	3	1.11	0.87	0.64	0.64	0.76
	2.0	3	1.44	1.13	0.79	0.79	0.74
	1.0	2	0.96	0.75	0.92	0.74	0.98
	1.2	2	1.14.	0.90	1.08	0.86	0.97
25	1.5	3	1.41	1.11	1.30	1.04	0.96
	2.0	3	1.84	1.44	1.63	1.30	0.94
	1.0	2	1.16	0.91	1.63	1.09	1.19
30	1.2	2	1.38	1.08	1.91	1.27	1.18
	1.5	3	1.71	1.34	2.32	1.55	1.16
	2.0	3	2.24	1.76	2.94	1.96	1.14
	1.2	3	1.86	1.46	4.68	2.34	1.59
	1.5	3	2.31	1.81	5.72	2.86	1.57
40	2.0	3	3.04	2.39	7.34	3.67	1.55
	2.6	4	3.75	2.94	8.83	4.41	1.53
	3.2	5	4.44	3.49	10.20	5.10	1.51
	1.5	3	2.91	2.28	11.42	4.57	1.98
50	2.0	3	3.84	3.02	14.77	5.91	1.96
	2.6	4	4.75	3.73	17.91	7.16	1.94
	3.2	5	5.64	4.43	20.85	8.34	1.92
	2.0	3	4.64	3.64	26.04	8.68	2.37
60	2.6	4	5.75	4.51	31.74	10.58	2.35
	3.2	5	6.84	5.37	37.14	12.38	2.33
	2.6	4	6.75	5.30	51.33	14.66	2.76
70	3.2	5	8.04	6.31	60.27	17.22	2.74
	4.0	5	9.31	7.31	68.81	19.66	2.72
	2.5	4	7.75	6.08	77.66	19.41	3.16
80	3.2	5	9.24	7.25	91.44	22.86	3.14
	4.0	5	10.71	8.41	104.68	26.17	3.12
	3.2	5	10.44	8.20	131.86	29.30	3.55
90	4.0	5	12.11	9.51	151.26	33.61	3.54
	4.2	6	13.76	10.80	169.98	37.77	3.52

SANAYİ BORULARI



DIŞ ÇAP mm	ET KALINLIĞI mm				
	1.0	1.2	1.5	1.8	2.0
	AĞIRLIK Kg/m				
8	0.173				
9.3	0.197				
10	0.222	0.260	0.314		
13	0.296	0.349	0.425		
16	0.370	0.438	0.536	0.630	0.690
17.2	0.395	0.486	0.573	0.675	0.740
19	0.444	0.527	0.647	0.763	0,838
21	0.493	0.586	0.721	0.852	0.937
22	0.518	0.616	0.758	0.891	0.936
25	0.592	0.704	0.869	1.030	1.134
28,6	0.666	0.793	0.980	1.163	1.282
30	0.715	0.852	1.054	1.252	1.381
32	0.764	0.911	1.128	1.341	1.480
35	0.838	1.000	1.239	1.474	1.626
38	0.912	1.089	1.350	1.607	1.776
40	0.962	1.148	1.424	1.696	1.874
42		1.207	1.498	1.784	1.973
45		1.296	1.609	1.918	2.121
48		1.385	1.720	2.051	2.269
50		1.444	1.794	2.140	2.367
51		1.474	1.831	2.184	2.417
55		1.592	1.979	2.361	2.614
60		1.740	2.164	2.583	2.861
63		1.829	2.275	2.717	3.009
70			2.534	3.027	3.354
76			2.756	3.294	3.650
80			2.904	3.471	3.847
89				3.871	4.291
90				3.915	4.340
100					4.833
110					5.327
114					5.600

Step 2:

$$\sigma_{cr} = \frac{1250}{A}$$

1st Iteration: For 15×15×1.5 mm profile

If A= 0.81×10^{-4}

$$\frac{1250}{0.81 \times 10^{-4}} = 5.0724 \times 10^{10} \times b^2$$

$$b^2 = 3.0423 \times 10^{-4} m$$
$$b = 0.01744 m$$
$$b = 17.44 mm$$

Since we could not reach 15 mm, iteration must be repeated.

2nd Iteration: For 15×15×1.2 mm profile

If A= 0.66×10^{-4}

$$\frac{1250}{0.66 \times 10^{-4}} = 5.0724 \times 10^{10} \times b^2$$

$$b^2 = 3.734 \times 10^{-4} m$$
$$b = 1.933 \times 10^{-2} m$$
$$b = 19.33 mm$$

Since we could not reach 15 mm, iteration must be repeated.

3rd Iteration: For 20×20×1.2 mm profile

If A= 0.90×10^{-4}

$$\frac{1250}{0.90 \times 10^{-4}} = 5.0724 \times 10^{10} \times b^2$$

$$b^2 = 2.738 \times 10^{-4} m^2$$
$$b = 1.65 \times 10^{-2} m$$
$$b = 16.5 mm$$

Since we can not reach 20 mm, iteration must be stopped.

The closest value from iterations was found from the first iteration. So, a 15×15×1.5 mm square profile is the most suitable choice for constructing the chassis of the apparatus.

3.7 Analysis of the Preferred Square Profile

As it is found from the above calculations, a 15×15×1.5 mm square profileis enough to construct the chassis but it was preferred to use profiles with a 40×40×2.0 mm size. The reason to give this decision is that in the future this apparatus might be modified such as installing a cooling system. To be sure that the chassis will not get damaged after any possible modifications, a bigger size of square profile is chosen to be used.

The critical strength of 15×15×1.5 mm square profile was determined by using equation 15:

$$\sigma_{cr} = 5.0724 \times 10^{10} \times b^2$$
$$\sigma_{cr} = 5.0724 \times 10^{10} \times 3.0423 \times 10^{-4}$$
$$\sigma_{cr} = 15431762.52 N / m^2$$

The critical load, when the dimensions of the profile are 40×40×2.0 mm was determined by using equation 12:

$\sigma_{cr} = \dfrac{P_{cr}}{A}$, and to find the area of 40×40×2.0 mm Profile:

$$A = \left[(a.b)_{out} - (a.b)_{in} \right] \quad (18)$$

$$A = [(0.04 \times 0.04) - (0.036 \times 0.036)]$$ mm^2
$$A = 3.04 \times 10^{-4}$$

$$P_{cr} = 15431762.52 \times (3.04 \times 10^{-4}) = 4691.26N$$

Determining the factor of safety of the profile that we chose by using equation 13:

$$P_{cr} = P \times (F.S)$$

$$4691.26 = 500 \times (F.S)$$

So the factor of safety becomes 9.38.

3.8 Beam Analysis of Rectangular Profile

To find the suitable rectangular profile size. all calculations has been done and shown one by one. Figures 3.8 and 3.9 indicate the parameters which are mentioned during the calculations.

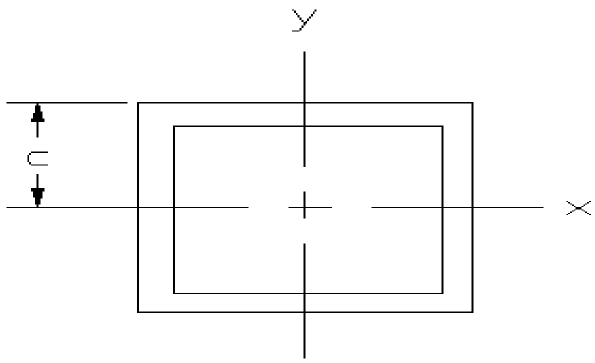


Figure 3.8. Rectangular profile with an indication of centroid

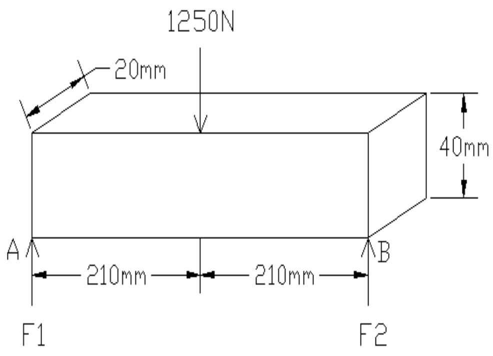


Figure 3.9. Isometric view of a square profile and its dimensions

To find the forces acting in the edges of the profile:

$+ \Sigma M_B = 0$

$-F_1(0.42m) + 1250N(0.21m) = 0$

F_1= 625N

Since the distances between load and the reaction forces are the same. Both reactions forces have the same value. By using this information, shear and moment diagram can be drawn. This diagram can be seen in Figure 3.10 below.

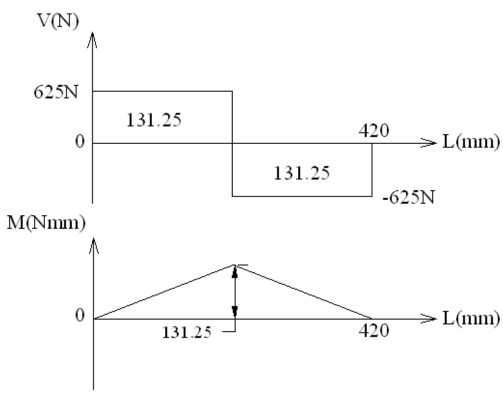


*Figure 3.10.*Shear and moment diagram

$$\sigma_{all} = \frac{Mc}{I} \qquad (19)$$

$$S = \frac{c}{I}$$

$$\sigma_{all} = MS \qquad (20)$$

$$S = \frac{\sigma_{all}}{M} = \frac{200}{131.25} \qquad (21)$$

$$S = 1.524 m^3$$

As a result of the above calculations, the value of S can be taken as 1.5. Since the profile with a value of S equal to 1.5 is not commonly use in the market, we can choose a value closer to this such as 2 mm.

4. MANUFACTURING OF PIN-ON-DISK APPARATUS

Manufacturing the apparatus was one of the most complicated processes in this work. The reason is that the apparatus is made up of completely stainless steel type 304. After finishing the design and drawing process it was focused on the easiest way to manufacture our apparatus. Stainless steel can be welded most efficiently by using MIG (metal inert gas) or TIG (tungsten inert gas) welding method but since, the facilities to perform this kind of welding is not available in the site of work, it is preferred to use arc welding as available facility. Arc welding can also be used to weld stainless steel with electrodes specially made for stainless steel. After welding the apparatus, connection points were cleaned with a special chemical. Special care was given to the weld areas. A special chemical was applied to the cut edges and sides of the stainless steel to protect against corrosion. Also the deposits on the joints as a result of the arc welding, was cleaned as much as possible by using abrasive paper and wheel.

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4.1 Parts Manufacturing

4.1.1 Manufacturing of the Chassis

After providing the stainless steel 304profiles to the workshop for the manufacturing process, the first step in manufacturing was cutting the profiles according to the desired dimensions mentioned in the drawings.Then, at one end of the profiles which will be in contact with the ground, adjustable bolts are welded as shown in Figure 4.1. The purpose of using these bolts is to provide a balanced level to the apparatus in every ground surface condition. By welding the profiles one by one from their joining points, the welding process was started. The distances between profiles were given according to the drawings so that no problem occurred during the welding process.

*Figure 4.1.*Adjustable bolts to provide balance

As it is mentioned before, the placement of the stainless steel sheet metal is between the chassis and the upper part. So, to allow the shaft of the DC motor to pass through the upper part, a hole with a size bigger than the diameter of the shaft must be drilled on the sheet metal. In addition, two more holes must be also drilled on the sheet metal so that the pivot can be joined to the metal plate on the chassis by using bolt and nut assembly. Drilling operations can be seen in Figure 4.2.

*Figure 4.2.*Drilling the hole on the sheet metal

4.1.2 Manufacturing of the Upper Part

The upper part of the apparatus consists of a beam, pivot, a counterweight and the pin holding part. The counterweight and the pivot were manufactured separately and connected to the slab with different methods. The pivot and beam were connected each other by using bolt and nut assembly. Pin holding part and counterweight are designed differently so that counterweight can be moved on the slab and the pin can be changed easily when required. Assembled shape of the upper part is shown from different angles in Figures 4.3 and 4.4.

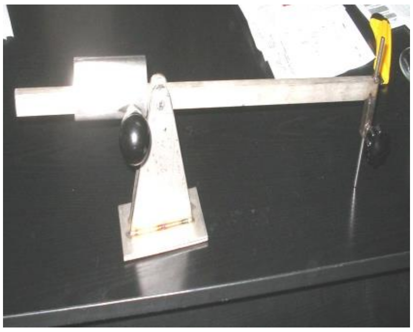

*Figure 4.3.*Assembled shape of the upper part

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Figure 4.4. Assembled shape of the upper part

4.2Assembling

The final, and probably the most important phase of the construction was related to the assembly of the apparatus. The chassis and the upper part were connected with each other by using bolt and nut assembly. To give a better appearance to the apparatus, between the upper part and the chassis, a stainless steel sheet metal is placed. It was bended nicely and the holes were drilled on the sheet metal so that the shaft of the motor can pass through it very easily and the pivot of the upper part can be joined to the chassis.In addition to these, DC motor with the shaft attached on it and rpm adjusting device,the most important equipment of the apparatus, is fixed to the chassis. Speed (rpm) adjusting device is very practical to use. There are buttons on it with the indications below them, so the user can easily understand how to use this control panel as shown in Figure 4.5. To start the device, main power and forward switches must be put into position "1". After that, the phase lamp turns into red and that means the device is ready to control the motor. Speed of the motor can be changed by using fast and slow buttons. To reach the desired speed, one of these buttons must be pressed and hold it like that until the desired speed is reached. Then, the button can be released. Speed is shown on the control panel of the device in terms of revolution per minute. Speed (rpm) adjusting device can be stopped by putting main power and forward switches into position "0". Emergency button can be also used to stop the device immediately in urgent situations.

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To obtain the most suitable and useful shape of the apparatus, some additions were done. First, a wooden plate was cut and placed at the middle of the chassis, which is for placing the test specimens and other necessary equipment. Then, several different weights, varying from 0.5 kg to 3 kg, were manufactured in the workshop, which are going to be used in the experiments as a load. These weights are attached to the wooden plate with the help of a metal platform which is also manufactured in the workshop as shown in Figure 4.6. Before the attachment, metal platform is painted and the weights are varnished to avoid corrosion. Lastly, small spirit level is purchased and attached on the upper part of the apparatus which will be useful in experiments to obtain a balanced system as shown in Figure 4.7. Final appearance of the apparatus is given in Figure 4.8.

*Figure 4.5.*Control panel of the speed (rpm) adjusting device

*Figure 4.6.*Weights and test specimens on the wooden plate

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*Figure 4.7.*Appearance of the upper part

*Figure 4.8.*Final appearance of the apparatus

6 DISCUSSION AND CONCLUSION

In this work, design and manufacturing procedures of a pin-on-disk wear testing apparatusis stated.

This paper was focused on the design and manufacturing process. It has given information about testing procedure and the working principles of the apparatus. Also calculations were applied in order to determine the dimensions of the materials that are used in manufacturing the pin-on-disk apparatus. In addition, the calculations helped in material selection as well as choosing the proper equipment's that is needed such as the electric motor.

Different types of experiments were done with several different test specimens to be able to make a comparison between wear test results of this work and that of another experiment found in literatures [6]. The comparison has been done with that tests using a pin- on –disc machine (Wear and Friction Monitor Tester TR-201made by M/S DUCOM, Bangalore, INDIA) conforming to ASTM G 99 standard [7]. As a result of this comparsion, it was concluded that there is a compatibilty in the results obtained by the present apparatus with that manufactured by M/S DUCOM, Bangalore, INDIA. The wear of the test specimens increases as the speed (rpm) of the motor increases and it is found also, if both the applied load and speed stays constant, wear decreases as the sliding distance increases.

It was concluded, that a pin-on-disk wear testing apparatus which is working properly is successfully designed and manufactured. Everything is done carefully to produce an apparatus that matches the whole requirements as stated in the related standard.

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