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Fault Diagnose of Gear Box: A Case Study

Premanand S Chauhan[1], Sudhir Sharma[2], Deepak Gupta[3] Ragini Gupta[4], Pradeep Soni[5] , Bilal Khan[6] & Jatin Prajapati[7]
[1]Sushila Devi Bansal College, Indore-453331, India
[2,3,4,5,6,7]IPS College of Technology and Management, Gwalior-474001, India

Abstract

The purpose of this study is to diagnose and mend the gear box used in Los Angeles Abrasion Testing Machine. It is found to be defaced due to overloading and running in dry condition (without proper lubrication). It is then resolved by replacement of worm wheel with it's similar one used in the gear box and furnished it with the suitable grade of lubricant.

Keywords: Gearbox, Los Angeles Abrasion Testing Machine, Phosphor Bronze, Lubricant, Worm Wheel,

1. Introduction

1.1. Los Angeles abrasion testing machine

It is used to determine the aggregates resistance to fracturing resulting from the impact of crashing and grinding in a rotating steel drum with inner diameter 720 mm and internal span 510 mm which contain twelve hardened steel balls having 46-48 mm weighing 390-410 grams.

1.2. Worm & worm wheel

A drive in which a worm and a worm wheel are in mesh. These elements are also known as the worm screw and worm gear. Worm gear is generally used to transmit the power and motion between two non-intersecting and non-parallel shaft. The input and out shaft for worm gear are typically at right angles reference by [1]

Characteristic of worm & worm wheel

- It improves load carrying capacity and also reduce the speed.
- Excellent Combination of strength, formability & hardness.
- Good electrical conductivity and corrosion resistance.
- Excellent soldering and brazing properties.
- Possessing excellent mechanical strength along with desirable for sheet metal processing.

1.3. Phosphor bronze

It is the type of copper alloy. It contains 0.5-11 % of tin and 0.01-.35 % of phosphorous and may contain other element like 0.5-3.0 % of lead and 85-90 % of carbon. The tin increases the strength of copper and also increases corrosion resistance while phosphorous enhance its resistance to wear and stiffness. The phosphorous also reduces the viscosity of the molten alloy reference by [2]

Properties of phosphor bronze[3].

- Good corrosion and fatigue resistant.
- High electrical conductivity.
- Lower coefficient of friction.
- Fine granular.
- Outstanding elasticity.

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Corresponding Author's E-mail ID: deepakgupt125@gmail.com

2. Literature Review

According to Kaushal Kishore et al. Worm gear are commonly used to reduce speed and increase torque transfer in a compact area. Phosphor bronze is used to satisfy this condition because of its lower coefficient of friction and have great fatigue and wear properties. It was the study of failure analysis of worm wheel due to intergranular brittle fracture using scanning electron microscopy. It was observed to have number of casting voids and intermetallic phases were also identified (Cu_3Sn and Ni_3P) by using dispersive spectroscopy technique[4].

According to Adil Muminovic & Nedzad Repcic et al. The aim of this paper is to increase the load carrying capacity and efficiency of worm gears with decrease in its utilisation cost. In order to attain this condition, it is quiet necessary to block out a gearbox that would be much near to the adequate solution at the corner of heat with the determination of operation losses. Along with the geometrical design of worm gearing which provides some sort of hydrokinetic lubrication, the applicable lubricant (mineral and synthetic oil) also plays an important role in order to attain the great efficiency and working of the worm gears [5]

Accoding to Hardik G. Chothani & Kalpesh D Maniya work on the optimization of a single start worm gear to improve its working with the help of three parameters. Input torque and lubricant heating time are taken parameters which are determined and improved successfully by Taguchi Grey Relational Analysis (GRA). They also proved that these parameters are dominant for the worm gear execution. The regulation of the single start worm gearbox can be increased with the help of these parameter [6].

3. Methodology

3.1 Gear box dismantling

When the gear box of Los Angeles abrasion testing machine was dismantled it was found that the profile of worm wheel was fully damaged and the gear box was totally dry (No Lubricant found).

(a)  (b) 

Fig. 1. (a) Damaged profile of Worm wheel (b) Dry Gear Box

3.2 Reason of failure

There are three possible reasons of this failure,

- The Machine ran in dry condition (No lubricant found).
- Due to excessive load.
- The design of worm wheel was not proper.

3.3 Possible solutions

There may be three possible solution for this failure,

- To change the design of the gear box.
- To fix the load capacity.
- To change the lubricant.
- To change the material of worm wheel.

3. 4 Most feasible solution

To change the design of gear box is very complicated and expensive. To fix the load is not suitable and it is also very complicated to change the material of worm wheel. So various forces and viscosity of the lubricating oil are calculated. On the basis of these parameters the proper grade of lubricant is selected for the gear box.

4. Abbreviations

Z_1	= Total number of starts on worm
Z_2	= Total number of teeth on worm wheel
d_1	= Diameter of pitch circle of worm(mm)
d_{a1}	= Outer diameter of worm (mm)
d_2	= Diameter of pitch circle of worm wheel (mm)
n_1	= Speed of worm (rpm)
n_2	= Speed of worm wheel (rpm)
a	= Centre to centre distance (mm)
P	= Power of motor (kW)
$(M_t)_1$, $(M_t)_2$	= Permissible torque on the worm wheel (N-mm)
X_{b1}, X_{b2}	= Speed factor for strength of worm and worm wheel
S_{b1}, S_{b2}	= Bending stress factors of worm and worm wheel
kW	= Power transmitted by gears on the basis or thermal consideration (kW)
k	= Overall heat transfer coefficient of housing walls
t	= Temperature of lubricating oil (^{0}C)
t_s	= Surrounding temperature (^{0}C)
A	= Effective surface area of housing (m^2)
η	= Efficiency of worm gear

5. Calculation

5.1 Given data for calculation

$Z_1 = 1$
$Z_2 = 45$
$d_1 = 29$mm
$d_{a1} = 33$ mm
$d_2 = 103$ mm
$n_1 = 1440$ rpm
$n_2 = 32$ rpm
a = 66 mm
P = 0.746 kW

5.2 Solution

Axial Module (m) = d_2/Z_2

$m = 103/45$

$m = 2.288$ mm

Diametral quotient (q) = d_1/m

$q = 29/2.288$

$q = 12.67$

Lead angle of worm (γ) = $\tan^{-1}(Z_1/q)$

$\gamma = \tan^{-1}(1/12.67)$

$\gamma = 4.5^0$

Axial Pitch (P_x) = $\pi \times m$

$P_x = \pi \times 2.388$

$P_x = 7.187$ mm

Lead (l) = $\pi \times m \times Z_1$

$l = \pi \times 2.288 \times 1$

$l = 7.187$ mm

Rubbing Velocity (V_s) = $\frac{2 \times n_1 \times d_1}{60000 \times \cos\gamma}$

$(V_s) = \frac{2 \times 1440 \times 29}{60000 \times \cos(4.5)}$

$(V_s) = 2.19$ m/s or 2 m/s (approx.)

The magnitude of coefficient of friction (μ) is lies between 0.035 to 0.045 for rubbing velocity 2 m/s [7]

Taking the magnitude of coefficient of friction **(μ) is 0.040**

The magnitude of coefficient of friction is based on two important assumptions.

- The worm is made of case hardened carbon steel, while worm wheel is made up of phosphor bronze [7].
- The gears are oiled (Lubricated) with specific oil which have viscosity of 16 to 130 centistokes at 60^0C [8].

The value of pressure angle (α) should not be less than 20^0 for single start worm [9]

Torque transmitted by gear (M_t) = $\frac{60\times10^6 \times P}{2 \times \pi \times n_1}$

$M_t = \frac{60\times10^6 \times 0.746}{2 \times \pi \times 1440}$

$M_t = 4947.066$ N-mm

Tangential component on the worm $(P_1)_t = \frac{2 \times M_t}{d_1}$

$(P_1)_t = \frac{2 \times 4947.066}{29}$

$(P_1)_t = 341.176$ N

Efficiency of worm gear drive (η) = $\frac{(\cos\alpha - \mu \tan\gamma)}{(\cos\alpha + \mu \cot\gamma)}$

$$\eta = \frac{(\cos 20 - 0.040 \tan 4.5)}{(\cos 20 + 0.040 \cot 4.5)}$$

$$\eta = 0.6468 \text{ or } 64.68\%$$

Clearance (c) = $0.2 \times m \times \cos\gamma$

$c = 0.2 \times 2.288 \times \cos 4.5$

$c = 0.45$ mm

Effective face breadth of worm wheel (F) = $2m\sqrt{q+1}$

$F = 2 \times 2.288 \times \sqrt{12.67 + 1}$

$F = 16.91$ mm

Span of root of worm wheel teeth (Lr) = $(d_{a1} + 2c) \sin^{-1}\left[\frac{F}{(da1 + 2c)}\right]$

$$Lr = (33 + 2\times0.45) \sin^{-1}\left[\frac{16.91}{(33 + 2\times0.45)}\right]$$

$$Lr = 1041.35 \text{ mm}$$

5.3 Strength rating of worm gears

The maximum permissible torque which a worm wheel can resist without its bending failure is given by:

$(M_t)_1 = 17.65\ X_{b1}\ S_{b1}\ m\ Lr\ d_2 \cos\gamma$

$(M_t)_2 = 17.65\ X_{b2}\ S_{b2}\ m\ Lr\ d_2 \cos\gamma$

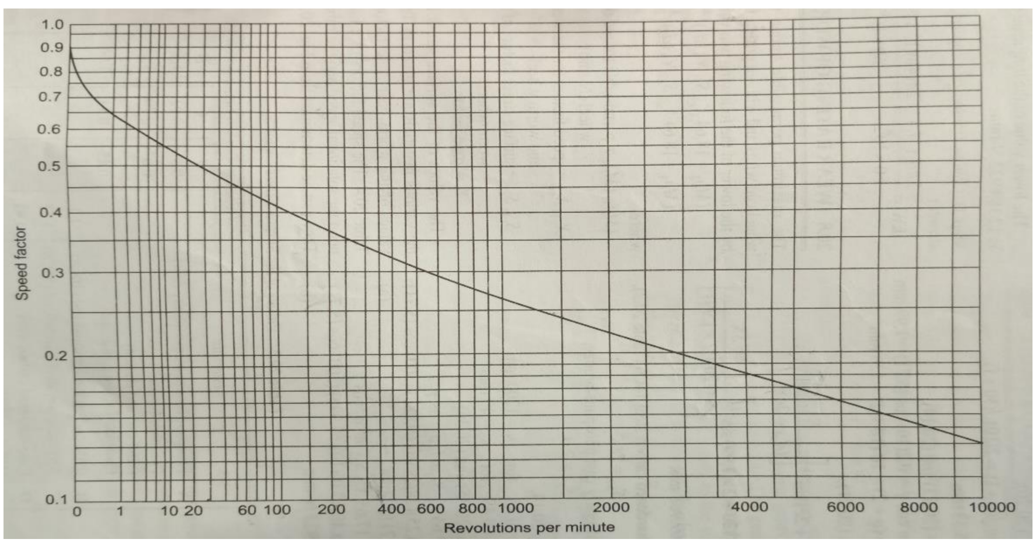

Fig. 2. Speed factor of worm gears for strength (X_b) [10]

From Fig. 2.

$X_{b1} = 0.25$ for $n_1 = 1440$

$X_{b2} = 0.45$ for $n_2 = 32$

Table 1. Value of bending stress factor S_b [11]

Material	S_b
Phoshor-bronze (sand-cast)	5.00
Case-hardened carbon steel (10C4, 14C6)	28.20

From Table 1.

S_{b1} = 28.20
S_{b2} = 5.00

Permissible torque on the worm wheel

$(M_t)_1 = 17.65\ X_{b1}\ S_{b1}\ m\ Lr\ d_2 \cos\gamma$
$(M_t)_1 = 17.65 \times 0.25 \times 28.20 \times 2.288 \times 1041.35 \times 103 \times \cos 4.5$
$(M_t)_1 = 30442684.04$ N-mm

$(M_t)_1 = 17.65\ X_{b2}\ S_{b2}\ m\ Lr\ d_2 \cos\gamma$
$(M_t)_1 = 17.65 \times 0.45 \times 5.00 \times 2.288 \times 1041.35 \times 103 \times \cos 4.5$
$(M_t)_1 = 9715750.225$ N-mm

From above both values, the lowest value of the torque on the worm wheel is 9715750.225 N-mm

3.4 Thermal consideration of worm gears

$t = 50^0$C
$t_s = 35^0$C
η = 64.68%

Projected area of worm wheel

$$A_g = \frac{\pi}{4} \times (d_2)^2$$

$$A_g = \frac{\pi}{4} \times (103)^2$$
$$A_g = 8332.289\ mm^2$$

Projected area of worm

$$A_w = \frac{\pi}{4} \times (d_1)^2$$

$$A_w = \frac{\pi}{4} \times (29)^2$$
$$A_w = 660.519\ mm^2$$

Total projected area of worm and worm wheel/effective surface area of housing

$$A = A_w + A_g$$
$$A = 8332.289 + 660.519$$
$$A = 8992.808\ mm^2$$
$$A = 8992.808 \times 10^{-6}\ m^2$$

On the basis of thermal consideration (kW), the power transmitted by gears can be calculated as,

$$kW = \frac{k\ (t - t_s)\ A}{1000 \times (1 - \eta)}$$

$$kW = \frac{24 \times (50-35) \times 8992.808 \times 10^{-6}}{1000 \times (1-0.6468)}$$

$$kW = 9.165 \times 10^{-3}$$

Rate of heat generation (H_g)

$$H_g = 1000 \times (1- \eta) \times kW$$
$$H_g = 1000 \times (1- 0.6468) \times 9.165 \times 10^{-3}$$
$$H_g = 3.2 \text{ W}$$

Rate of heat dissipation (H_d)

$$H_d = k (t - t_s) A$$
$$H_d = 24 \times (50 - 35) \times 8992.808 \times 10^{-6}$$
$$H_d = 3.2 \text{ W}$$

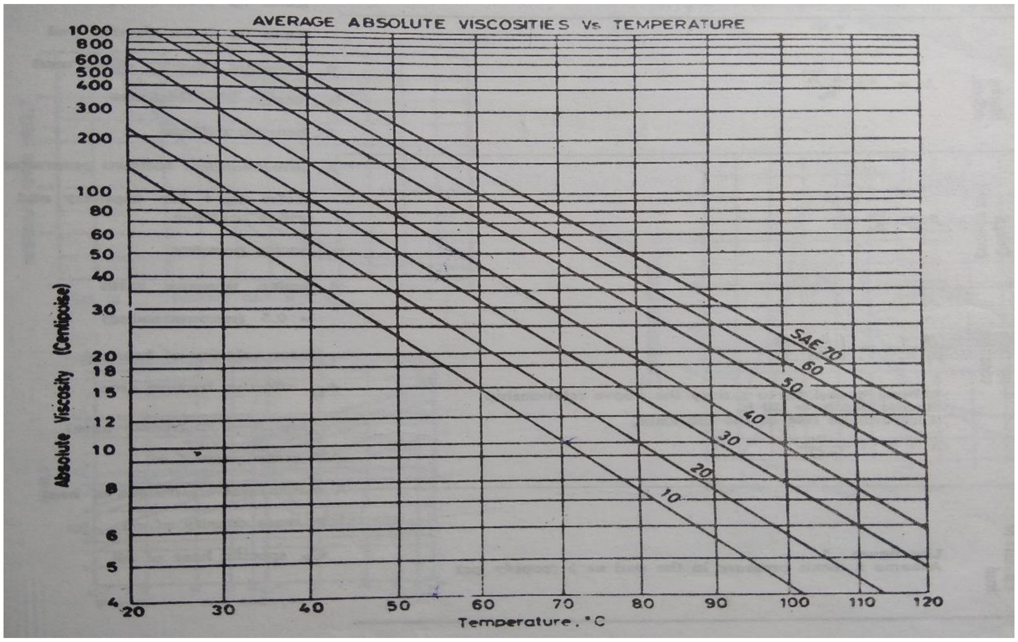

Fig. 3. Average absolute viscosity Vs Temperature [12]

As per Fig. 3. For 50^0C and absolute viscosity 16 to 130 centipoise the most preferable grade of lubricants are **SAE 40 and SAE 50.**

6. Result

After providing the suitable grade of lubricant **" SAE 40 "**, the Los Angeles Abrasion testing machine is working in proper condition without any failure.

7. Conclusion

It is concluded that the worm wheel of the gear box replaced by its similar one and with the help of all possible calculations, the suitable grade of lubrication (SAE 40) made available to the gear box of Los Angeles Abrasion testing machine for its smooth and proper functioning.

References

[1] Witold Rybczynski, One good turn : a natural history of the screwdriver and the screw. London, 2000. Page 139
[2] Phosphor Bronze ; Copper Development Association.
https://www.copper.org/resources/properties/microstructures/phos_bronze.html

[3] Dani Weinhandl, Commo uses for phosphor bronze, Posted on June7, 2017.
https://www.meadmetals.com/blog/common-uses-for-phosphor-bronze
[4] Kaushal Kishore, Gautam Mukhopadhyay & Manashi Adhikary, Metallurgical Analysis of Premature Failure of s Phosphor Bronze Worm Wheel, Journal of Failure Analysis and Prevention, Published online on 29 October,2018.
[5] Adil Muminovic, Nedzad Repcic, Dragan Zezelj, The efficiency of worm gears lubricated with oils of mineral and synthetic bases
| Transactions of Famena XXXVII-4 (2013)
[6] Hardik G. Chothani, Kalpesh D Maniya, Determination of optimum working parameters for multiple response characteristics of worm gearbox | Volume-8, Issue-3, september 2019
[7] V B Bhandari, Machine Design Data Book, Page No. 23.7, Table No. 23.13
[8] V B Bhandari, Machine Design Data Book, Page No. 23.7, Note.
[9] V B Bhandari, Design of Machine Elements, Page No. 732
[10] V B Bhandari, Design of Machine Elements, Fig No. 20.14, Page No. 743.
[11] V B Bhandari, Design of Machine Elements, Table No. 20.2, Page No. 742.
[12] Faculty of Mechanical Engineering, Design Data, Data book of Engineering, PSG College of Technology, Coimbatore-641 004, Page No. 7.41 .