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RELIABILITY DETERMINATION OF ELASTOHYDRODINAMIC LUBRICATION, AFFECTING THE WEARING ON SPUR GEARS IN SELECTION OF LUBRICANT VISCOSITY

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ABSTRACT
In this study, performed as theoretically, and experimentally, variation of the wearing and lubrication characteristics occurred on the spur gears, in the closed-loop gear wearing mechanism, have been investigated by making spectrometric analysis with using mineral lubricants which have various viscosities(CARTER EP 68-150-320-680). The variation of lubricant's life versus viscosity is shown numerically by graphics, and tables. Also the relationship between the variation of lubricant's viscosity and gear surface wearing is investigated. The reliability of elastohydrodynamic lubrication viscosity is determinated with making real calculations by using a program, written in Visual-basic software.
Keywords: lubricant, pitting, spur gear, wear, EHD

1. INTRODUCTION
The main duty of a lubricant aims to make a lubrication film distinguish the movement surfaces with rolling elements and in addition decrease the energy loss of the system. Based on the relation between the thinnest lubrication thickness in the EHD lubrication theory with roughness quantity on the gear surface, viscosity of chosen gear lubrication must be calculated. Based on the mathematical formula of the thinnest lubrication and the covering it must be analyzed with using reliable methods and lubrication viscosity needed by gear must be calculated. On the subject of lubrication used definition and terminology, definitions can be sorted without following any order.
TAN (Total Acid Number) is the determination of the necessary potash quantity with milligram unit to neutralize the organic and mineral acids in the one gram of lubrication. Added additives to the lubrication have TAN value. This value results from the additives and this does not form any risk and this is the important indicator of the function of the lubrication. It is sensitive to interpret and necessitates the experience. ASTM D 974, ISO 6618 (NF T 60-112).
Color; appeared as reflection color or its transparent color. Naftinik or aromatic lubrication are green, paraffin lubrications reflect blue color. Color of the lubrication is calculated from the transparency. From 0 to 8 it is ordered in 0.5 units. In application, it gives information about the lubrication quality and degree of contamination. ASTM D 1500, ISO 2049 (NF T 60-104).
In elasto–hydrodynamic lubrication, friction is an absolute criterion. In these theories for the lubrication to be occurred, minimum lubricant film should be $h_{min} > R_{sum}$.
In this case R_{sum} is the composite surface roughness occurred from the roughness of two surfaces. This value is calculated from the following equation:

$R_{top} = (R^2_{a1} + R^2_{a2})^{1/2}$ (1)

The following equation due to Dawson and Higginson [4] gives the minimum film thickness ($h_{\min}$) that occurs near the exit of the contact. [1-4].

Gap parameter; $H_{min} = \dfrac{h_{\min}}{\rho} = 2.65 G^{0.54} U^{0.7} W^{-0.13}$ (2)

Material parameter; G = α E (3)

Velocity parameter; U = $\eta_o \dfrac{u}{E\rho}$ (4)

Load parameter; W= $\dfrac{\omega}{E\rho}$ (5)

The following can serve as criteria for possible scoring damage (λ)

$5 \leq \lambda \leq 100$	Hydrodynamic Lubrication (No damage)
$3 \leq \lambda \leq 5$	EHD Elasto-hydrodynamic Lubrication (No damage)
$1 \leq \lambda \leq 3$	Partial Lubrication (Damage possible)
$\lambda < 1$	Limit Lubrication (Damage probable)

$\lambda = \dfrac{h_{\min}}{\Sigma R_a}$ (6)

R_a = composite surface roughness;

$\sum R_a = (R_{a1}{}^2 + R_{a2}{}^2)^{0.5}$ is found [4, 5]. (7)

2. PROCEDURE FOR CALCULATING FILM THICKNESS

The following procedure should be used when applying elasto-hydrodynamics to gear design;

- Determine effective values for velocity, load, modulus of elasticity and curvature
- Determine the effective temperature
- Determine viscosity and the pressure- viscosity coefficient as a function of temperature
- Calculate film thickness
- Compare film thickness with peak-to-valley height and calculate scoring resistance [4, 5].

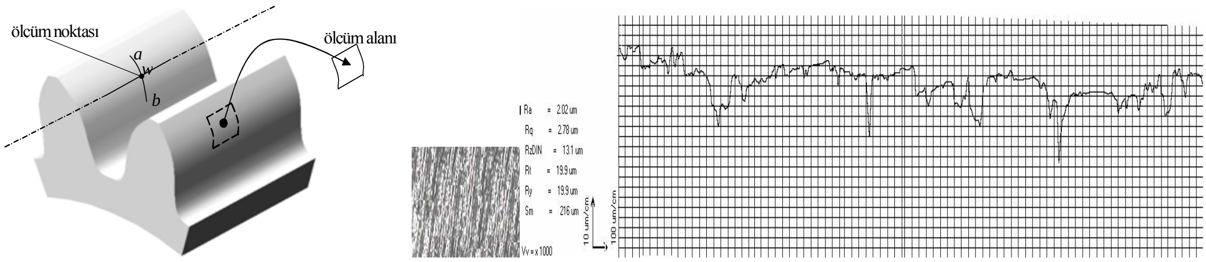

Figure 1. Digital macro appearance (zoom X 100) and surface roughness.

Visual basic program is written to gain a much practical solution from the results that Dawson and Higginson [4] found in elasto hydrodynamic theory , To make the program portable exe file is composed. This form is given to be practically converted to a chart for all kind of calculations.

3. EXPERIMENTAL WORK and RESULTS

Planned experiments are applied on the fatigue test equipment which entangles period power gear shown in Figure3. Experiment equipment is produced two gears box which gives the same cycle rate. It is aimed to prevent abrasive wearing with putting two powerful magnets in to the test gear [6-7].

3.1 Gears subjected to test

Cast iron GG25 is used in the production of gears that are tested. The aim of the utilization is both to gain time from the production of gears and provide faster pitting than steel material. It is aimed that the gears have close surface roughness rate with doing the all wheel opening process on the same stand, with the same sharp equipment and at the same speed of cutting rate. Features of experimental gears are in Table 1.

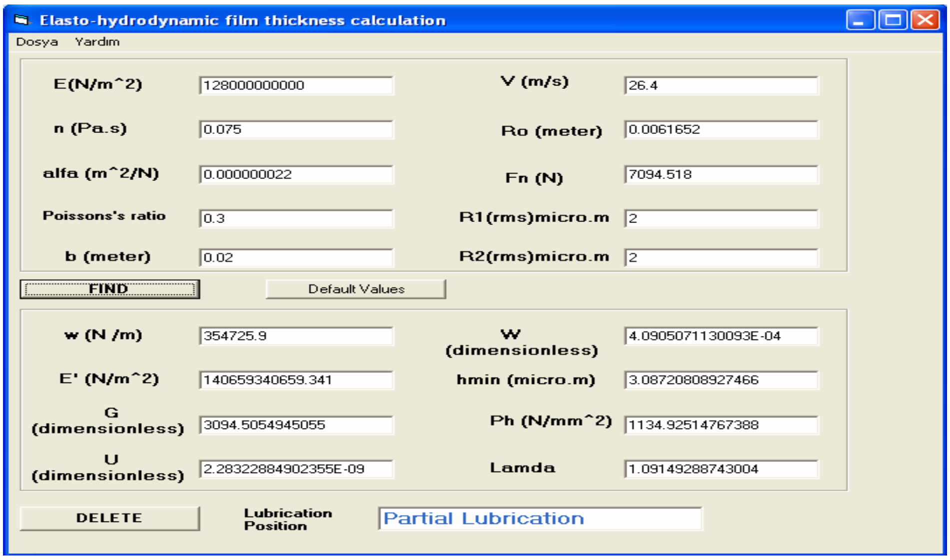

Figure 2. Making real calculations by using a program, written in Visual-basic software

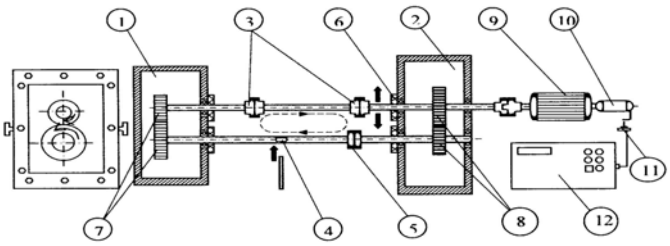

Figure 3. Experimental equipment, 1-Test gear box; 2-Power transmitting gear box; 3-Torsion mile; 4-Portable torque arm; 5-loading coupling; 6- slippery bed ; 7-Test spur gear; 8-Power transmitting spur gear; 9-Electric motor; 10-Reduction; 11-indicator of cycle number; 12-control panel.

Table 1. Tooth form of test gears

Tooth form	Pinion	Gear
Number of teeth	17	41
Module (m_n) mm	3	3
Cutter pressure angle (α_0) deg.	20	20
Wideness of tooth (b) mm	20	20
Material	GG25	GG25
Hardness	83 HRB	81 HRB
Total cycle number	5000000	
Elasticity of material. (kN/mm^2)	118-128	118-128
load (kg)	17	
Roughness of gears contact surface(R_1,R_2) μ m	2	2

3.2. Examination of Wear Components and Characteristic of Lubricant Rate with Spectrometric Analysis.

In this study industrial oils used in the experiment are evaluated by spectrometric analysis method. From Table 2 it is seen that the most important pitting components are Fe and Si. As the rates of Fe and Si in lubricant increase lubricant loses its feather, and its color changes. Main components of EP additive material are P and Zn Also total acid number (TAN) rate increase is affected by temperature, environmental conditions, moistness accumulated water in air and indirectly by speed, load and rotation. In industrial lubricant of the TAN rates lower than 2.5 is still suitable for using lubricant but the rates the rates ≤ 2.5 is said to be that lubricant becomes acidic and should be changed.

From the Table 4, it is seen that first lubricant, which has the lowest viscosity, has the highest TAN rate, which is 2.55. Also color change of first lubricant has been seen by visual observation. These mentioned above means that this lubricant should be changed with a newer one. However rest of lubricants in Table 4 can be still usable due to lower TAN rates [8].

Table 2. The Post-Experiment Lubricant Analysis rates of the Lubricant Used in Experiment.

Lubricant No	Kinematics Viscosity mm^2/sn (40^oC)	Lubricant temp. before, and after the test ^oC	TAN before and after the test mgKOH/gr	Additive components (ppm)				Wear components (ppm)							
				B	Mg	P	Zn	Fe	Pb	Cu	Sn	Cr	Al	Ni	Si
1	69.05	13.5 - 42	0.5 2.55	0	0	342	4	19.9	5.1	0.2	0	0.3	0.0	0.2	4.8
2	145.14	14 - 38	0.5 2.15	0	1	359	7	13.3	3.9	0.1	0	0.2	0.0	0.2	4.1
3	293.88	14 - 24	0.5 1.45	0	22	410	50	5.4	0.0	0.1	0	0.1	0.0	0.2	3.3
4	707.62	15 - 35	0.5 1.7	0	0	339	2	1.6	0.0	0.0	0	0.1	0.0	0.2	2.2

4. CONCLUSION

In the experiment it is seen that reducing the gear pitting is one of the most important criteria in selecting the lubricant viscosity rate. As high as the viscosity rate of lubricant is selected the minimal wearing is occurred. However in EHD lubrication tooth surface roughness is a fundamental criterion in lubricant viscosity.

Based on the study and references following results are obtained about the lubricant layer occurred between the tooth choice.

Color; change in lubricant system should be observed, also energy loss increases as the lubricant viscosity is selected in high rates. If lubricant is very dense, it produces extreme heat. Heat increases the lubricant temperature and decrease the viscosity. As it increases the (TAN) rate at the same time, the viscosity should be limited. Also to reduce the wearing to minimally case system oil should be examined with spectrometric analysis periodically.

The probability of being high of thinnest EHD lubrication thickness between the contact surfaces of two gears bigger than sum of surface roughness degree of two gears should be equal or greater than absolute (R_{sum}) confidence degree.

$$P(h_{min} > R_{1,2}) = P(h_{min} - R_{1,2} > 0) \geq R_{sum}$$

In the study a visual basic program is also written for gear wearing according to the results of Dawson and Higginson [4].

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