# Determination the wear rate by using XRF technique for Kovar alloy under lubricated condition

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*Abstract-* **Kovar alloy was machined and prepared as half bushes with diameter 1.6cm and length of 1.5 cm. Many specimens were prepared and subjected to wear testing system under lubricated condition. The tests were carried out under different condition such as sliding speed of 750rpm and fixed lubricant type and under variable conditions such as sliding time and normal loads. Weight loss and wear rate were determined for all samples and under different conditions. Kovar debris suspended in oil lubricant and placed in special container and subjected to X-Ray Fluorescence system to determine the quantitative and qualitative analysis.**

*Index Terms— Kovar alloy, wear rate, XRF*

## I. INTRODUCTION

When the components of machinery move in contact with one another, natural wear process take place which results in the removal of wear material from surfaces [1- 3]. The free material may be transported in the lubricant. Wear particles analysis are concerned with analyzing this material to determine the wear condition of the machine [4-7]. The rate of emission of wear particles from a particular source is the most direct indication of the extent of wear and for maintenance of the source. Thus, wear rates and debris (material lost by wear actions) compositions are the measurable closest to the desired information on wear degree and wear sources [8]. Most of the machine parts , suffer from friction and wear at the interfaces , this friction and wear affected the efficiency of machine and cause changes the mating parts .Wear particle analysis , seeks to determine the quantity of worn material ,the composition of the wear debris , and the wear rate of each source.

Wear particles analysis measures the mass (and its various attributes) lost by the wear process. Composition of particles and in the most direct indication of the identity of sources of the wear particles. Production rates of wear particles are derived from measurements carried out at known intervals of machine operating time, while taking into account such factors as concentration in the lubricant, volume of oil and particle removal rates where applicable [9-12].

Wear as a part of the tribology science is now receiving considerably more attention although still behind fatigue and corrosion in research effort [13]. The major difficulty in the field of wear is the inability to predict the progress of wear form fundamental material properties. This is part to the complexity of most wear environment refers to the complete set as factors that describe a given interface. These factors include the nature of solids contact (strength, hardness) [14]. The mechanical condition of each surface, the surface reaction layers or adsorbed film, intentionally interspersed layers (i.e. lubricant, liquid, gaseous, or solid) the relative velocity movement, the forces applied the surface; and the temperature. This system of environment factors is tribo-mechanical system [15-18]. The first technique called wavelength dispersive X-ray analysis (WDX) while the second called energy dispersive X-ray analysis (EDX) . Of the two , EDX is much more compact , while WDX offers the best spectral resolution [19-24]. For WDX the radiation emitted by the sample is diffracted by the lattice planes of known d-spacing in a single crystal according to Bragg's law [25-29].

$$\lambda = 2 d_{hkl} \sin \theta.$$

Where $\lambda$ is the wave length of radiation diffracted through an angle $\theta$ by planes in the analyzing crystal of known d-spacing, and n is an integer. The radiation of only a single wave length is reflected for each angular setting of the crystal, and the intensity of this radiation can be measured with a suitable detector. Two types of detectors are used , scintillation detector which is efficient for short wave length less than 2 $^{o}$A, and gas proportional detector which is efficient for short wave length more than (6 $^{o}$A) . The region between 2 -6 $^{o}$A both detectors were used [30-33]. In this work we used this technique for analyzing all samples qualitatively and quantitatively since the advantages of this technique WDX on EDX is that diffraction produce very sharp defined peak for multi element matrix, and high sensitivity, suitable lower limit detection for all samples under test, were as the other technique EDX is poor sensitivity and not effective in lower limit detections since it has significant peak overlap in multi element matrix [34-38]. XRF determines both wear rate and composition, the two most direct indicators of the need for maintenance and the source of wear, which are the key issues for any machinery condition monitor. Weighing method is the

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simplest way of detecting wear. The specimen is weighed before ($w_1$) and after running ($w_2$) , and the weight loss ($W$) calculated according to equation 1, to get the wear rate according to equation 2 [39-42] :

$$W = w_1 - w_2 \quad (1)$$

$$w.r = \frac{W}{\pi D v t} \quad (2)$$

where $w.r$: wear rate (g/cm) , $D$ : shaft outside diameter (cm) , $v$: sliding speed (r.p.m.) ,
$t$ : running time (min.).
The aim of this work summarized by a study the behavior of kovar alloy samples with curvature shape under normal loads and Determination the wear rate debris in oil engine by using XRF technique.

## II EXPERIMENTAL PROCEDURE

### A. Samples preparation:

All samples were machined as half bush. The important properties of the main materials used in the wear tests were shown in table (1). Each sample was first polished and cleaned using acetone before wear test.

Table 1: The important properties of kovar alloy used in the wear tests.

| Material and supplier | Kovar<br>Wasting house (USA Product) |
|---|---|
| Composition (%) | Fe: 53<br>Ni: 29<br>Co: 18 |
| Density | 8.36g/cm$^3$ [28] |
| Shape and dimension | Half bush<br>D:1.6cm<br>L:1.5cm |

### B. Wear testing system:

Wear testing system consists from the following parts:
Electrical motor with reducing speed pulleys.
1-Rotating hard shaft supported by two ball bearings immersed in oil container.
2- Half bush holder (for testing samples) with loading system.
3- Perspex oil container to avoid metallic contaminations.
4- Two grams from oil and additives were diluted with white spirit.

### C. Wear test procedure:

All wear samples were prepared and tested as illustrated in table 2. Initial and final weights ($w_1, w_2$) for each sample were measured using sensitive balance type Sartorius (Germany product) of accuracy 0.1mg. Hardness was measured using hardness instrument type Brooks of UK product. Stop watch was used to determine each sliding time. The weight loss (equation 1) and hence the weight wear rate (equation 2) in each sample caused by wear process was determined after carefully cleaning the samples by acetone from oils. All specimens (Table 2) were conducted to microscopic tests before and after each wear experiments for sliding time of 10 minutes using optical microscope type Rinkin of Japan product conducted with digital camera. The difference in weights (W) for each wear test was mainly dissolved in the oil for a fixed sliding speed (S.S =750rpm) .Two grams were taken from the oil under test for X-ray fluorescence analysis.

Table 2: Wear tests conditions

| Wear test specimen | Sliding time(min) | Load(N) | Initial weight(g) |
|---|---|---|---|
| Kovar alloy | 2 | 4, 6 , 9 | $w_1$= 2.0493g<br>HRC=41.6 |
| | 4 | 4 , 6 , 9 | |
| | 6 | 4 , 6 , 9 | |
| | 8 | 4 , 6 , 9 | |
| | 10 | 4 , 6 , 9 | |

### D. X-ray fluorescence spectrometry (XRF)

A Siemens type SRS-200 sequential wavelength dispersive X-ray spectrometer was used to analyze all wear test samples mentioned in tables 2. The instrumental parameters are listed in table 3. A molybdenum (Mo) tube target was used to obtain high detection sensitivity.

## III RESULTS AND DISCUSSIONS

### A. Weight loss results

Figure 3.1 represents the weight losses kovar alloy lubricant oil as a function of sliding time under different normal loads 4, 6, and 9N. In all specimens the weight loss increased gradually under different circumstances, until reaching to steady state condition. In the beginning of the sliding, the removal of some materials from the specimens was due to wear, arises when junctions weld together become broken by relative motion [28- 30]. In the steady state condition, the action of lubricant minimize the friction force by separate the mating surfaces , and to work hardening [31, 32] of the surface after 4- minutes .

Table 3: instrumental parameters of XRF system

| | |
|---|---|
| X-ray tube target | Mo |
| Power | 30kv , 17mA |
| Filter | Al - foil |
| Atmosphere | Vac.10$^{-3}$ (m bar) in both sample and analyzing chamber. |
| Sample holder diameter | 24mm |
| Analyzing crystal | LiF(100) with 2d 4.03°A |
| Collimator | 0. 15$^0$ positioned between the specimen and the analyzing crystal |
| Detector type | Scintillation counter |
| Collection time | 10 sec. |
| Samples holder | A demountable liquid sample container were designed and manufactured from Teflon The bottom window was fitted with 6 µm Myler film . |

The action lubricant oil was very clear in reduction of the weight loss for all specimens under tests, this due to Zinc react with the metal to prevent scuffing wear. This result agrees with [33, 34] Figure 3.2 illustrates weight losses of kovar specimen in lubricant oil as a function of normal loads with different sliding times.

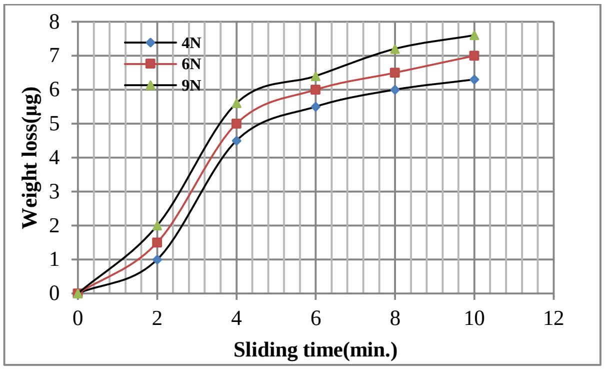


Fig. 1: Weight loss of kovar as function of sliding time at different loads

A general trend of an increase in weight loss with applied normal load was clearly demonstrated. For normal load less than 4 N, the weight loss is limited for all specimens. Increasing the normal loads, the weight loss increased slightly, since the wear process transformed from mild wear to transition wear, due to plastic deformation of the surfaces.

*B. Wear rate results*

Figure 3 represent the wear rates variation with sliding time at different loads for kovar alloy tested in oil lubricant. At the beginning of the sliding time the values of wear rates for all specimens under tests will increase. A steady state condition will be reached after four minutes of sliding time, due to the separation of the junctions between the shaft and the specimen (half bush) by the lubricant film as well as the flattening of the specimens which will lead to stability in wear rate behavior with sliding time [43-50].

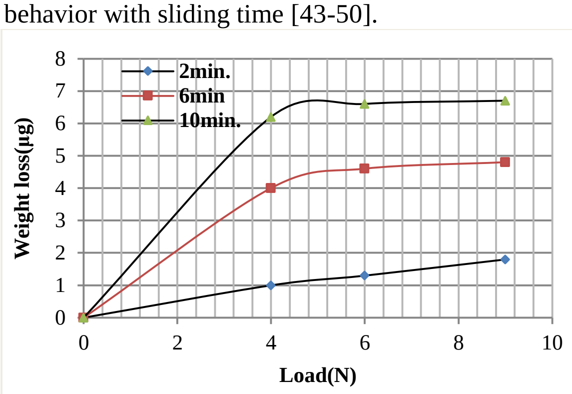


Fig. 2: Weight loss of kovar as function of loads at different sliding time

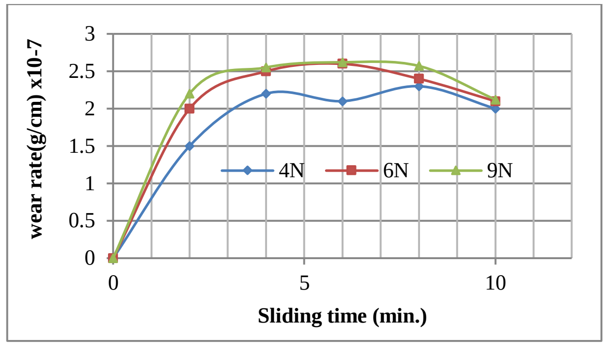


Fig. 3: Wear rate of kovar in oil variation with sliding time at different loads.

In the case of final oil lubricant the separation between the junctions will be enhanced, leading to minimum wear rate. The variation of wear rate as a function of normal loads has been plotted in figure 3.4 kovar alloy in oil lubricant.

For low loads (less than 4N) wear rates will increase rapidly while for higher loads (greater than 4N) the increase will be slightly. This is may be due to an increase in stability of adhering oil films to specimen surface at high loads, and decreasing the friction force. This leads to minimize the wear rate for all specimens under testes. This result agrees well with some references [51-57].

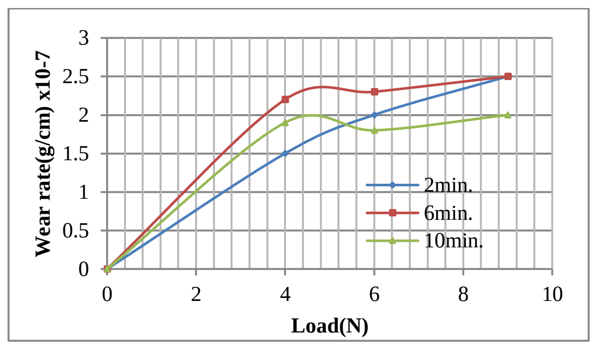


Fig. 4: Wear rate of kovar in oil variation with at loads different sliding time

## IV. CONCLUSIONS

The main points were concluded from this work can be summarized as follows:

1- The qualitative and quantitative determination for elements in lubricating oils can be performed in a few minutes for each element.
2- In a homogeneous sample (metal particles dissolved in lubricating oils), particle size effects do not appear to be as serious, since the accuracy of XRF measurements was within the accuracy of weighting method.
3- It is clear from the present results that the conditions of increasing sliding time and normal loads will increase the wear weight loss and hence the wear rate for all specimens.

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