SECOND A.M.E. CONFERENCE
6 - 8 May 1986 , Cairo

AN EXPERIMENTAL STUDY OF THE FRICTION TORQUE OF THRUST BEARINGS COVERED BY SOFT METAL FILMS WHEN OPERATING IN VACUUM

T.E.S.EL-SHAFEI

Military Technical College,Cairo,Egypt.

ABSTRACT

The life of bearings is mainly affected by the efficiency of its lubrication,for bearings operating under severe conditions such as high vacuum and temperature,conventional lubrication presents many problems.

Permenent thin soft metal-films give a solution to this problem. A rig was built to measure the friction torque for ball thrust bearings operating in vacuum.

This paper describes an investigation of the friction torque of thrust bearings covered by thin lead and silver films operating in vacuum. The effect of normal load and ball-track conformity have been studied.It is shown that the friction torque for the uncoated bearings increases when operating in vacuum especially for high values of ball-track conformity.It is also shown that the coating decreases the friction torque for all values of ball-track conformity and the value of the friction torque for these bearings does not increase when operating in vacuum.

INTRODUCTION

For bearings operating under severe conditions such as high vacuum and temperature,permenent thin soft metal films are succesfully used for lubrication. A survey of the methods used for film deposition showed the superiority of the ion-plating technique due to the high adhision and uniformity of the film. It is the aim of this paper to describe the investigation of the friction torque of thrust ball bearing where its tracks are covered by thin films of lead and silver operating in vacuum.

To eleminate the effect of the sliding friction with balls retainer or cage,free balls without retainer have been used to study the effect of both normal load and ball-track conformity on the total value of the friction torque induced due to rolling of balls along curvelinear track .

EXPERIMENTAL DETAILS

Specimen Preparation

The races of 1.5 inches thrust ball-bearing were used as our test specimens.The test specimens were coated with films of lead and silver using the ion-plating process.
Calibration specimens were weighed before and after plating and subsequently sectioned so that the film thickness can be measured in a scanning electron microscope.Having this established,a calibration between weight gain and film thickness, subsequent film thicknesses were determined simply from weigh gain.Specimens were prepared with film thickness 1 um to guarantee elastic behaviour of the film.

Experimental Procedure

The apparatus,illustrated schematically in fig.1, was designed to measure the friction torque in a vacuum chamber.While fig.2 shows the details of the measuring head used .
The friction forces were measured by means of four strain gauges (1) attached to two leaf springs (2) forming two opposite sides of a cruciform part (3). The other two arms were used to hang this part freely through a universal joint (4) in the middle of a hollow cylinder(5). The upper race is connected to the lower part of the cylinder at its centre supported over three free equally spaced balls over the circuler track of the lower race which is connected to the driving motor through a magnetic drive. The normal forces were applied by dead weights on the top of the hollow cylinder at its centre. The friction forces represent the forces applied by the leaf springs to prevent the upper race

together with the hollow cylinder and the dead weights from rotation with the lower race.
These forces as deteced by the strain gauge bridge, were fed to a UV recorder through a c rier amplifier.
The strain gauge bridge and the leaf springs were calibrated before assembly by using small dead weights. The calibration chart for different values of the amplifier gain is shown in fig.3.
Tests have been carried out on uncoated bearings, and both lead coated and silver coated bearings of thickness 1 um each. The effect of ball-track conformity was studied by using several balls 3.175,3.96,4.76,5.55 and 6.35 mm radious. Normal loads used were 2 and 4 kg/ball.All tests were carried out in atmosphere and repeted in vacuum 5.10^{-8}-5.10^{-7}Torr ($3.7.10^{-10}$-$3.7.10^{-9}$ N/m^2).

RESULTS AND DISCUSSION

For thrust ball bearings, the total amount of friction energy dissipated in the running process can be devided into three main parts:

1- Elastic hysteresis losses.
2- Energy losses due to microslip originated by the action of the tangential traction and ball-track conformity.
3- Extra energy losses due to the applied spin torque,which arrises from the change of the distribution of the stick and the slip zones and also from a small change of shape of the contact zone in case of rolling in a circular conformal track.

Haines and Ollerton(1) introduced the strip theory to be applied for theoretical calculation of the rolling friction forces. Halling(2,3) utilizing the same theory analysed the motion of a ball subjected to both tangential traction and spin torque for thrust ball bearings.Ignoring the effect of transverse traction,he was able to calculate the friction moment and he emphasised the importance of conformity and track radious on the distribution of stick and slip zones and hence on the amount of the frictiontorque.

Considering the effect of working in vacuum for the uncoated ball thrust bearings, we should expect that the effect will be through the increase of the coefficient of sliding friction within the slip zones.

Fig.(4a,4b) represents graphs of λ v r/R for the uncoated ball thrust bearings under normal loads of 2 and 4 kg/ball .

It is shown that working in vacuum increased the friction torque especially for high values of r/R where the slip zone increases with conformity.

It is also shown from fig.4b that with increasing the normal force N the value of λ increases in vacuum more than in atmosphere due to the increase of the contact area and the increase of its elliptic dimentions.

Fig.5a,5b represent the same graphs for coated bearings with lead 1 um thickness. It is shown that no change in the friction torque occured due to operation in vacuum. Similer results were obtained with silver coatings,fig.6a,6b.

CONCLUSION

Although the life of bearings has not been studied in this paper, it has been shown that for ball thrust bearings operating in vacuum, the cause of the increase in the friction torque is mainly due to the increase of the coefficient of sliding friction in vacuum and not due to the increase of the real contact area. Presence of thin lead and silver films decreased the value of the friction torcue and eleminated the effect of working in vacuum.

NOMENCLATURE

λ = Dimensionless value of the rolling friction coefficient

$$= \frac{\text{Friction force}}{\text{Normal Force}}$$

t = Film thickness μm

r = Radius of the ball.

R = Radius of curvature of the track.

REFERANCES

(1) Haines, D.J. and Ollerton, E. proc. Inst. Mech. Engrs. Vol. 177, No. 4, 1963.

(2) Halling,J., J. Basic Engng. Trans. ASME, 88, 1966 p213.

(3) Halling,J., Proc.Inst.of Mech. Engrs., vol. 181,1966-67.

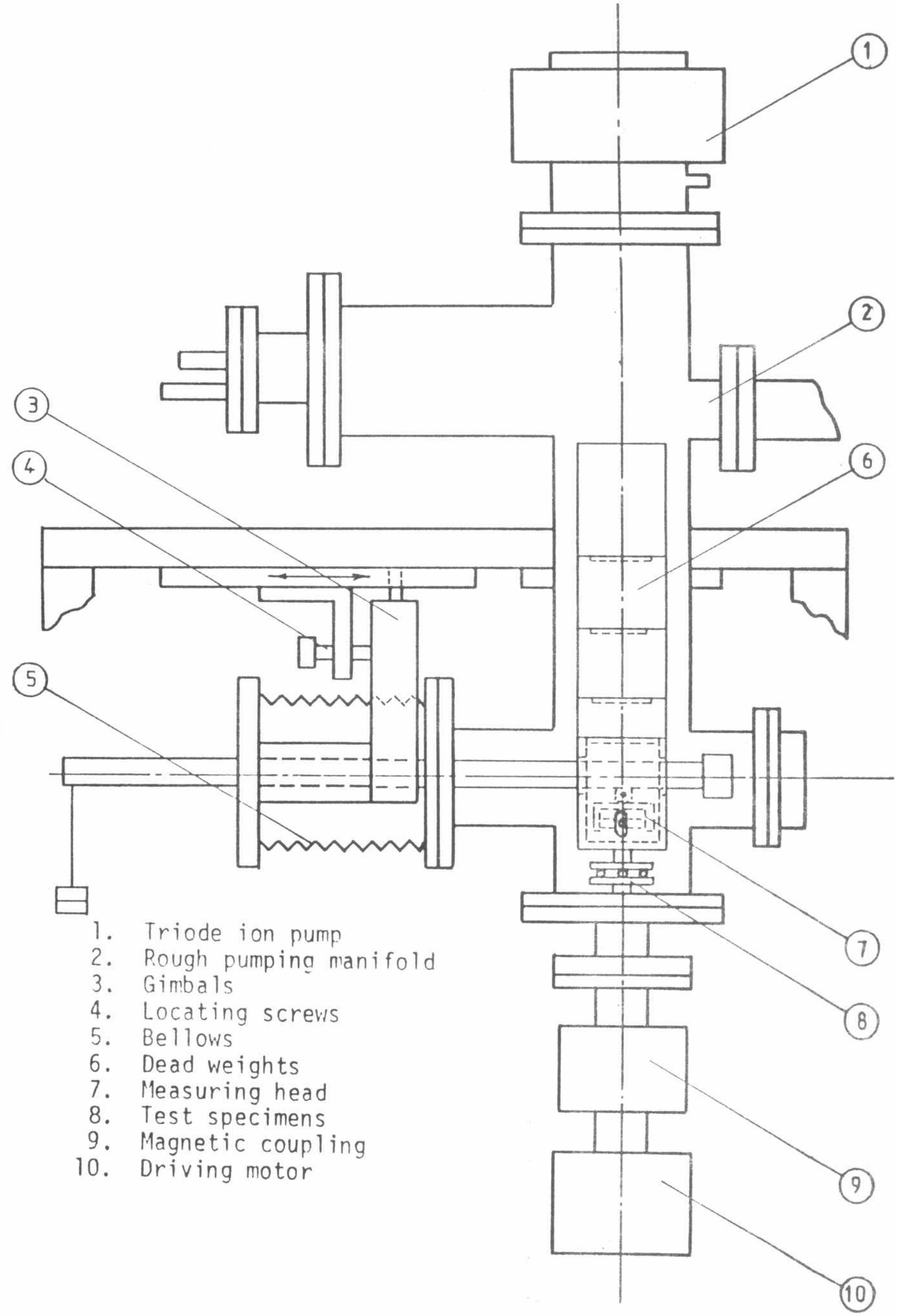


Figure (1) Schematic diagram of ultra high vacuum rolling friction torque measuring machine

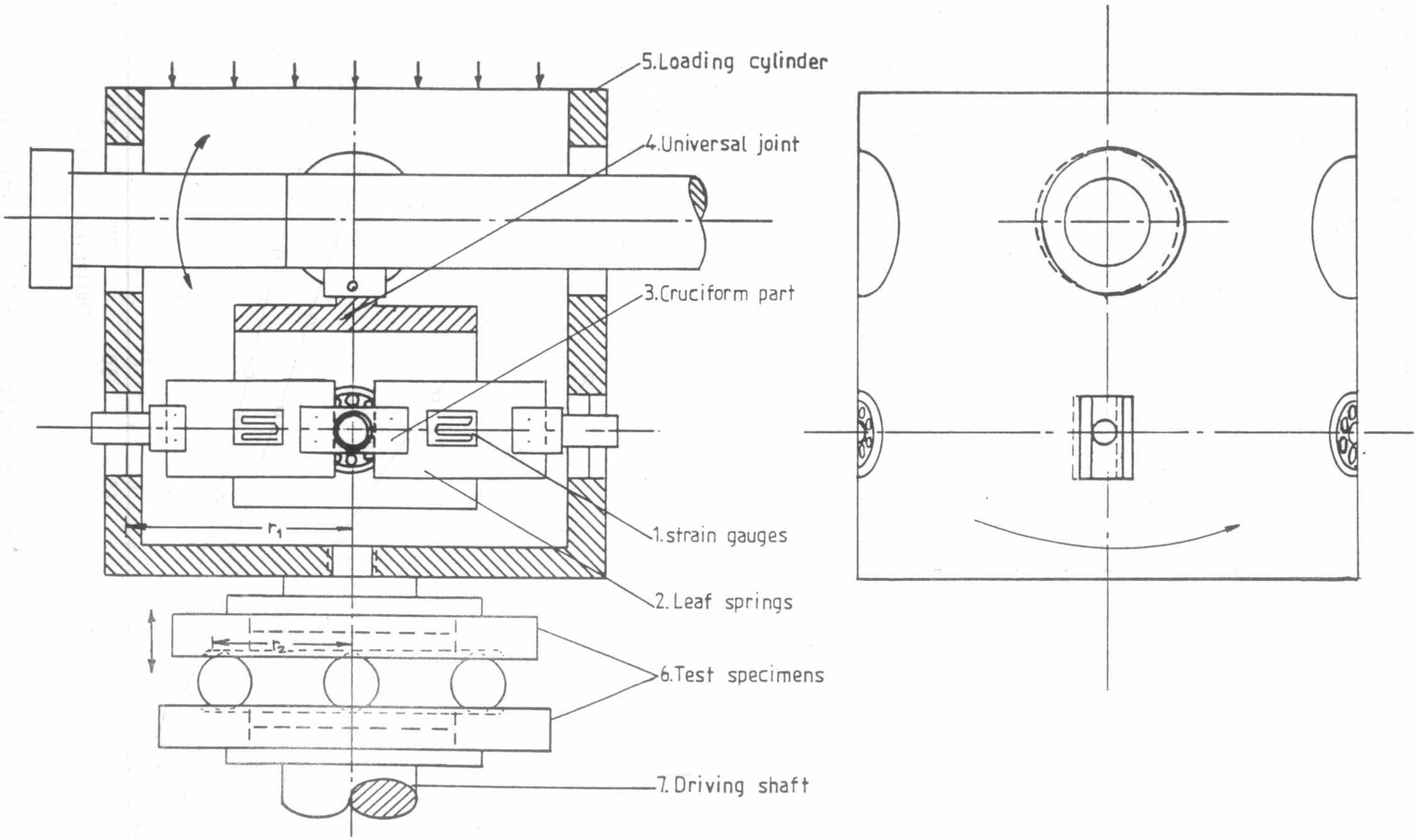


Figure (2) Measuring head used in the rolling friction torque measuring machine

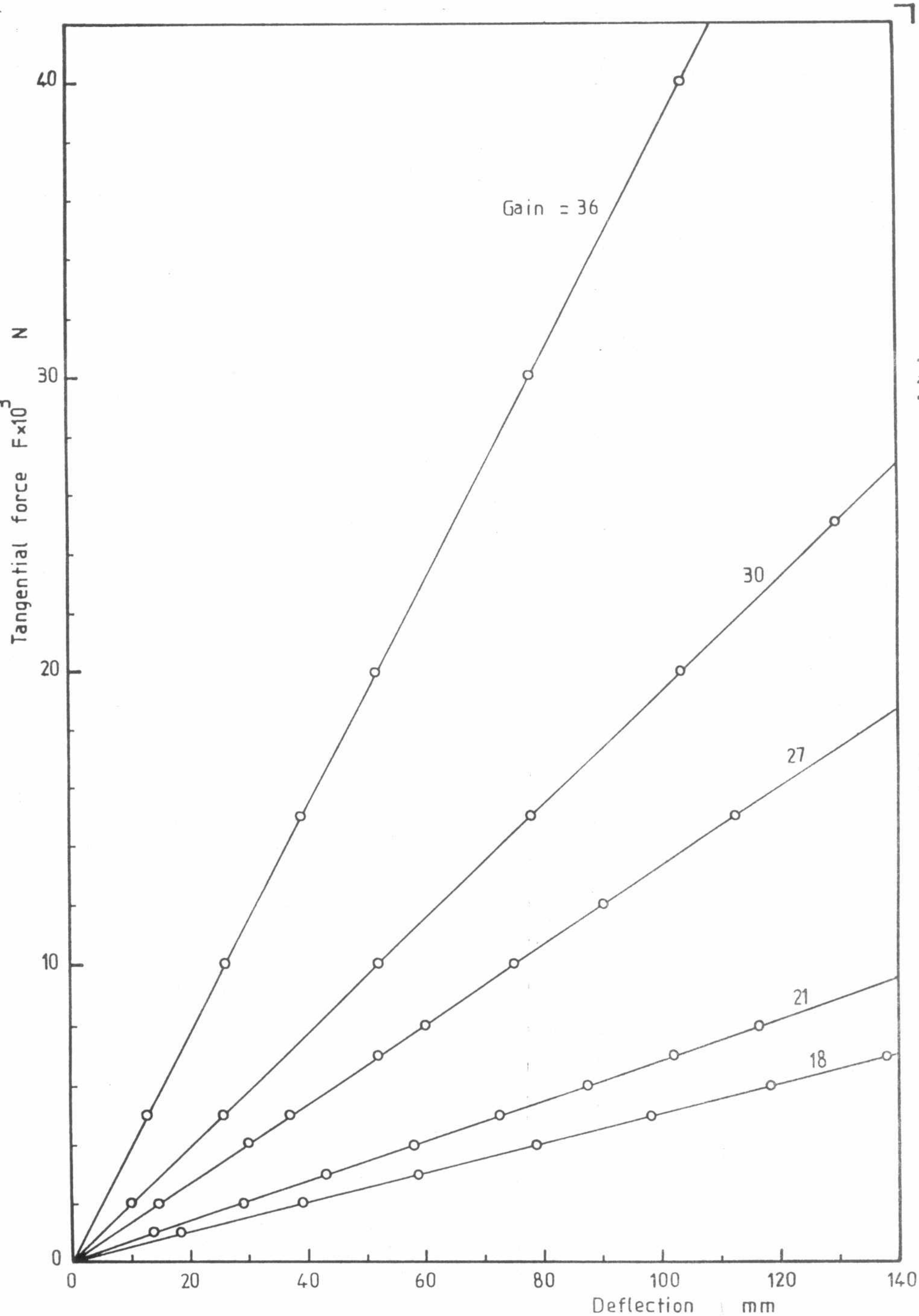
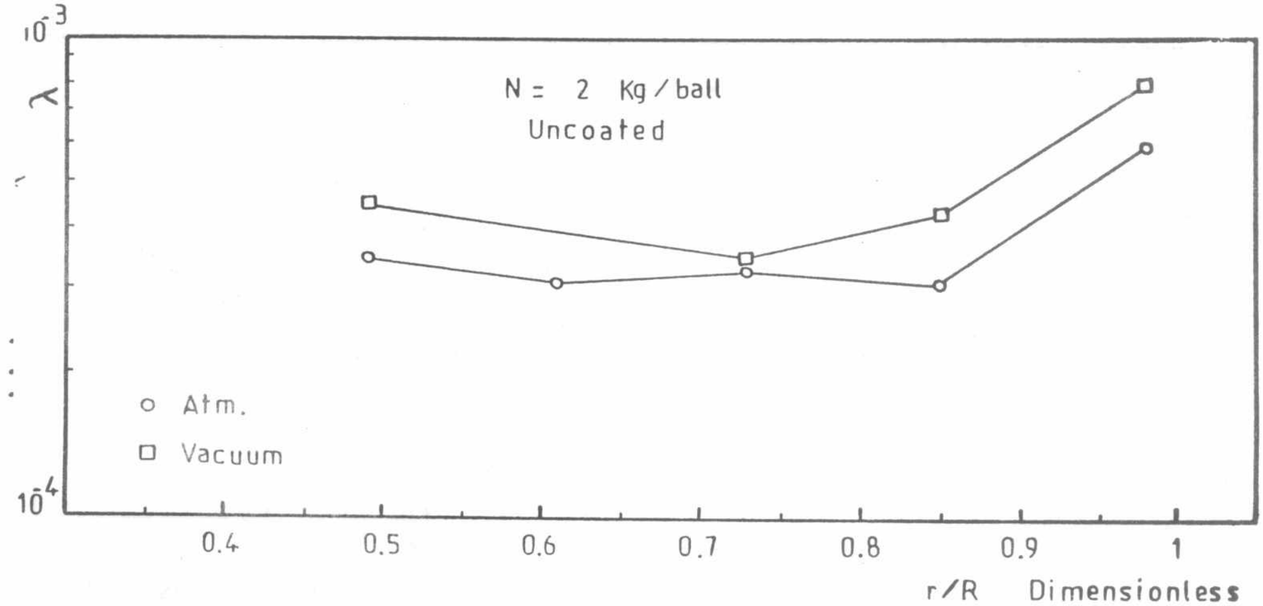
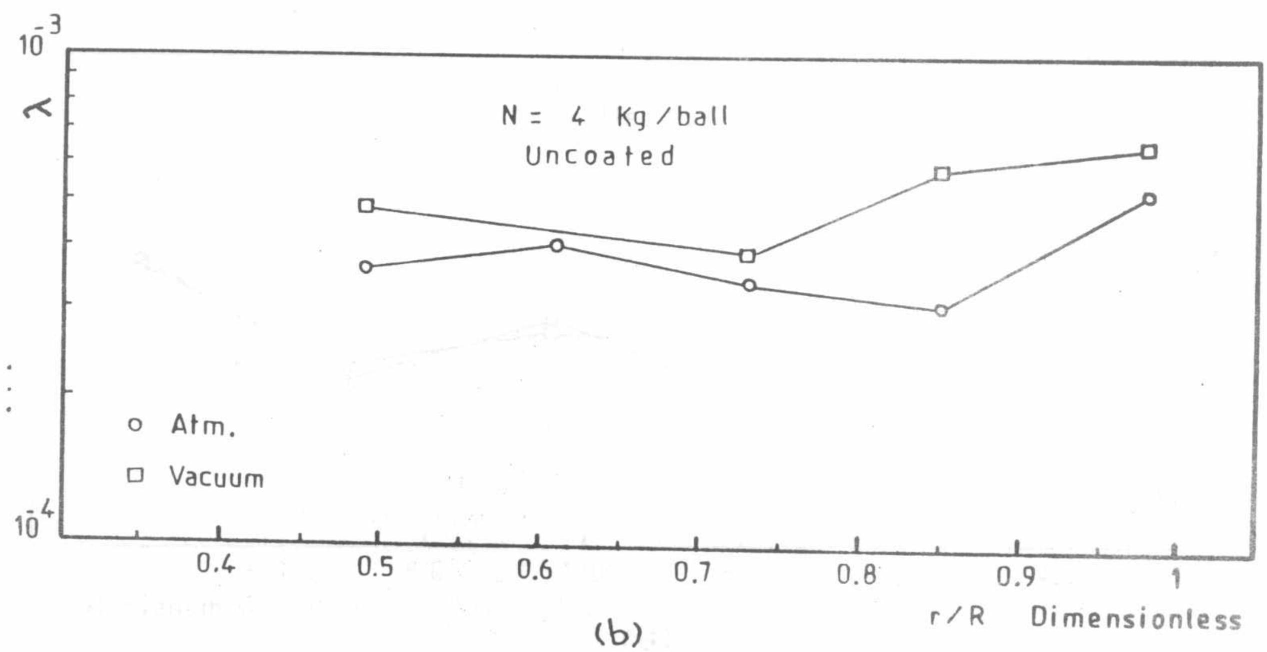


Figure (3) Calibration chart for rolling friction torque measuring machine

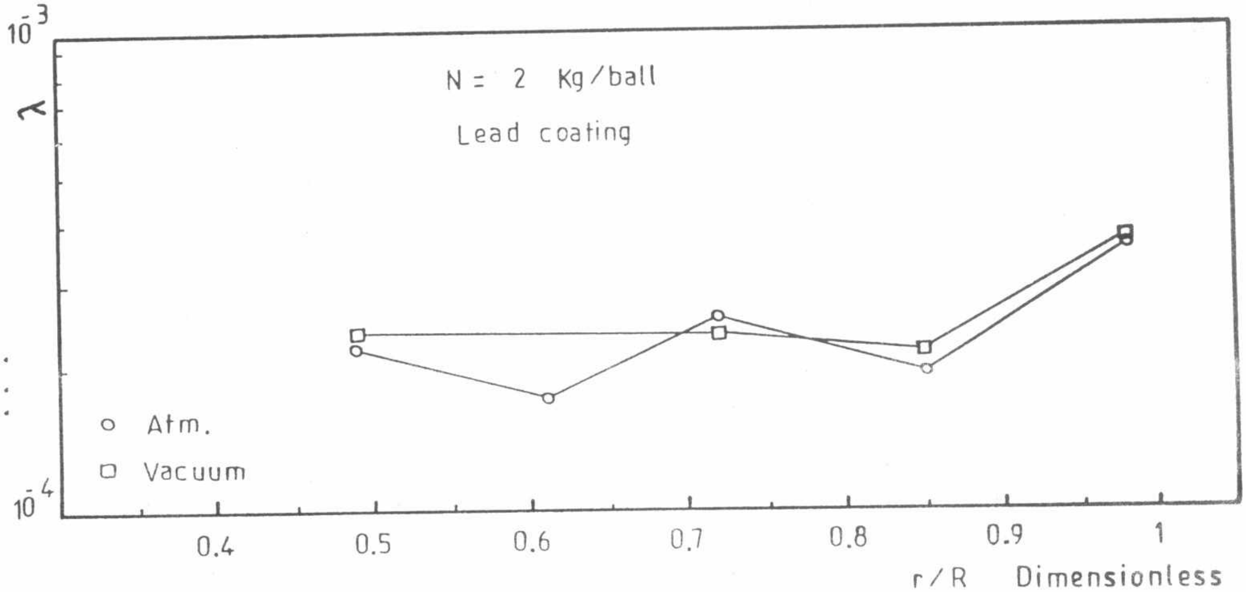


(a)

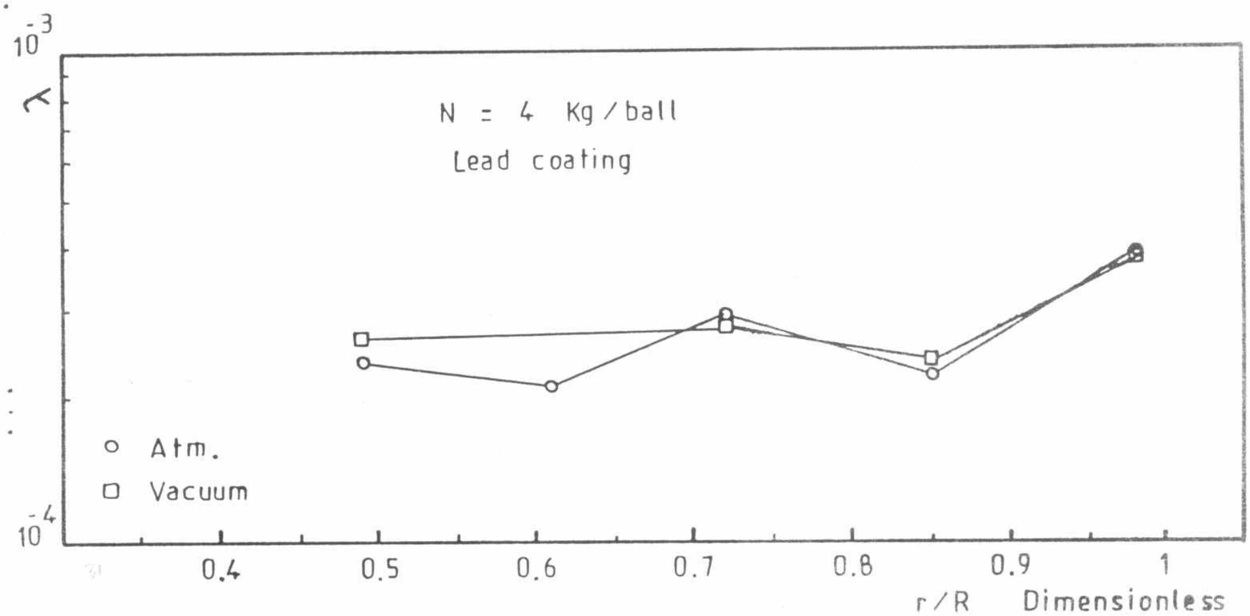


(b)

Figure (4) - Uncoated thrust bearing in vacuum

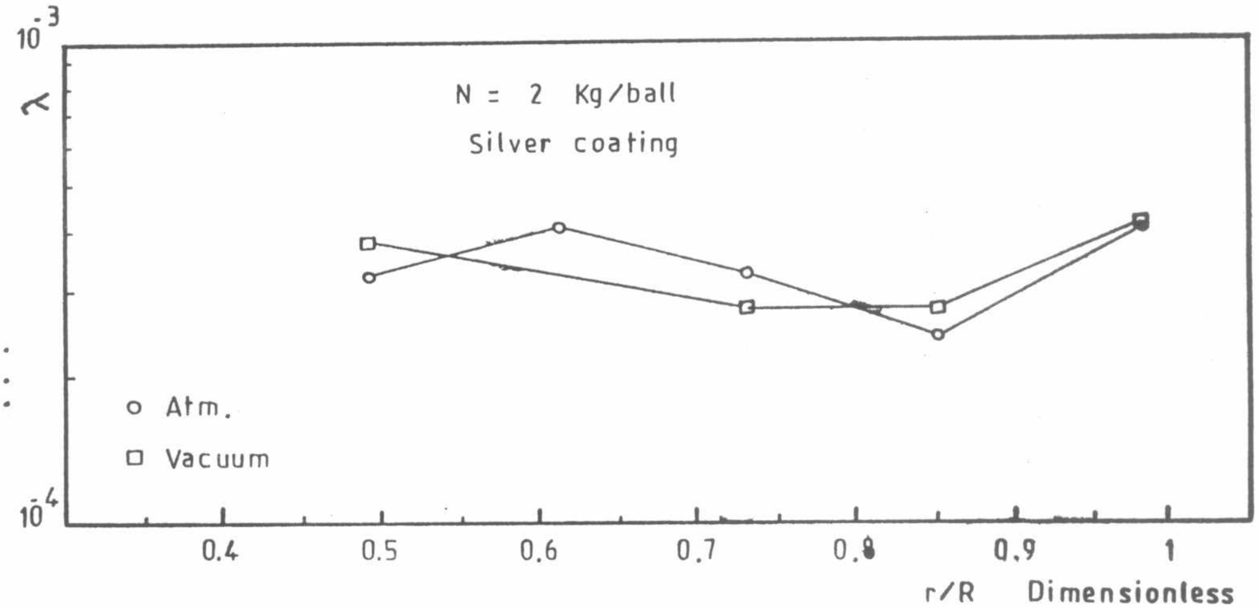


(a)

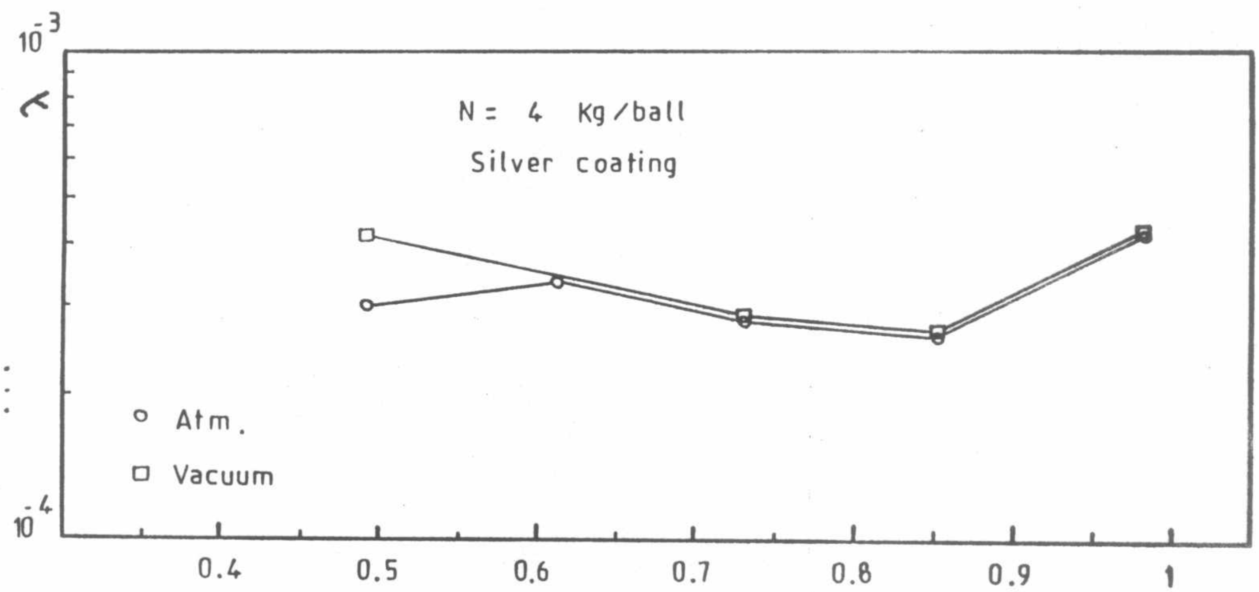


(b)

Figure (5) Lead ion plated thrust bearing in vacuum



(a)



(b)

Figure (6) Silver ion plated thrust bearing in vacuum