Determination of adhesive properties of lubricants on surfaces

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Summary

There are various approaches to describe the physico-chemical dependencies in the case of total wetting or non-wetting and the conditions in between, as well as measurements which directly or indirectly describe indications of the adhesive and dispersive energy of the liquids and surfaces. The interpretation of results achieved through laboratory tests in terms of function prediction of real components however is challenging and needs some experience. Within the scope of a development project a test method has been developed which allows to dynamically measure the adhesive force of a lubricant drop directly on the respective materials and surfaces with the technology of a centrifuge. The detection of adhesion forces under dynamic conditions extends the range of laboratory test methods for the characterization of surface wetting properties. In particular, the possibility of testing on real component surfaces and with small oil volumes opens up new aspects for the function prediction of life-time lubricated systems in precision engineering.

1 Introduction

Choosing the correct lubricant for micromechanical parts is amongst other things hindered by the fact that the parts to be lubricated are very small and the life time of components sometimes is decades. The demands onto the lubricants, especially in terms of for-life lubrication, minimum quantity lubrication and single application lubrication therefore is very high. The evaluation of the adhesive properties of the lubricants is a critical aspect, since due to long-term wetting and spreading effects a lack of lubricant may occur, which results in a raise of friction and wear up to a failure of the component.

2 Modelling of Tests

There are various approaches to describe the physico-chemical dependencies in the case of total wetting or non-wetting and the conditions in between, as well as measurements which directly or indirectly describe indications of the adhesive and dispersive energy of the liquids and surfaces [1]. These include e.g. the surface tension of the liquids or the surface energy of the material surfaces. However, in the direct contact of lubricant and surface, the interfacial tension dominates, which cannot be measured directly, and which only indirectly can be determined via the contact angle. If no equilibrium occurs at the interface, the measurement is made more difficult because the contact angle decreases as a function of time. Furthermore, in the field of precision mechanics, capillary forces are increasingly superimposing the wetting effects in narrow gaps, on rough surfaces and small drop volumes, and thus the transferability of measuring results into practical application is difficult.
Another point to consider is, that under practical running conditions of lubricated sliding bearings frictional heat is created, which results in an acceleration of wetting processes due to Marangoni convection effects [2]. Time lapse recordings for the visualization of wetting and creep effects under special exposure systems exist and can provide helpful additional information on the behavior of lubricants on surfaces. However, they are relatively complex and do not yield a usable measured value.

3 Dynamic Adhesion Measurement

Within the scope of a development project [3] a test method has been developed which allows to dynamically measure the adhesive force of a lubricant drop directly on the respective materials and surfaces.

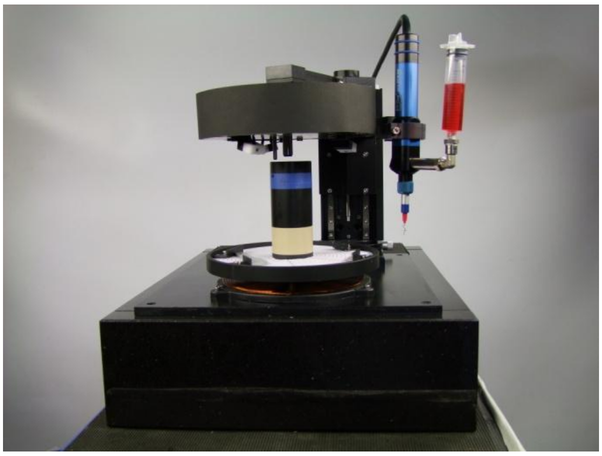

Fig. 1 APG Adhesion tester with rotating disk and dosing unit (swiveling)

The developed APG Adhesion Tester is based on the technology of a centrifuge. On a rotating disc oil droplets with a defined volume are selectively positioned on the material surfaces in different radii, and are subjected to different graduated centrifugal accelerations when the disc rotates. From the specific gravity, the drop volume, the distance from the axis of rotation and the rotational speed, the centrifugal force can now be precisely determined, at which acceleration force the drops are moving. At that point the adhesion force must be overcome respectively. This characteristic value expressed as a numerical force can thus be precisely determined, even directly on the components.

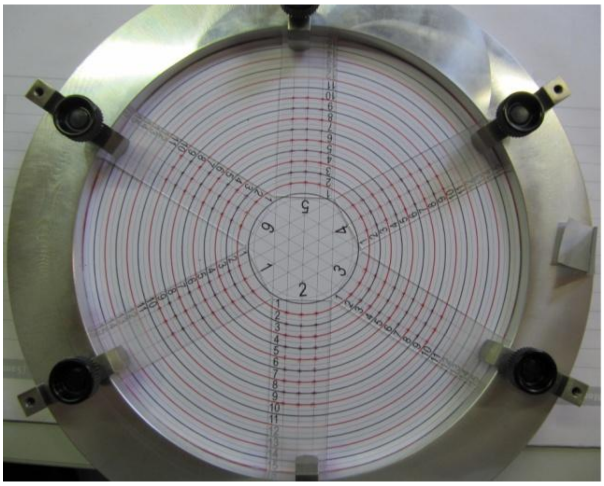

Fig. 2 Rotating disc with test samples containing oil droplets on different radii

The rotating speed of the disc is raised in steps of 25 seconds up to the point, where a movement of the oil droplets can be observed (transition force). By dividing the transition force value through the specific gravitiy, the transit factor is calculated, which allows to better compare results obtained with varying drop volumes.

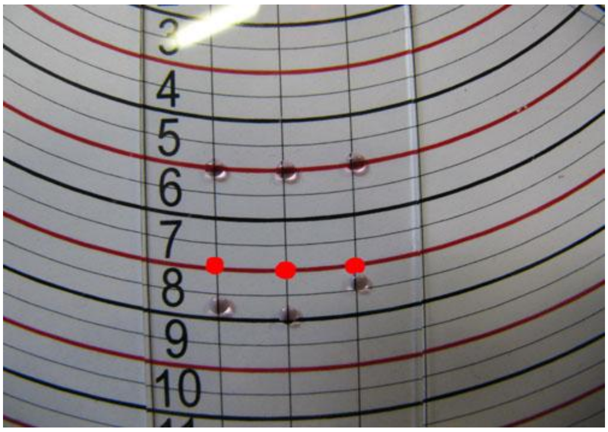

Fig. 3 Movement of droplets at transition point

3 Test Plan and Results

The test plan for the comparative assessment comprises three base oils used as lubricants in fine mechanics, a polyalphaolefin, an ester oil, and a silicone oil. The materials used are glass, steel, polyamide 66, polybutylenetherephtalate and polyacetale. Glass has additionally been tested with two surface roughnesses. In addition, the influence of wetting-changing surface coatings as used in for-life lubricated fine precision components on the adhesiveness of the lubricants has been tested.

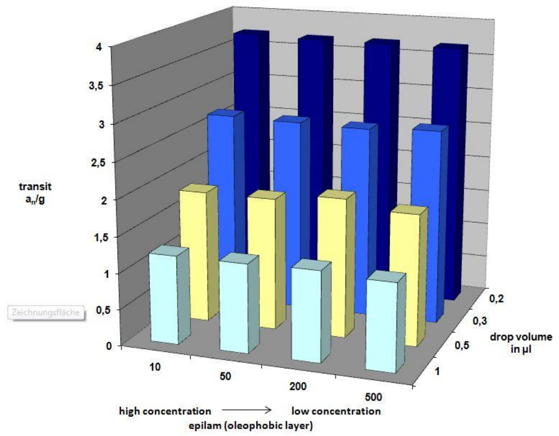

Fig. 4 Influence of drop volume and concentration of oleophobic layers on the transit factor of silicone oil on glass: small droplets show higher adhesion

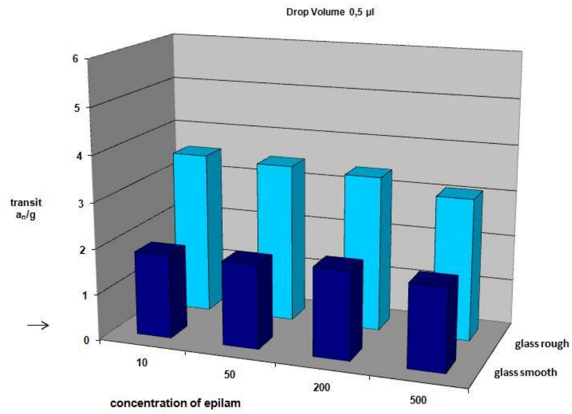

Fig. 5 Influence of surface roughness and concentration of oleophobic layers on the transit factor of silicone oil on glass: rough surfaces show higher adhesion

4 Conclusion

The detection of adhesion forces under dynamic conditions extends the range of laboratory test methods for the characterization of surface wetting properties. In particular, the possibility of testing on real component surfaces and with small oil volumes opens up new aspects for the function prediction of life-time lubricated systems in precision engineering.

5 References

[1] DIN 55660 Paints and varnishes; Wettability with Parts 1, 2 and 3 (Dec. 2011), Parts 4 and 5 (Apr. 2012, Parts 6 and 7 (Oct. 2014)

[2] Stehr, Werner: Spontanausfall von heißlaufenden Gleitlagern durch Ölverlust. 15. International Colloquium TRIBOLOGY, 17.-19. January 2006, Ostfildern, Germany

[3] ZIM Research Project KF 238 7401 DF9 Sept. 2009 to Aug. 2011: Entwicklung eines Messgeräts zur dynamischen Prüfung der Adhäsionskräfte von beschichteten Festkörperoberflächen in Kontakt mit Schmierstoffen. Dr. Tillwich GmbH Werner Stehr