



EXPERIMENTAL STUDY ON THE STRIBECK CURVE

Xiaobin Lu
Ph.D. Candidate

Faculty Advisor: Dr. Michael. M. Khonsari

INTRODUCTION

Stribeck (1902) carried out systematic experiments to show the existence of the minimum point proposed by Thurston (1885) and provided a clear view of the characteristic curve of the coefficient of friction versus speed. In recognition of his contribution, this curve is universally referred to as “the Stribeck curve” (Dowson, [1]). In some sense, especially after the speed parameter was extended to the Sommerfeld number ([2]), the Stribeck curve acquired a much greater breadth as its applicability extended to a far greater number of tribological components than merely journal bearings. It has been long recognized that the coefficient of friction is influenced by many parameters such as the material properties, the surface finish, the viscosity of the oil, and the operating conditions such as the speed and the pressure on the bearing. While many researchers illustrated the shift of the Stribeck curve under various conditions, none attempted to predict the transition point—the point that marks the watershed of the mixed and the hydrodynamic lubrication. This problem was tackled by Vogelpohl (1958) [3] who was probably the first researcher to have succeeded in developing an empirical equation to calculate the lift-off speed. We present the results of a series of experiments that were conducted to explore the behavior of the lift-off speed. We study the influence of oil inlet temperature, the oil type and the load. Comparison with Vogelpohl’s equation is also presented.

EXPERIMENTAL

Figure 1 shows the schematic of the apparatus (Lewis LRI-8H) used for measuring the coefficient of friction of journal bearings.

Experiment procedure

The system is balanced so that the coefficient of friction is nil when the shaft is at static position. At each speed, the history of the coefficient of friction is monitored and recorded.

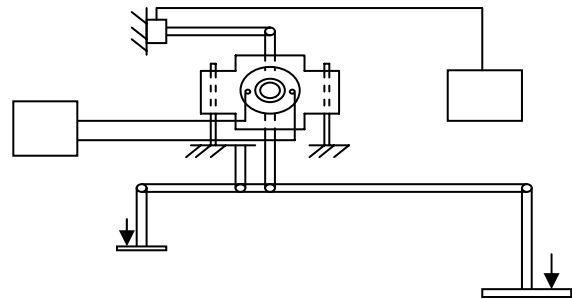


Figure 1

Experiment results

Effect of oil inlet temperature

temperature effect at 100lb

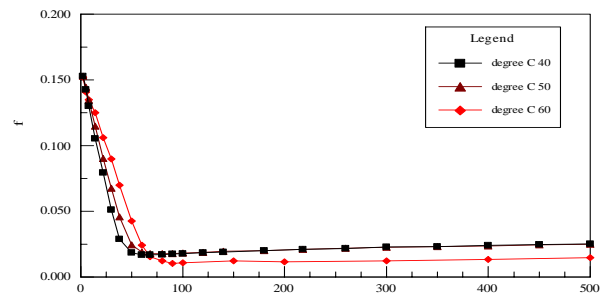


Figure 2

Effect of load

load effect at 40 degree C oil

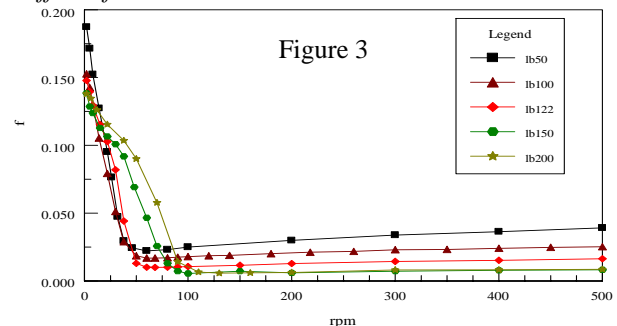


Figure 3

THEORETICAL PREDICTION OF THE LIFT-OFF SPEED

Theory development

When lift-off occurs, the speed N_T satisfies the definition of the Sommerfeld number

$$S = \frac{\mu \times N_T}{P_L} \left(\frac{R_s}{C} \right)^2$$

So that

$$N_T = \frac{S \times P_L}{\mu} \left(\frac{C}{R_s} \right)^2 \times 60$$

Khonsari & Booser (2001 [4]) obtained the following equation based on the numerical solution of Reynolds' equation

$$S = \frac{h_{\min}}{4.678C(L/D)^{1.044}}$$

The minimum film thickness can be calculated by the definition of Λ

$$h_{\min} = \Lambda \times (R_a^2 + R_b^2)^{1/2}$$

Combining those equations, the lift-off speed can be determined by

$$N_T = \frac{60P_L \Lambda (R_a^2 + R_b^2)^{1/2}}{4.678C \left(\frac{L}{D} \right)^{1.044} \mu \left(\frac{R_s}{C} \right)^2}$$

Comparison of theoretical prediction and experiment results

Load N	Lift-off speed (rpm) Vogel			Lift-off speed (rpm) Khonsari			Lift-off speed (rpm) Experiment		
	40°C	50°C	60°C	40°C	50°C	60°C	40°C	50°C	60°C
445	45	57	84	53	67	97	55	68	90
543	55	---	---	64	---	---	68	---	---
667	68	---	---	79	---	---	95	---	---
890	90	---	---	106	---	---	115	---	---

CONCLUSION

Increasing oil temperature and load shifts the lift-off speed to the right. In mixed or boundary lubrication regime, higher temperature creates bigger friction coefficient, while in the full-film lubrication regime, the opposite is true. Higher load causes smaller friction coefficient in the full-film lubrication regime. It is also shown that an equation derived based on the numerical solution of the finite Reynolds equation can effectively predict the lift off speed.

ACKNOWLEDGMENTS

The project is sponsored by Caterpillar Corporation, for which I am grateful. I would like to acknowledge CeRoM members at LSU for their kind help.

REFERENCES

1. Dowson, Duncan, History of Tribology, 2nd Edition, Professional Engineering Publishing, London and Bury St Edmunds, UK, 1998.
2. Hersey, M. D., Theory of Lubrication, 2nd Edition, John Wiley & Sons, Inc, New York, NY, 1938.
3. Vogelpohl, Georg, Thermal Effects and Elastokinetics in Self-acting Bearing Lubrication, Proceedings of International Symposium on Lubrication and Wear, Houston, 1965, 766-815.
4. Khonsari, M. M. and Booser, E. R., Applied Tribology Bearing Design and Lubrication, John Wiley & Sons, Inc, New York, NY, 2001.