Building a test equipment for measuring chaotic behaviour in a frictional oscillator

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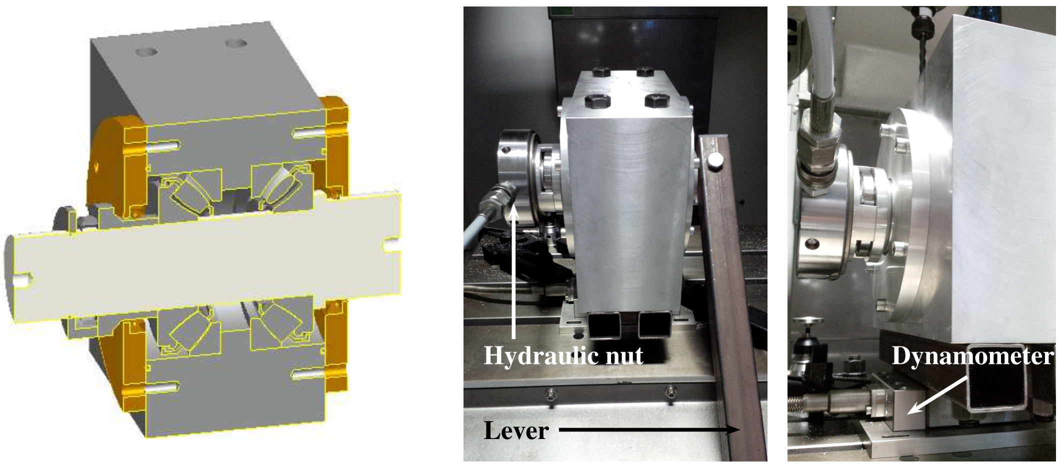
Summary. In this paper we present the status of a continued research on chaos and chaotic transients in a simple dry friction oscillator. A test equipment will be introduced that uses bearings instead of friction pairs meant to create high sticking to sliding force ratio. The first results obtained with the test rig will also be presented.

Introduction

In an earlier study [1] we investigated in theory how chaos can emerge in a simple one degree-of-freedom oscillator that incorporates Coulomb-type friction. By using the method of chaos synchronization [2] we have found that the system exhibits chaotic behavior if we can ensure high sticking friction force together with low sliding friction force. This, however, is very challenging if we are searching among proper material pairs for two reasons: 1. It is very uncommon that a material pair exhibits a sliding to sticking ratio close to $1:8$ [3]. 2. Even if a pair with such ratio would exist it would be very hard to maintain this value during the various tests that we want to carry out. The wear of the surfaces and the changing conditions like air humidity or changing surface temperature due to heating up may yield to non-reproducible results. Therefore, we were searching for a better solution that could solve these problems. We have found that there exist high performance bearings that according to the supplier [4] can require a starting torque that is up to eight times higher than the operational torque. The application of these spherical roller thrust bearings can be a reasonable choice for our test bench since the model equations we use for a single degree-of-freedom lateral motion can easily be rewritten to rotational motion.

Test equipment

The equipment is basically a shaft in its housing that is supported by the two spherical roller thrust bearings in back to back configuration. The cross sectional view in Figure 1(a) shows the placement of the bearings.



(a) (b) (c)

Figure 1: CAD model and photos of the test equipment before testing

The two bearings are of type 29412 and are made by ZWZ Group. The axial pretension of the bearings is an important variable parameter of the system that has an effect on the ratio of the static and dynamic torques. A hydraulic bearing nut of type HMV 12E was used to set the axial pretension. This nut can produce forces up to 198kN. Optionally, the pretension can be made permanent with the help of a conventional bearing nut. For the first tests we did not use this option but permanently applied the force by the hydraulic nut. The bearing housing was placed on top of a Kistler 9129AA multicomponent dynamometer using an adapter frame. The dynamometer measures forces and torques acting in three perpendicular directions. A lever was used to generate a torque on the shaft by hand. Until reaching the starting torque for the current pretension the complete assembly moves like a rigid body. As the shaft starts to rotate the measured axial torque drops and the peak value that we defined as starting torque can be detected.

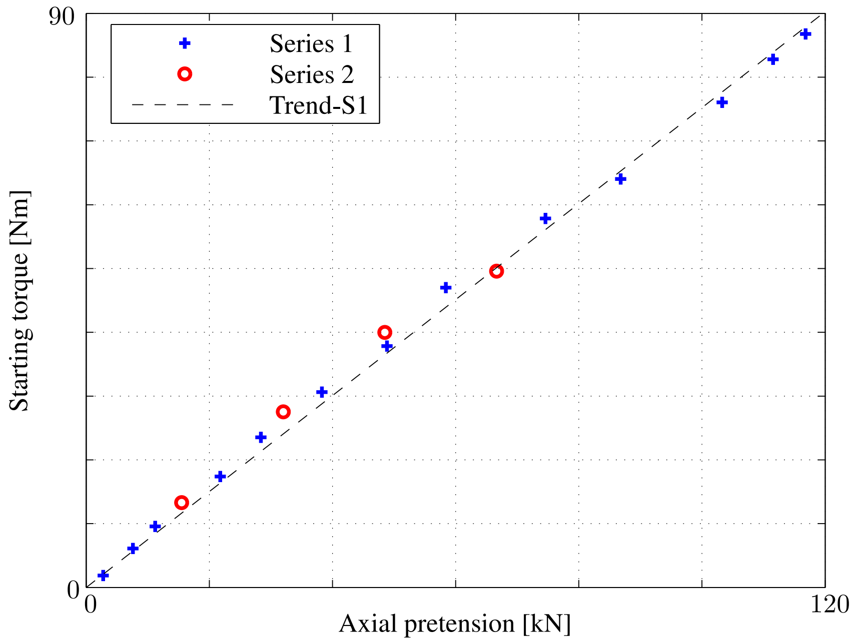


Figure 2: Starting torques measured by the Kistler 9129AA multicomponent dynamometer

First results

Two series of measurements were performed with the same condition i.e. without grease lubrication. It was possible to register the starting torque because of a visible drop of its value in time. However, the drop was less than expected. The starting torque values for the two series are presented in Figure 2 together with the linear trend line calculated using the values of the first series.

Once the shaft started to spin the torque dropped down to a value that is in average half of the starting torque. This value is clearly not enough for our subsequent analysis because we need at least a ratio of 1:8. One possible solution could be to try bearings from different manufacturers. The bearing type and dimensions are standardized, however, there are slight differences in the design that could have an impact on the starting torque as well. Besides this a linear relation can be observed between the pretension force and the starting torque of the bearing.

The test was repeated using a grease of type LGEP. In this case it was found to be very hard to distinguish between starting torque and operational torque. Due to this result no diagram was created, however, this issue emphasizes the importance of lubrication circumstances.

Conclusions

A test equipment was built to host two spherical roller thrust bearings. Having the first results we can conclude that the lubrication circumstances have significant effect on the torque ratio. Moreover, we have found that without lubrication the starting torque has a linear dependence on the value of the axial pretension force. The application method of axial pretension worked well and can be used further on in later tests.

Acknowledgement

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