Introduction to spindle error motion testing

The basic idea is that a perfect spindle rotates around an axis (Z) that is fixed in position and orientation in space. A real spindle does not do that; its axis of rotation moves both in position and in orientation as the spindle rotates. These motion errors lead to, for instance, non-circularity of parts being machined, or to errors in the determination of the circularity of parts being inspected.

We can measure this motion along a particular axis perpendicular to the axis of rotation by monitoring the runout of a precision artifact as the stage rotates. We can measure the motion in two directions, i.e., in the X,Y plane, by using two sensors aligned at 90 degrees one with respect to the other.

If we measure the X,Y motion of the spindle at two different Z axis positions, then we can determine changes in the orientation of the spindle axis as well. Such orientation change is called Tilt Axis Motion in the official specification that covers such measurements (ASME B89.3.4).

It is not necessary to get the artifact perfectly centered on the axis, as one can easily remove the signal due to decenter. It is also not necessary to have a perfect artifact, because one can determine the errors in the artifact by reversing the artifact and the sensor with respect to the spindle and repeating the test. I have provided two opposed sensors along each the X and Y axes to do essentially the same thing, however I found that the errors in my artifacts were small enough for me to ignore.

Given that, there are two classes of error motion. Synchronous error motion is motion that repeats from revolution to revolution of the spindle. Asynchronous error motion is motion that does not repeat from revolution to revolution; thus it can be averaged out as the number of turns of data are increased.

Introduction to the Summary Report

My test results for each spindle are presented in a Summary Report. I suggest that you open one of the reports and refer to it while reading the following.

The second page of the report presents data on the Asynchronous error motion of the spindle. The first four graphs are polar plots of the typical Async error motion along each axis; for these I simply took the results of the first 3 revolutions in the data set. What is shown here is the result of bearing noise, and it is characteristic of moving element bearings. It is the asynchronous error motion of a spindle which contributes, for instance, to the surface finish, or lack thereof, in a lathed part.

I used a total of 180 turns of data to generate the Summary Reports. Thus, it was possible to determine how the asynchronous error motion would decrease as the number of turns averaged is increased, and the final plot on the second page of the report shows that result. This was the most significant plot in the report for my purposes.

The third page of the report presents data on the Synchronous error motion. This is simply the residual after the asynchronous is averaged over the 180 turns. The top 4 plots give the synchronous motion along each of the X and Y axes at each of the two Z axis positions. It is the synchronous error motion of a spindle which determines, for instance, the lobing of a lathed part.

The bottom two plots give the synchronous tilt error motion corresponding to the data above. From this, one can determine what the synchronous error motion of the spindle would be at any position along the Z axis. I can't do that for the asynchronous error motion, because I did not measure at both Z positions simultaneously.

The document SupplementaryNotes.PDF provides more detail on the measurement hardware and the way the data were handled for these measurements. It also compares my presentations of results to those preferred by the Standard (ASME B89.3.4). In general my quoted results are more conservative than they would be if I strictly followed the Standard.