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SPINDLE DESIGN

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SPINDLE DESIGN

Introduction

Spindles for lathes in the early years and up to the year 1935 were generally of sleeve design. Some were split cast from halves lined with babbit, bronze and even cast iron.

The stiffness of these spindles was not considered important because, in general, high speed tools - such as double A, triple A, and M grade crucibles - were not sensitive to chatter and loose slides, and as a result we had very little tool breakage.

It was not uncommon to be able to see the work piece and chuck climb on the tool during heavy cuts.

Roundness - well, we considered that if it was turned on a lathe it just had to be round. If we desired better fits, we lapped and hand scraped.

I guess to us a bearing was just a bearing and had to be round on a lathe, grinder, or boring machine.

How often have many of you added weight to chucks, tightened the belts a little more, or even clamped a pair of toolmakers' clamps to a tool holder to get a good finish cut?

What happened when the first piece of tungsten carbide was given to you. Perhaps many of you can remember the sad and disappointing results - for our dreams of fast and high-speed turning went out the window.

Again we must have wondered how the German manufacturing industry had been so successful during World War I with its newly found use of tungsten carbides.

I can only assume, since I was but a young boy at that time, that they had found that rigidity in spindles and slides was the answer.

To this time, no mention has been made of spindle thrust bearings; but I am sure many of us can remember the old fashioned threaded collar in the gear change box at the outboard end of the spindle.

Let us not belittle the skill of the old time machinist; for often indeed, the work produced was only through his skill and patience and a perfect understanding about his machine and its capability.

Early Improvements

Gradually time has changed these first approaches through research and changing demands, and too often through military demands caused by war. Consideration for bettering spindles has gone hand in hand with the development of exotic high speed cutting tools. Manufacturers have had to recognize these needs and have changed and redesigned these tools to meet our too often, seemingly wild, blue-yonder dreams. I think, though, we have all bettered the state of the art through necessity to produce certain parts to closer tolerances.

Peripheral speed control to give us good surface finishes regardless of progressively varying diameters in cutting has made us conscious of spindle growth.

Control of spindle temperature can now assure us of reasonable control of part size.

How many times have we been asked what class bearing is to be installed in a machine tool that required new bearings. Often as not .0001 T.I.R., as we thought at that time in 1952, would have been very acceptable.

How did we solve the problem of producing parts having various counterbores, slots and flanges? As a general rule, we would ask maintenance to remove as much end play as possible without overheating the bearings.

And so it had seemed to us that if a bearing was round it would still be round when pressed into the bearing housing, but in our final reasoning we found this a problem also.

State of the Art

In summarizing what we have learned to date, there is a state of art which can produce good reliable bearings for turning work pieces more accurately round.

Ball bearings have been, and are being, made through a new process that guarantees their roundness to 2 and 3 millionths. The same is true in the production of needle and roller bearings. Here again, foreign manufacturers have surpassed our efforts until quite recently. We have now reached the point where we consider all the components of a bearing for true roundness; namely spindle shaft, bearings, races, housing, and adding such design features

as increased stiffness, temperature control and spindle growth away from the nose section.

Such design features to allow for overall spindle location and mounting are now considered to maintain a true center of location with reference to tool height - a vital factor for accurate parts.

No doubt the requirements for all the fine features in a bearing for turning or boring would not be a consideration for those of us desiring a standard off-the-shelf machine tool; but I think that the state of the art, in many cases, has been included as standard performance specifications from reliable and well known machine tool manufacturers.

Acceptance tests at the machine tool manufacturer's plant in the past have been made in a variety of ways and with various devices.

Common practice was to turn a part and check it for roundness on the Talyrond or Indo-Ron apparatus. Other methods, such as dial indicators, Mikrokator indicators, and portable amplifiers and motion pickups, were used to measure spindle motions. However, I think many of us came to realize that the dampening action and slow response time of meters were not giving us accurate and complete answers, not to mention the fact that we were only seeing the spindle at one given point of contact.

The use of oscilloscopes having wide frequency ranges adjustable to our demands with sensitive non-contact sensing units placed 90° apart and connected to high gain amplifiers will give us the true path in which a spindle rotates at any given speed or load factor.

This is an excellent means for spindle measurement and it may be recorded for permanent record of any spindle performance.

Not so of our past tests because they were either estimates given verbally or obtained by using some method of recording discreet points by number, repeating this procedure as often as 12 to 20 times. This was done at one contact point and in relation to the same point on a circle of 360 degrees.

Spindle Specifications

So in the event we wish to purchase a good spindle for a special purpose, we must specify requirements on:

- Spindle growth overall
- Spindle balance
- Spindle weight carrying capacity
- Spindle axial and radial motions
- Spindle drive system
- Spindle ruggedness
- Spindle stiffness

What kind of spindle are we looking for?

- Dynamic
- Hydrodynamic
- Anti-friction, roller, ball and needle
- Hydrostatic air and fluid

The tests we are interested in depend upon what use we want it for:

1. Spindle growth from cold start to normal operating temperature.
2. Spindle growth or shrinkage with variable speeds.

3. Spindle shrinkage during machine cycle periods.
4. Spindle overall growth and shrinkage related to normal center line.
5. Axial and radial spindle motion at various speeds, loaded and running free.
6. Effect of drive system in this regard if belts or gears are used.
7. Spindle sag out from spindle nose related to spindle stiffness.
8. Vibration from spindle drive system.
9. Bearing life.

Last but not least - Valid data and performance records through 360° degree rotation.

Available Equipment

There are at this date a number of spindle and bearing manufacturers that have many special features to offer:

1. Superaccurate ball bearing spindle assemblies, accuracy from 3 to 8 millionths, depending upon your requirements of speeds and loads.
2. Standard off-the-shelf spindle assemblies, accuracy from 20 to 40 millionths, compensated for spindle growth by design and/or automatic temperature control.
3. Spindles designed for a front locked-in-position bearing, preloaded, with all of the coefficient of expansion toward the outboard end. Using temperature control in combination with the above features gives us the desired control of coefficient of expansion within 30 to 40 millionths accuracy.

4. Hydrostatic bearing spindles with accuracies in the 5 millionth range. High stiffness, immunity to shock loading and negligible wear are additional desirable features claimed.

Pertinent to hydrostatic bearings, Dr. Skulski will give a brief summary of the purpose and current results of hydrostatic bearing investigations at Rocky Flats.