# Spindle design

Major performance measures for high speed machining spindle design include

* Desired spindle power , peak and continuous
* Max spindle load , axial and radial
* Max spindle speed
* Tooling style, size and capacity
* Belt driven or integral motor

Fast and accurate machine tool demands a reliable high speed spindle system.

High speed spindle design

Major components required for a high speed milling spindle design include(<https://www.mmsonline.com/articles/high-speed-spindle-design-and-construction>) accessed 2018/03/06

* Spindle style
* Spindle bearings
* Spindle motor
* Spindle shaft
* Spindle housing

1. Spindle style: belt driven or integral motor-spindle

Generally belt driven spindles cost much less than built in spindles. The spindle style should be determined by evaluating the requirements of the machine tool, including the maximum speed, power and stiffness required.

* 1. Belt driven spindles

Belt driven transmission systems are the conventional method of torque transmission for spindle designs. The belt driven assembly consists of a spindle shaft, supported by a set of bearings and spindle housing. The spindle shaft houses the tool taper, draw mechanism and tool release system.

Main advantage of a belt driven spindle

* + - Reasonable cost
    - Wide application area
    - Can achieve high power and torque

Disadvantages of belt driven spindle

* Maximum speed is limited
  + Mechanical connections have a limited speed
  + Pulley belts slip
  + Pulley belts produce high levels of vibrations and heat at high speed
* Belts utilize bearing load capacity

Typically belt driven spindles are used up to maximum rotational speed of 12,000-15,000 RPM and maximum power of up to 30HP.

* 1. Integral motor-spindle design

Integral motor-spindle uses a built in motor that provides the necessary torque and power within the spindle assembly. The integral spindle assembly is compact and permits high rotational speeds of the shaft.

Complete spindle assembly consist of a motor element, spindle shaft and a tooling system. The shaft is held in position by a set of precision bearings that will generally require a lubrication method, such grease or oil.

1. Spindle bearings: Type, quantity, mounting and lubrication method.

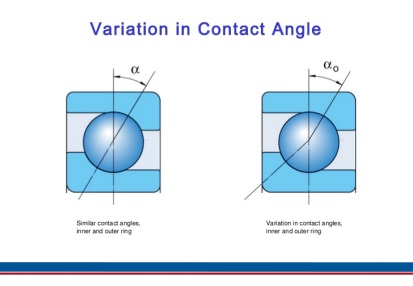
Bearing selection for high speed spindle application requires that the spindle provide high rotational speed, transfer torque and power to the cutting tool and capable of reasonable loading and life. The type of bearings used for high speed spindles include roller, tapered roller and angular contact bearings.

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| **Requirement** | **Best bearing type** | **Design impact** |
| High speed | Small angular contact | Small shaft |
| High stiffness | Large roller | Low Power |
| Axial loading | High contact angle | Low speed |
| Radial loading | Low contact angle | Large shaft |
| High accuracy | ABEC 9, high preload | Low speed |

* 1. Angular and contact ball bearings v/s Tapered roller bearings

Angular contact bearings are the most commonly used bearings, because they offer precision, load carrying capacity and speed for metal cutting spindles. In some application tapered roller bearings are preferred and used due to the fact that they exhibit higher load carrying capacity and greater stiffness. But tapered roller bearings are not suitable for high speed application.

Angular contact ball bearing can offer both radial and axial load support when properly preloaded. A bearing contact angle is defined as the nominal angle between the ball to race contact line and plane through the ball centre, perpendicular to the bearing axis (fig below).The contact angle determines the ratio of the axial to radial load carrying capacity of a bearing. Available bearing contact angles are 12, 15 and 15.The lower the contact angle, the greater the radial carrying capacity. Typical spindle life for very high speed operation should be in the range of 5000-7000 hours assuming machine is used for the intended application.



1. Spindle motor design

(Use this in detailed design)

As you can see, there are many factors that determine the final decision. A spindle that is desired to have the highest speed will not have the maximum stiffness possible, and, the spindle with the highest stiffness cannot run at high speeds without sacrificing bearing life. So, as designers, compromises must be made in order to arrive at a final design that will offer the compromise.