3.4 Machine Tool Measurement Using Laser Interferometer

When the machine tool is idle and unloaded, tests performed are called as alignment tests.

Alignment test is carried out 'to check grade of manufacturing accuracy of the machine tool'. It consists of checking the relation between various machine parts or elements (such as bed, table, spindle etc.)

3.4.1 Alignment Testing on Machine Tools and its importance

The accurate production of the component parts depends on the accuracy of the machine tools. The quality of workpiece depends on the following factors:

- Rigidity and stiffness of machine tool and its components.
- Alignment of various components in relation to one another,
- Quality and accuracy of the control devices and the driving mechanism.

Precise alignment of machine tool components has the following advantages:

- It produces high quality machined components.
- It reduces power consumption of machinery.
- It increases machine reliability and productivity.
- It reduces machine repair costs.
- It minimizes the machine installation and repair time.
- It reduces machine down time and increases machine availability.
- It decreases wear on bearings, seals, shafts and couplings.
- It reduces vibrations in machine tools.
- It significantly reduces the damage to machine tool components.

Various types of alignment tests conducted on machine tools are as follows

a) Straightness
b) Flatness
c) Parallelism, Equidistance and Coincidence
   i. Parallelism of Lines and Planes
   ii. Parallel Motion

d) Squareness of straight lines and planes

e) Rotation

   i. Concentricity or out of round
   ii. Eccentricity
   iii. Out of true running
   iv. Periodical axial slip
   v. Radial throw of an axis at a given point

f) Movement of all working components

In general, the following alignment test for applied to any Machine tools

- Test for levelling the installation of a machine tool in horizontal and vertical plane
- Test for perpendicularity of guideways to other guideways
- Test for flatness of machine bed straightness and parallelism of bed ways on the bearing surface
- Test for true running of the main spindle and its Axis movements
- Test for a line of moment of various members such as spindle tables and cross slides
- Test for parallelism of spindle axis to guideways for the bearing surfaces

Laser as means of alignment checking

Laser alignment checking can be used for the following purposes

- To Align horizontal boring Mills, Vertical boring Mills, vertical machining centres, vertical turret lathe, gantries, surface grinder, injection moulding machines, presses, high Precision laser and water Jet cutting machines.
- To verify and correct roll parallelism in paper mills, printing presses, film line and blown film lines
- To measure and align the flatness of almost any surface (square, frames, ways, flanges, circles Etc.).
- To ensure the squareness up to three surfaces
- To ensure the straightness of horizontal and vertical surfaces
- To ensure the parallelism of horizontal and vertical surfaces

- for other applications such as checking the plumpness of a vertical surface Checking way twist and parallelism between horizontal surfaces and checking way twist and parallelism between vertical surfaces

Laser systems can be used to measure a great number of geometric and dynamic properties of a machine tool. Following measurements can be performed using laser interferometer

a. linear positioning accuracy and repeatability of Axis
b. straightness of Axis
c. squareness between Axis
d. flatness of surface
e. levelness of the plane surface
f. parallelism between surface
g. testing accuracy of rotary axis

3.4.2 Straightness testing using laser interferometer

Straightness error is one of the fundamental geometric tolerances that must be strictly controlled for precision guideways or stages. Several methods used for straightness measurements are: laser interferometer with straightness optics, a straight edge with displacement sensors such as linear variable displacement transducer and gap sensor, and incremental angular measurements using autocollimator or angular measurement optics, etc. Among these methods, the laser interferometer has been widely adopted to obtain high precision straightness measurement.

Some commercial instruments have been successfully developed, such as the Agilent 5529A interferometer and the Renishaw ML10 interferometer a common disadvantage in these instruments is that they cannot provide information about the relative position of the measured straightness errors Therefore in practice it is inconvenience to repair the guideways or to adjust the stages because the users do not know the exact position of the straightness error. a new interferometer design based on heterodyne interferometry for measuring straightness and its position is proposed, which can overcome the disadvantage described above. The theory and optical configuration of this new interferometer are developed and subjected to experimental testing with a linear stage to verify the feasibility of the interferometer as well as a flexure-hinge stage to demonstrate the interferometer's capability of nanometer measurement accuracy.

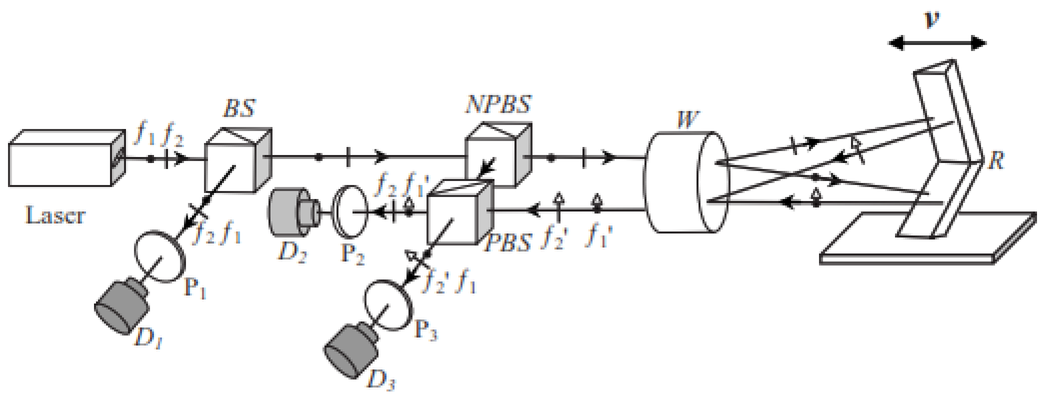

Fig. 3.26 schematic diagram of the laser interferometer for measuring straightness and its position based on heterodyne interferometry.

[source: https://www.researchgate.net/figure/Schematic-of-the-Twyman-Green-Interferometer-Based-on-Born-and-Wolf-1999_fig4_44788333]

A stabilized laser as light source emits a orthogonally linearly polarized laser beam with dual frequencies (f_1 and f_2). The laser beam is divided by a beam- splitter (BS) into two beams. One beam, as the reference beam, passes through the first polarizer (P1) and projects on to the first photodetector (D1), and then a reference signal is produced. Another beam, as the measurement beam, is divided by a nonpolarizing BS into a reflected beam (RB) and a transmitted beam (TB). The RB incidents onto a polarizing BS (PBS). The TB passes through a Wollaston prism (W) and is split into two divergent beams containing f_1 and f_2 separately. The two divergent beams are then incident onto a retroreflector (R) which is composed of two right-angle prisms.

The R is placed on the measured object which straightness is required to be tested. The R reflects the two divergent beams, whose frequencies become f1±f1 and f2±f2 caused by the Doppler effect, back into the W where they are recombined into one beam at another point of the W. After passing through the W, the combined beam incidents onto the PBS. Then, (a) the beam with frequency of f1 ±f1 transmitting through the PBS and the beam f2 of the RB reflected by the PBS recombine into one beam (BI). The BI passes through the second polarizer (P2) and projects onto the second photodetector (D2). So, the first measurement signal is produced. (b) The beam with frequency of f2 $\pm\Delta$f2 reflected by the PBS and the beam f1 of the RB transmitting through the PBS recombine into another one beam (BII). The BII passes through the third polarizer (P3) and projects onto the third photodetector (D3). So, the second measurement signal is produced.

Use of Laser for Alignment Testing

The alignment tests can be carried out over greater distances and to a greater degree of accuracy using laser equipment.

- Laser equipment produces real straight line, whereas an alignment telescope provides an imaginary line that cannot be seen in space.
- This is important when it is necessary to check number of components to a predetermined straight line. Particularly if they are spaced relatively long distances apart, as in aircraft production and in shipbuilding.
- Laser equipment can also be used for checking flatness of machined surface by direct displacement. By using are optical square in conjunction with laser equipment squareness can be checked with reference to the laser base line.

3.4.3 ALIGNMENT TESTS ON MILLING MACHINE

3.4.3.1. Cutter Spindle Axial Slip or Float:

Axial slip is defined as, "an axial movement of spindle, which may repeat positively with each revolution". Clamp the dial gauge stand to table, such that, the plunger or feeler of dial gauge indicator is touching the face of locating spindle shoulder.

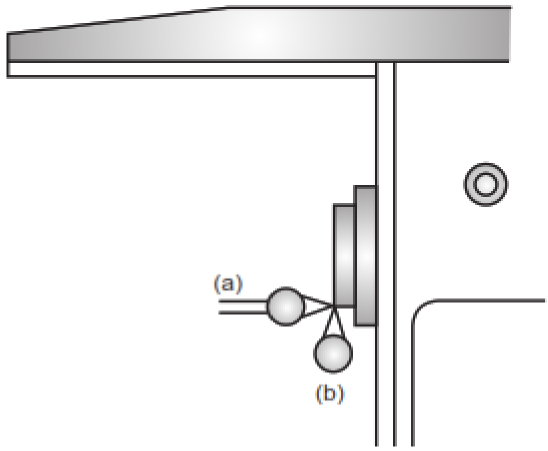

Fig. 3.27 Cutter Spindle Axial Slip or Float

[source: Metrology And Quality Control by Vinod Thombre Patil, Pg. No 8.20]

- Now rotate the spindle about its centre and note down the variations observed in the readings shown on dial gauge indicator.
- This is to be tested at two points 180° apart from each other. It is expected that, the value of maximum variation in dial gauge readings should not be more than specified permissible range.

3.4.3.2. Transverse Movement Parallelism with Spindle Axis:

- Fig. shows the arrangement required to carry out test, using a dial gauge indicator along with its mounting stand arrangement.

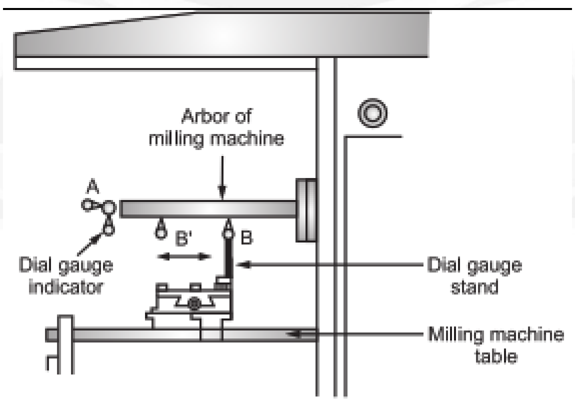

Fig. 3.28 Transverse Movement Parallelism with Spindle Axis

[source: Metrology And Quality Control by Vinod Thombre Patil, Pg. No 8.21]

- Mount and fix the dial gauge indicator with the help of its stand, on the table of milling machine.

- Use Arbor of milling machine as shown in Fig. A stationery mandrel can also be used instead of Arbor.
- Initially, place the plunger (or feeler) of dial gauge indicator touching the Arbor at point 'B' to check along vertical plane. Note down the reading of dial gauge indicator (1^{st} reading).
- Now move the dial gauge indicator along with its stand in transverse direction up to point B' and note down the second reading of dial gauge indicator (2^{nd} reading).
- If no variation is found in first (1^{st}) and second (2^{nd}) reading, then transverse movement is parallel with spindle axis.

3.4.3.3. True Running of Internal Taper:

• Fix a mandrel as shown in Fig.

•Dial gauge indicator is mounted with the help of dial gauge stand, in such a way that, plunger will touch the surface of mandrel.

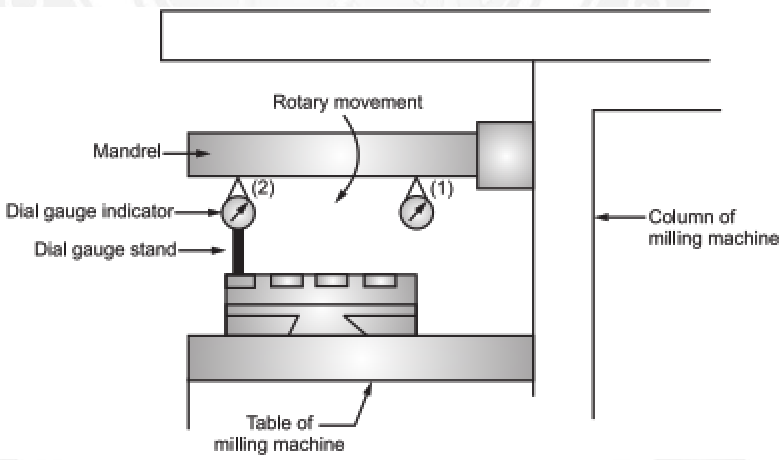

Fig. 3.29 Transverse Movement Parallelism with Spindle Axis

[source: Metrology And Quality Control by Vinod Thombre Patil, Pg. No 8.21]

- It is ensured that, plunger remains in contact with mandrel, while carrying the test.
- This test is carried out at two places, given below:

(i) Near to spindle nose, refer position (1).

(ii) At a distance of 300 mm from spindle nose, refer position (2).

- Consider that plunger of dial gauge indicator is at position (1). Now, rotate the mandrel and observe the readings shown on dial indicator, to find out the value of maximum variation (if present) is noted down as 1st reading.
- Now, dial gauge indicator is mounted with the help of its stand at position (2), which is 300 mm away from position (1). Repeat the same procedure and note down 2nd reading.
- Difference between 1st and 2nd readings indicates an error in true running of internal taper.
- This error should not exceed the specified permissible value.

3.4.3.4. Surface Parallelism with Longitudinal Movement:

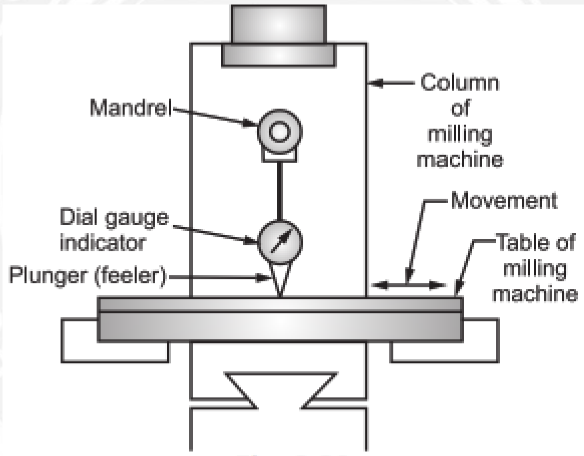

Fig. 3.30 Transverse Movement Parallelism with Spindle Axis

[source: Metrology And Quality Control by Vinod Thombre Patil, Pg. No 8.22]

- Fix a mandrel and a dial gauge indicator in such a way that, the plunger of dial gauge indicator will touch the table surface. Also, plunger is slightly pressed against the table surface, so that, it will be always in contact with table surface throughout the test. Refer Fig.
- Test the table surface for maximum travel.
- Readings shown by dial gauge indicator are observed to find out maximum variation, i.e., error in parallelism of surface during horizontal movement. This error should not exceed more than the specified permissible value.