

- a. Have two or more axes that can be coordinated simultaneously for "contouring control"; and
- b. Have any of the following characteristics:
  1. Two or more contouring rotary axes;
  2. One or more contouring "tilting spindles;"

**NOTE:**

c.1.b.2. applies to machine tools for grinding or milling only.

4501. 2. c. 1. b. 3. "Cammings" (axial displacement) in one revolution of the spindle less (better) than 0.0006 mm total indicator reading (TIR);

**NOTE:**

4501.2.c.1.b.3. applies to machine tools for turning only.

- 4. "Run out" (out-of-true running) in one revolution of the spindle less (better) than 0.0006 TIR.

- 5. The "positioning accuracies," with all compensations available, are less (better) than:

- a. 0.001° on any rotary axis
- b. 1. 0.004 mm along any linear axis (overall positioning) for grinding machines
- 2. 0.006 mm along any linear axis (overall positioning) for milling or turning machines

**NOTE:**

4501.2.c.1.b.5.b.2. does not control milling or turning machine tools with a positioning accuracy along one linear axis, with all compensations available, equal to or greater (worse) than 0.005 mm.

**NOTE 1:**

Sub-item 4501.2.c. does not include cylindrical external, internal, and external-internal grinding machines having all of the following characteristics:

- a. Not centerless (shoe-type) grinding machines;
- b. Limited to cylindrical grinding;
- c. A maximum workpiece outside diameter or length of 150 mm;
- d. Only two axes that can be coordinated simultaneously for "contouring control"; and
- e. No contouring c axis.

**NOTE 2:**

Sub-item 4501.2.c. does not include machines designed specifically as jig grinders having both of the following characteristic:

- a. Axes limited to x, y, c, and a, where the c axis is used to maintain the grinding wheel normal to the work surface, and the a axis is configured to grind barrel cams and
- b. A spindle "run-out" not less (not better) than 0.006 mm.

**NOTE 3:**

Sub-item 4501.2.c. does not include tool or cutter grinding machines having all of the following characteristics:

- a. Shipped as a complete system with "software" specially designed for the production of tools or cutters;
- b. No more than two rotary axes that can be coordinated simultaneously for "contouring control";
- c. "Run-out" (out-of-true running) in one revolution of the spindle not less (not better) than 0.0006 mm TIR; and
- d. The "positioning accuracies," with all compensations available, are not less (not better) than:
  1. 0.004 mm along any linear axis for overall positioning; or
  2. 0.001° for any rotary axis.

4501. 2. c. 2. Electrical discharge machines (EDM);

- a. Of the wire feed type that have five or more axes that can be coordinated simultaneously for "contouring control";

- b. Non-wire EDMs that have two or more contouring rotary axes and that can be coordinated simultaneously for "contouring control."

4501. 2. c. 3. Other machine tools for removing metals, ceramics, or composites:

- a. By means of:

1. Water or other liquid jets, including those employing abrasive additives;
2. Electron beam; or
3. "Laser" beam; and

- b. Having two or more rotary axes that:

1. Can be coordinated simultaneously for "contouring control"; and
2. Have a "positioning accuracy" of less (better) than 0.003°.

4501. 2. d. "Software"

1. "Software" specially designed or modified for the "development," "production," or "use" of equipment controlled by sub-categories 4501.2.a., b., or c. above;
2. Specific "software," as follows:

- a. "Software" to provide "adaptive control" and having both of the following characteristics:

4501. 2. d. 2. a. 1. For "flexible manufacturing units" (FMUs) that consist at least of equipment described in (b)(1) and(b)(2) of the definition of "flexible manufacturing units"; and

2. Capable of generating or modifying in "real time processing," "part program" data by using the signals obtained simultaneously by means of at least two detection techniques, such as:
  - a. Machine vision (optical ranging);
  - b. Infrared imaging;
  - c. Acoustical imaging (acoustical ranging);
  - d. Tactile measurement;
  - e. Inertial positioning;
  - f. Force measurement;
  - g. Torque measurement.

**NOTE:**

This sub-item does not include "software" that only provides rescheduling of functionally identical equipment within "flexible manufacturing units" using prestored "part programs" and a prestored strategy for the distribution of the "part programs" and

4501. 2. d. 2. b. "Software" for electronic devices other than those described in sub-items 4501.2.a. or b. that provides the "numerical control" capability of the equipment controlled in sub-item 4501.2.

4501. 2. e. Technology

1. "Technology" for the "development" of equipment controlled by sub-items 4501.2.a., b., or c. above, 4501.2.f. or g. below, and of the sub-item 4501.2.d.

2. "Technology" for the "production" of equipment controlled by sub-items 4501.2.a., b., or c. above, 4501.2.f. or g. below;

3. Other "technology":

- a. For the "development" of interactive graphics as an integrated part in "numerical control" units for preparation or modification of "part programs";
- b. For the "development" of integration "software" for incorporation of expert systems for advanced decision support of shop floor operations into "numerical control" units.

4501. 2. f. Components and parts for machine tools controlled by sub-item 4501.2.c. as follows:

1. Spindle assemblies, consisting of spindles and bearings as a minimal assembly, with radial ("run-out") or axial ("cammings") axis motion in one revolution of the spindle less (better) than 0.0006 mm TIR;

4501. 2. f. 2. Linear position feedback units (e.g., inductive-type devices, graduated scales, "laser," or infrared systems) having with compensation, an overall "accuracy" better than  $800 + (600 \times L \times 10^{-3})$  nm, where L equals the effective length in millimetres of the linear measurement; except measuring interferometer systems, without closed or open loop feedback, containing a "laser" to measure slide movement errors