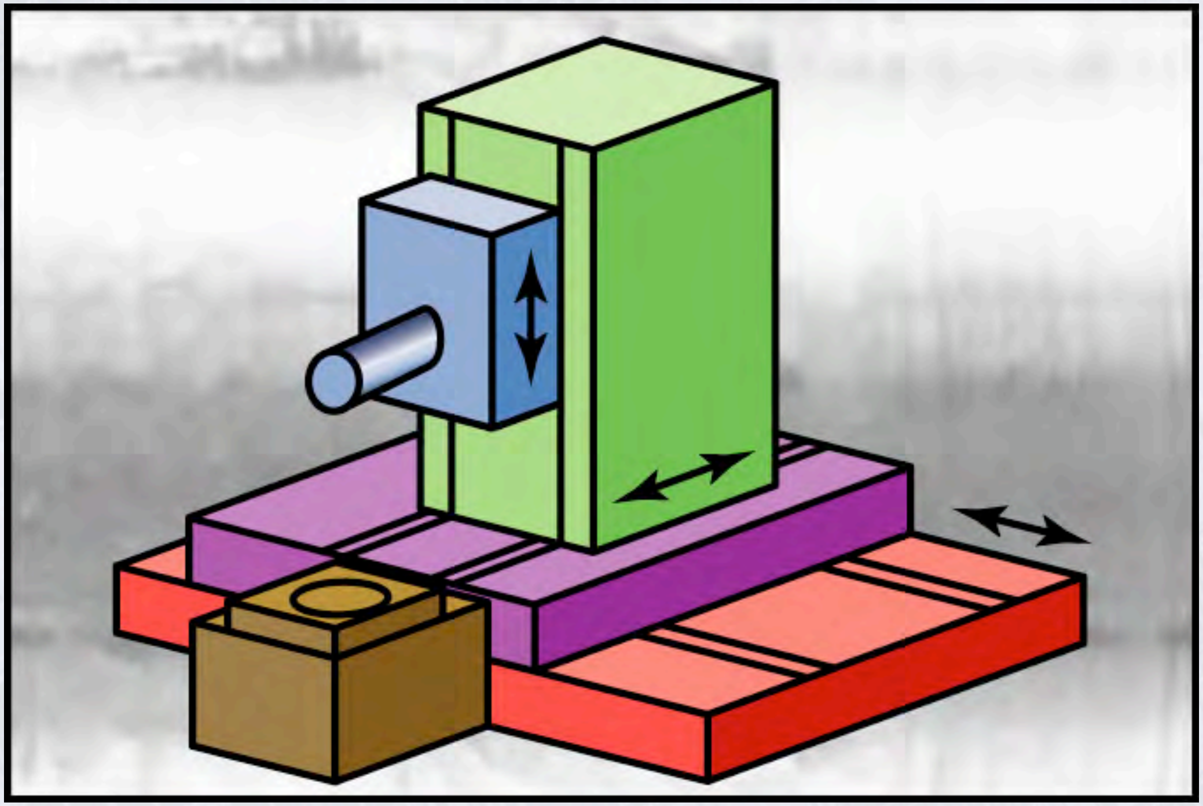
Chapter 25

Machining Centers, Advanced Machining Concepts and Structures, and Machining Economics



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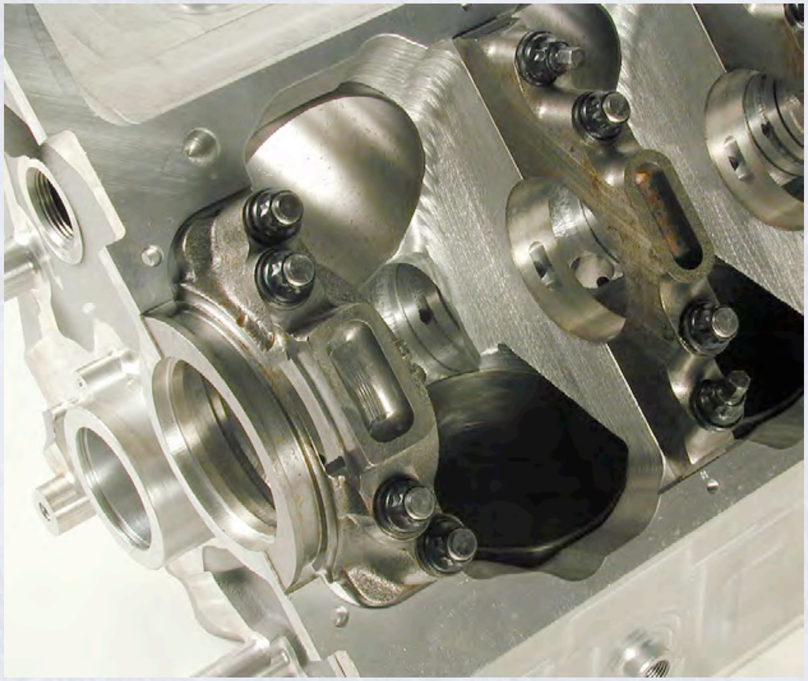
ISBN 0-13-148965-8.

Parts Made on Machining Centers

(a)



(b)

Figure 25.1 Examples of parts that can be machined on machining centers using various processes such as turning, facing, milling, drilling, boring, reaming, and threading. Such parts ordinarily would require the use of a variety of machining tools to complete. *Source*: Courtesy of Toyoda Machinery.

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Horizontal-Spindle Machining Center

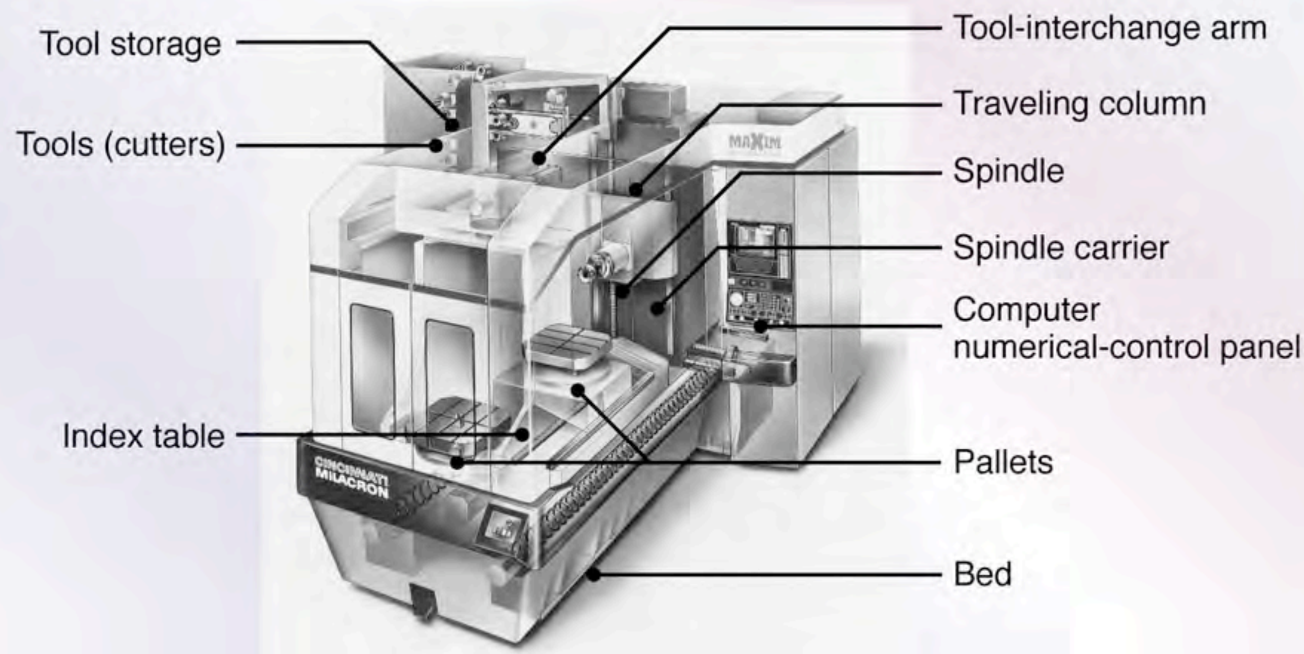

Figure 25.2 A horizontal-spindle machining center equipped with an automatic tool changer. Tool magazines can store up to 200 cutting tools of various functions and sizes. *Source*: Courtesy of Cincinnati Milacron, Inc.

The Principle of a Five-Axis Machining Center

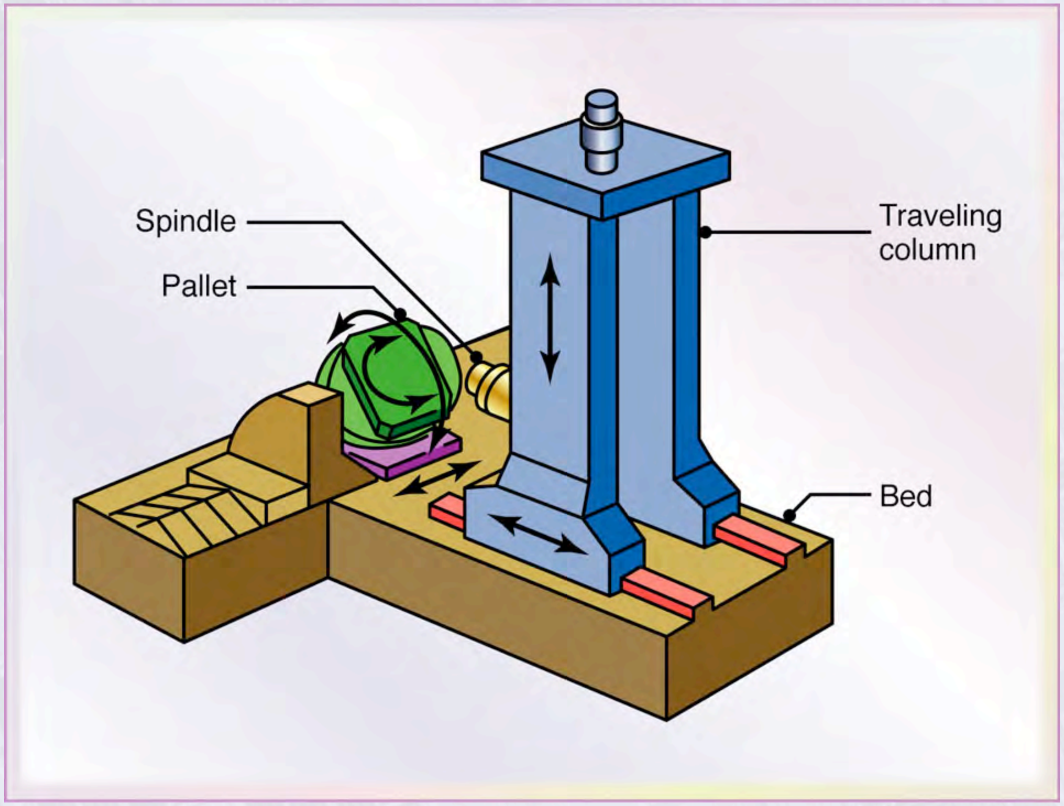

Figure 25.3 Schematic illustration of the principle of a five-axis machining center. Note that in addition to the linear movements (three axis), the pallet, which supports the workpiece, can be swiveled around two axe (hence a total of five axis), allowing the machining of complex shapes, such as those shown in Fig. 25.1. *Source:* Courtesy of Toyoda Machinery.

Machining Centers

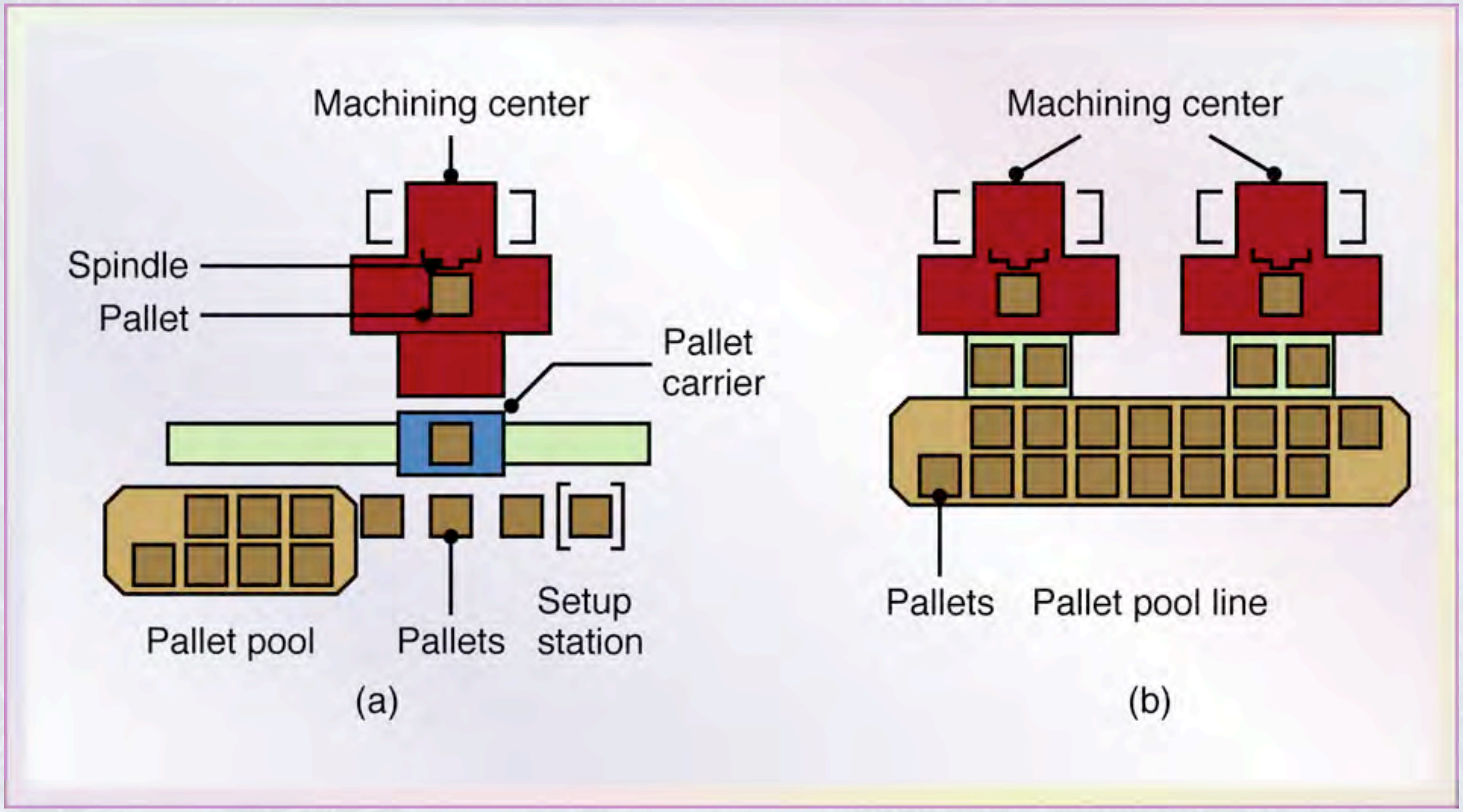

Figure 25.4 (a) Schematic illustration of the top view of a horizontal-spindle machining center showing the pallet pool, set-up station for a pallet, pallet carrier, and an active pallet in operation (shown directly below the spindle of the machine). (b) Schematic illustration of two machining centers with a common pallet pool. Various other pallet arrangements are possible in such systems. *Source:* Courtesy of Hitachi Seiki Co., Ltd.

Swing-Around Tool Changer on Horizontal-Machining Center

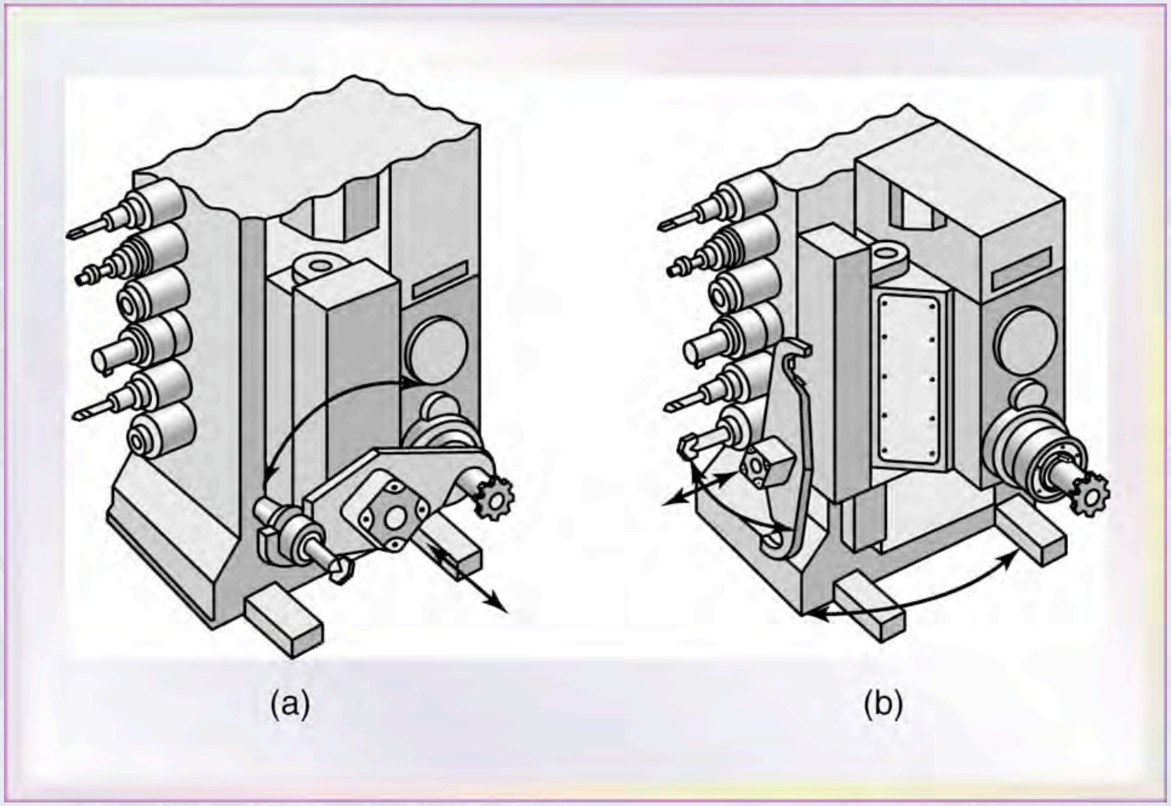

Figure 25.5 Swing-around tool changer on a horizontal machining center. (a) The tool-exchange arm is placing a toolholder with a cutting tool into the machine spindle. Note the axial and rotational movement of the arm. (b) The arm is returning to its home position. Note its rotation along a vertical axis after placing the tool and the two degrees of freedom in its home position.

Touch Probes used in Machining Centers

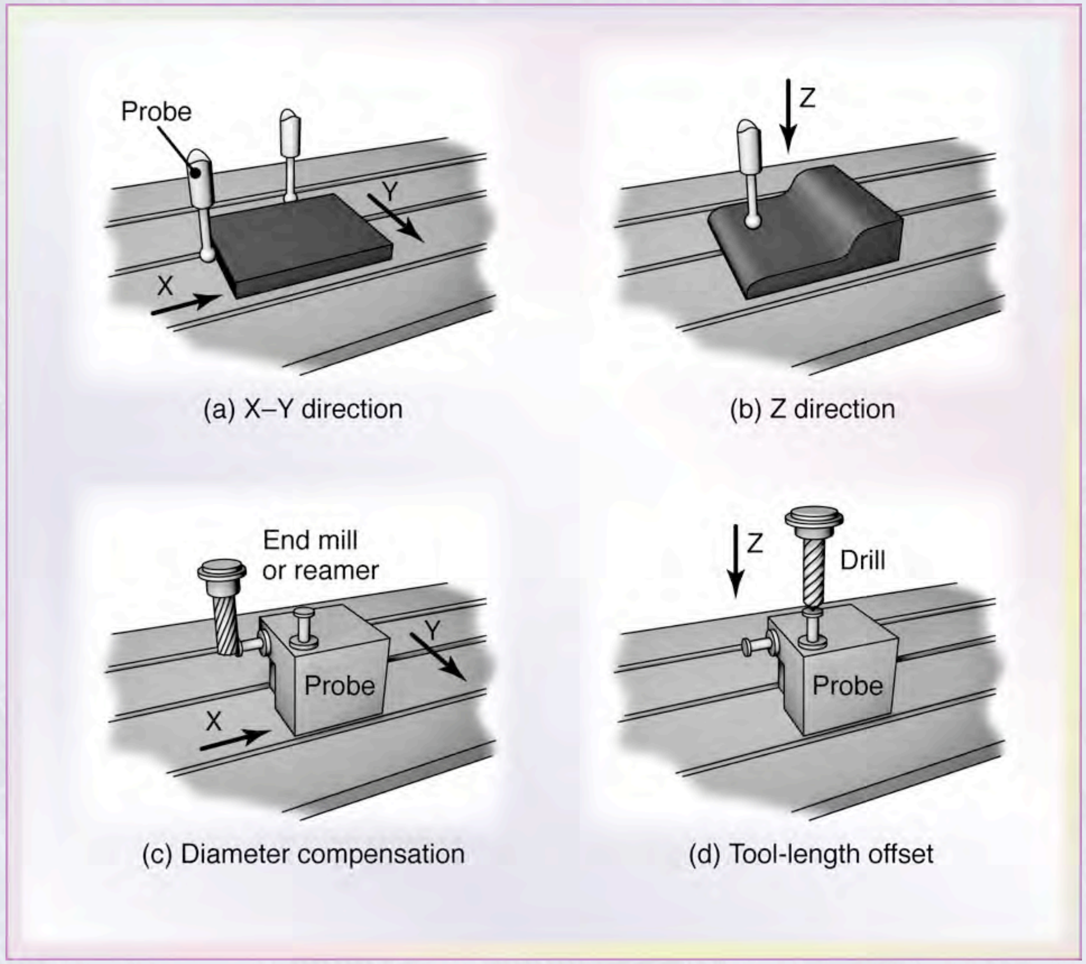

Figure 25.6 Touch probes used in machining centers for determining workpiece and tool positions and surfaces relative to the machine table or column. Touch probe (a) determining the X-Y (horizontal) position of a workpiece, (b) determining the height of a horizontal surface, (c) determining the planar position of a surface of a cutter (for instance, for cutter-diameter compensation), and (d) determining the length of a tool for tool-length offset. *Source*: Courtesy of Hitachi Seiki Co., Ltd.

Vertical-Spindle Machining Center

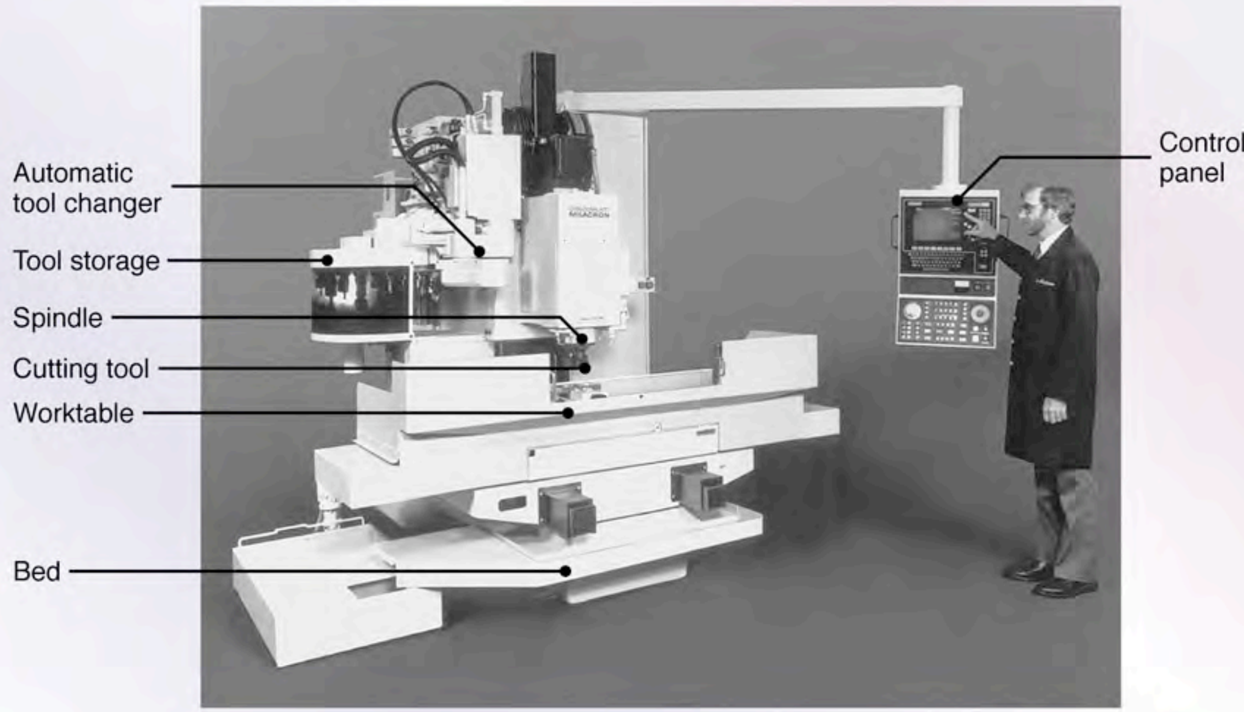

Figure 25.7 A vertical-spindle machining center. The tool magazine is on the left of the machine. The control panel on the right can be swiveled by the operator. *Source:* Courtesy of Cincinnati Milacron, Inc.

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Computer Numerical-Controlled Turning Center

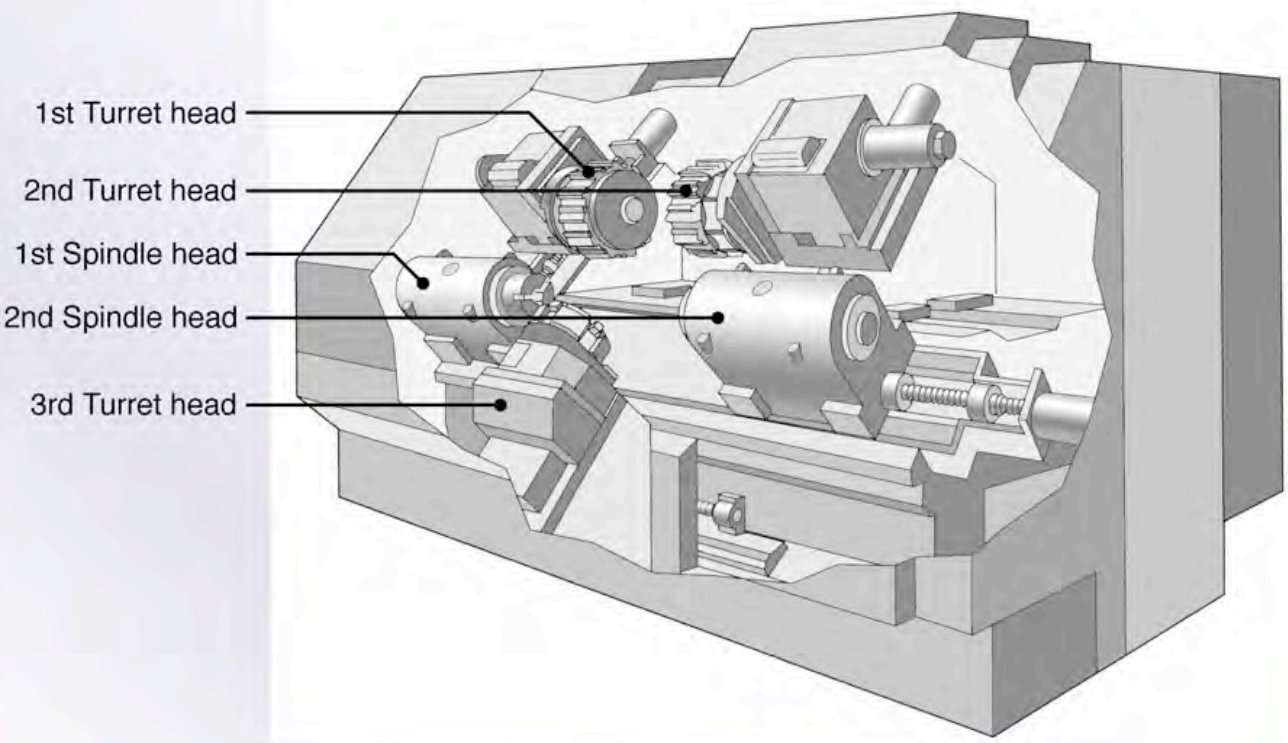

Figure 25.8 Schematic illustration of a computer numerical-controlled turning center. Note that the machine has two spindle heads and three turret heads, making the machine very flexible in its machining capacities. *Source*: Courtesy of Hitachi Seiki Co., Ltd.

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Machining of Outer Bearing Races

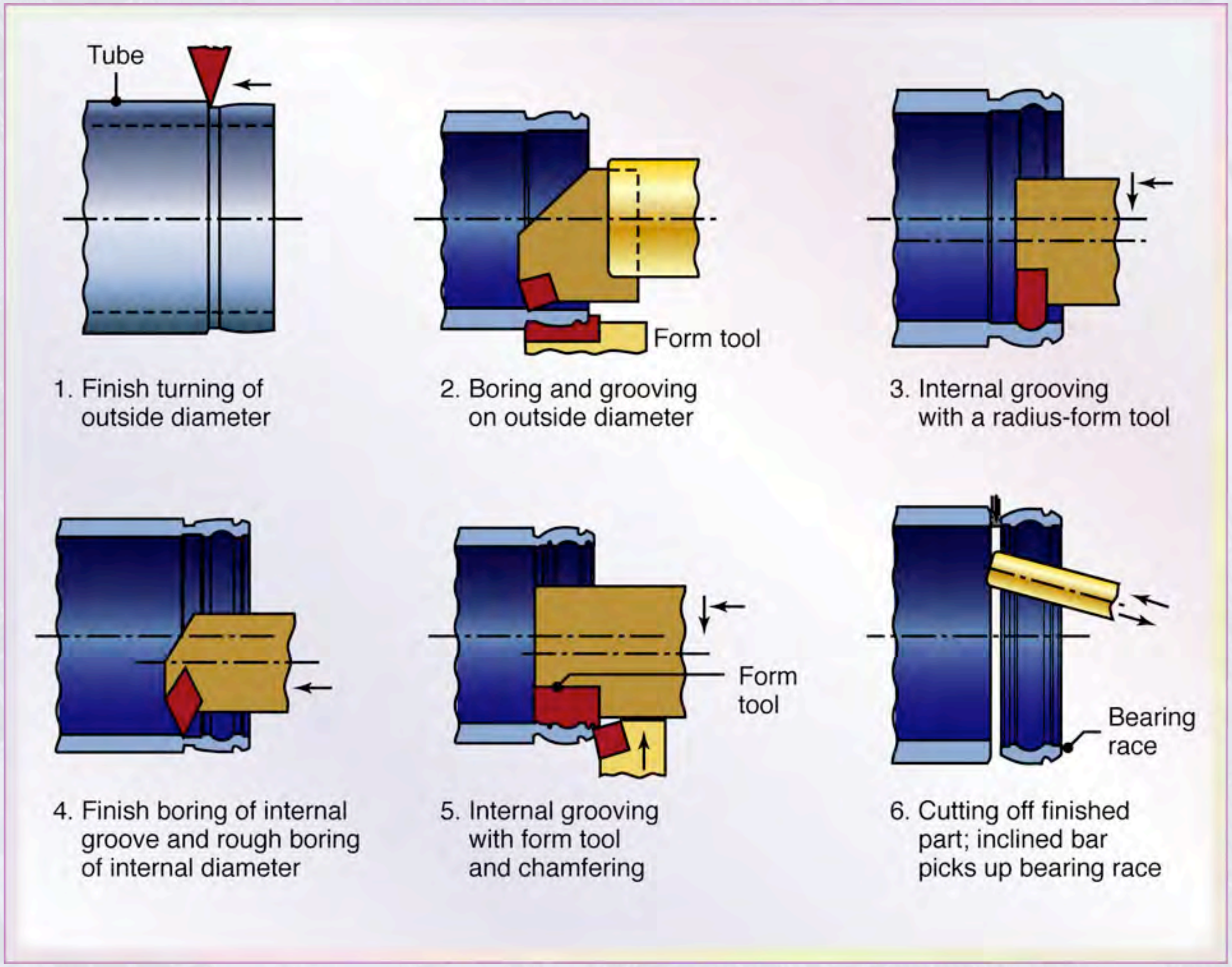

Figure 25.9 Machining of outer bearing races.

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Reconfigurable Modular Machining Center

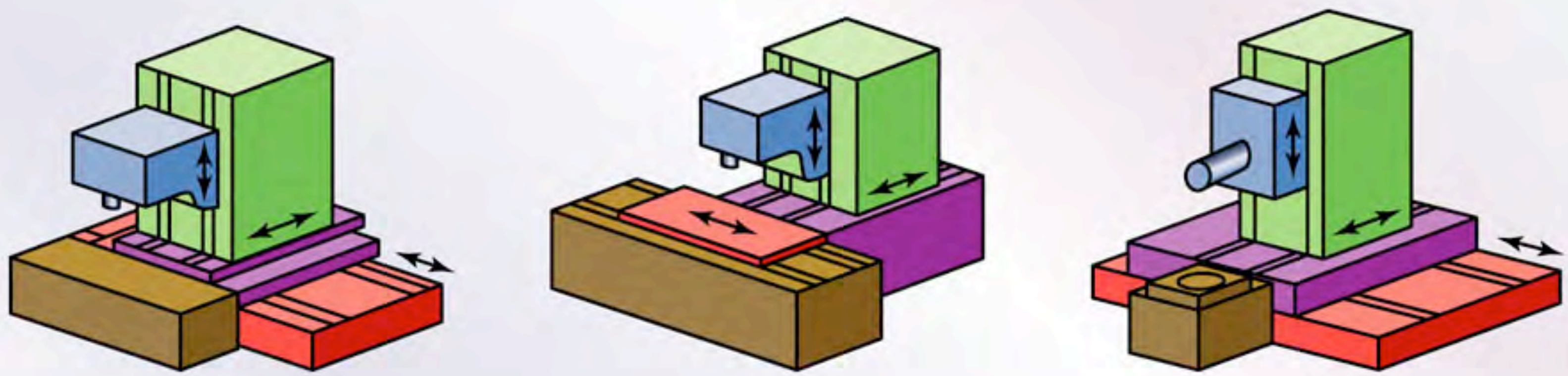

Figure 25.10 Schematic illustration of a reconfigurable modular machining center capable of accommodating workpieces of different shapes and sizes and requiring different machining operations on their various surfaces. *Source:* After Y. Koren.

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Assembly of Reconfigurable Machining Center

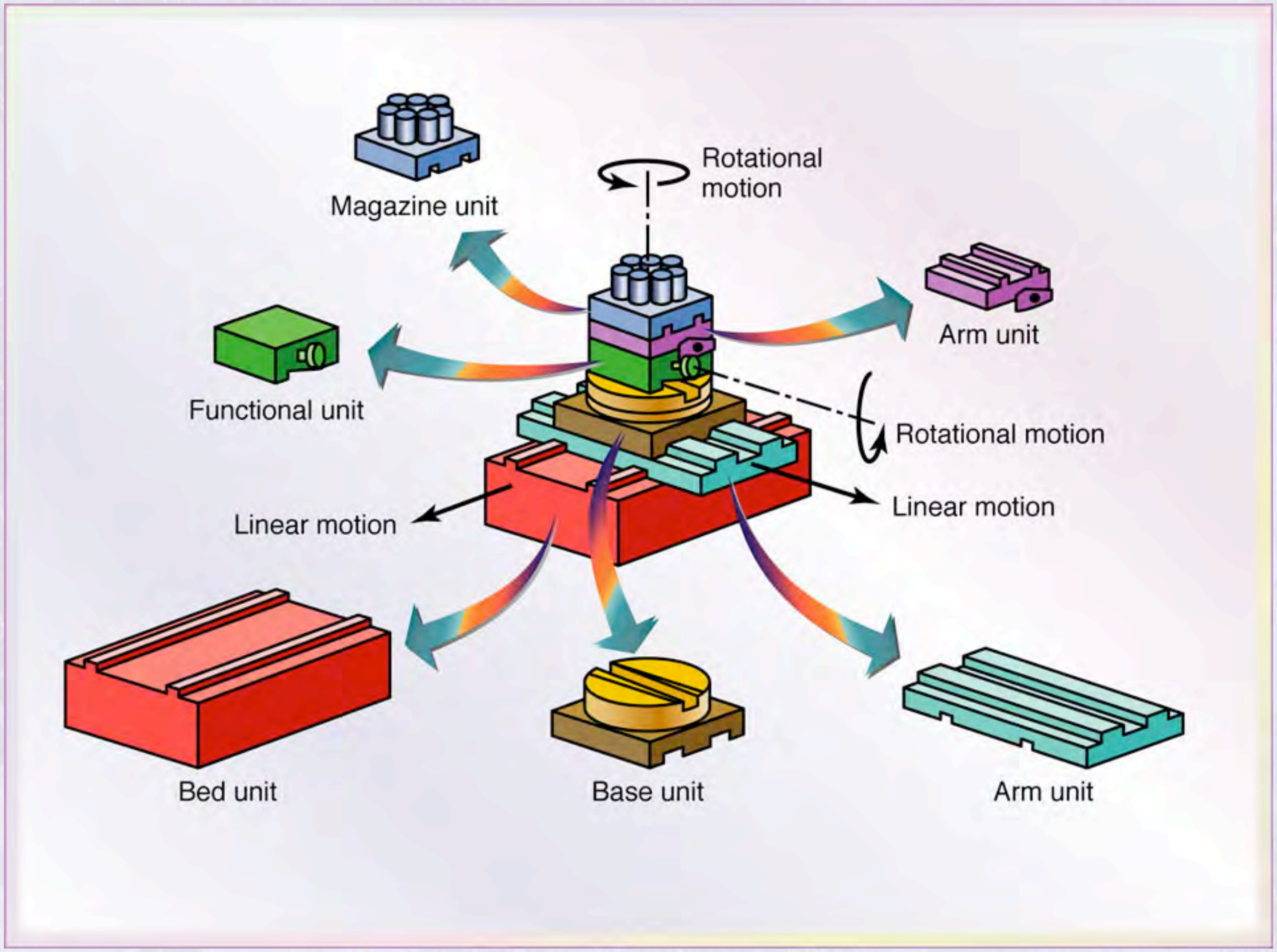
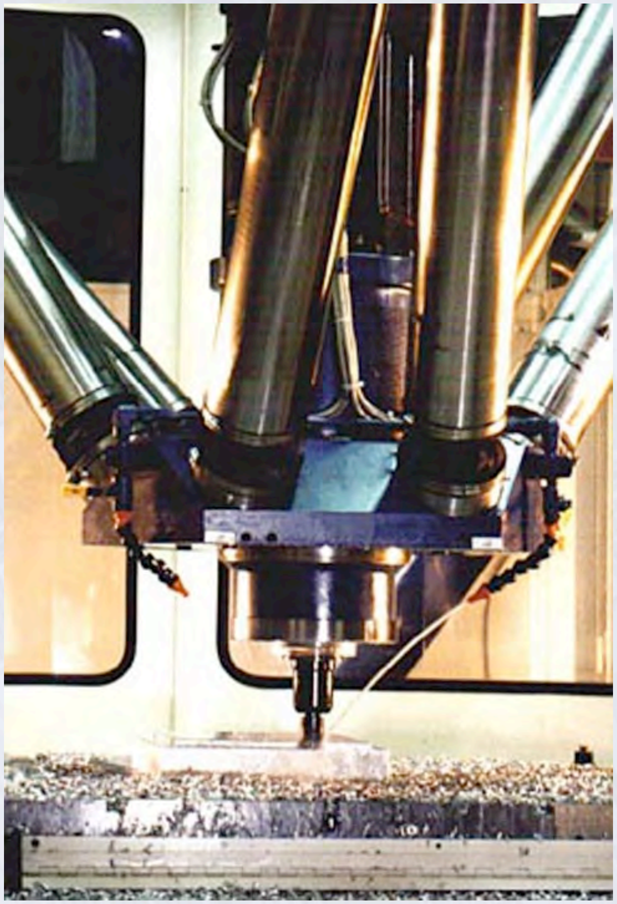


Figure 25.11 Schematic illustration of the assembly of different components of a reconfigurable machining center. *Source:* After Y. Koren.

Hexapod Machining Center

(a)



(b)

Figure 25.12 (a) A hexapod machine tool, showing its major components. (b) A detailed view of the cutting tool in a hexapod machining center. *Source*: Courtesy of National Institute of Standards and Technology

Chatter Marks on Surface of Turned Part

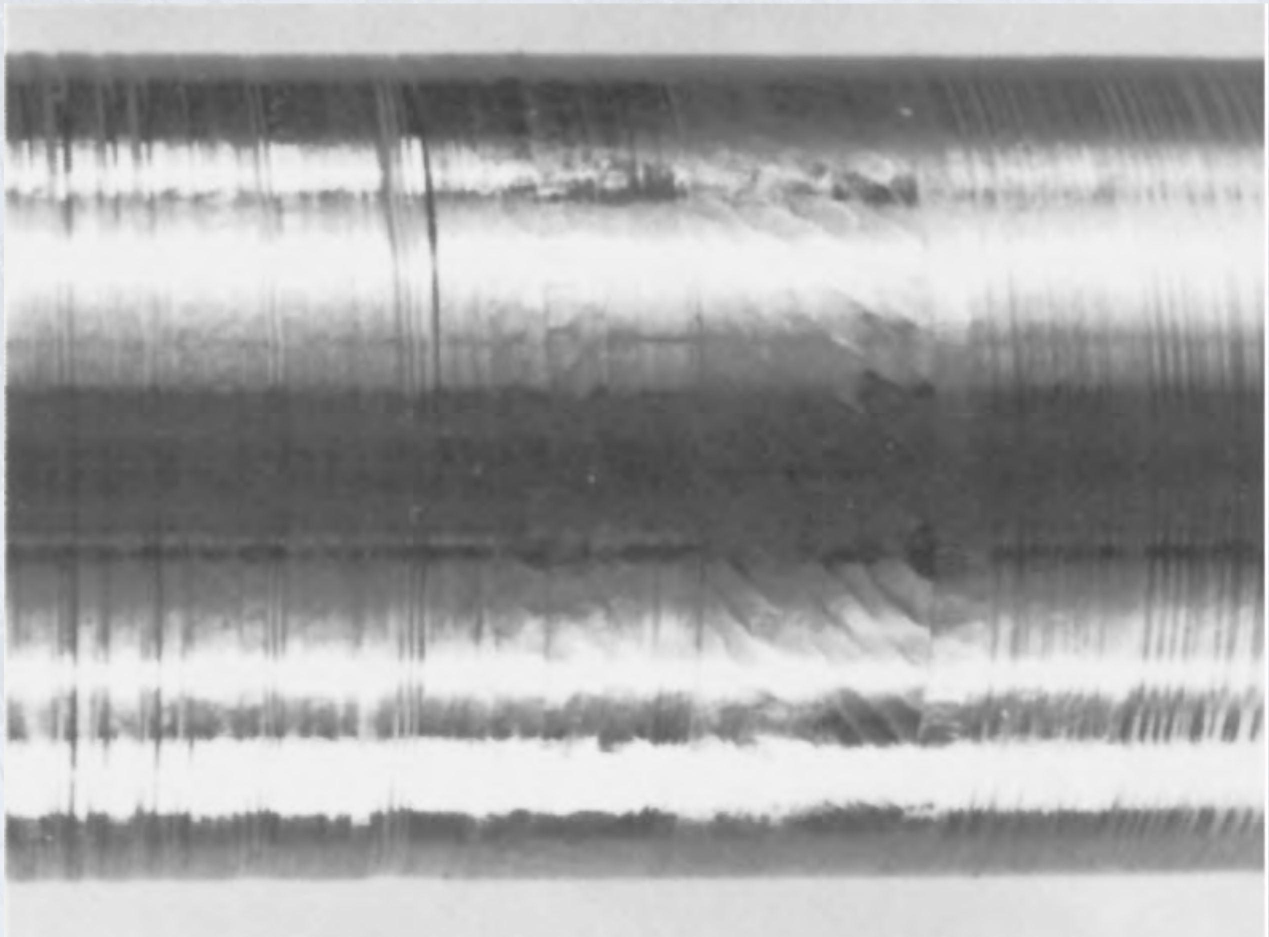


Figure 25.13 Chatter marks (right of center of photograph) on surface of a turned part. *Source*: Courtesy of General Electric Company.

Relative Damping Capacity

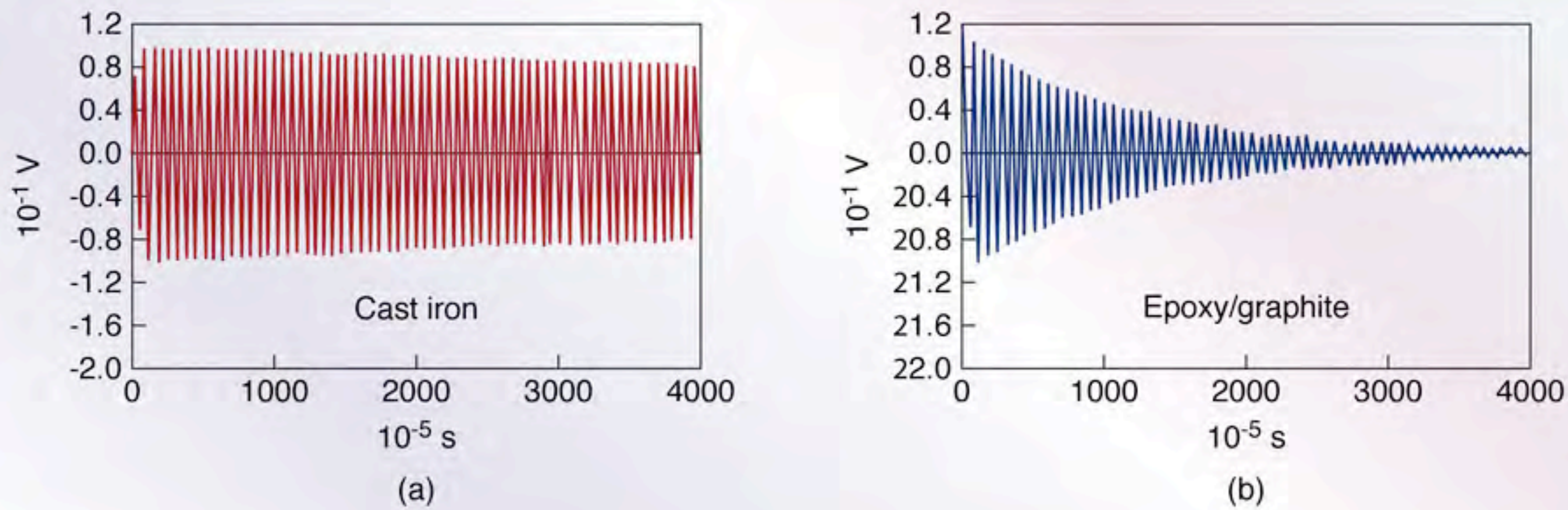


Figure 25.14 The relative damping capacity of (a) gray cast iron and (b) an epoxy-granite composite material. The vertical scale is the amplitude of vibration and the horizontal scale is time.

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Damping of Vibrations as a Function of the Number of Lathe Components

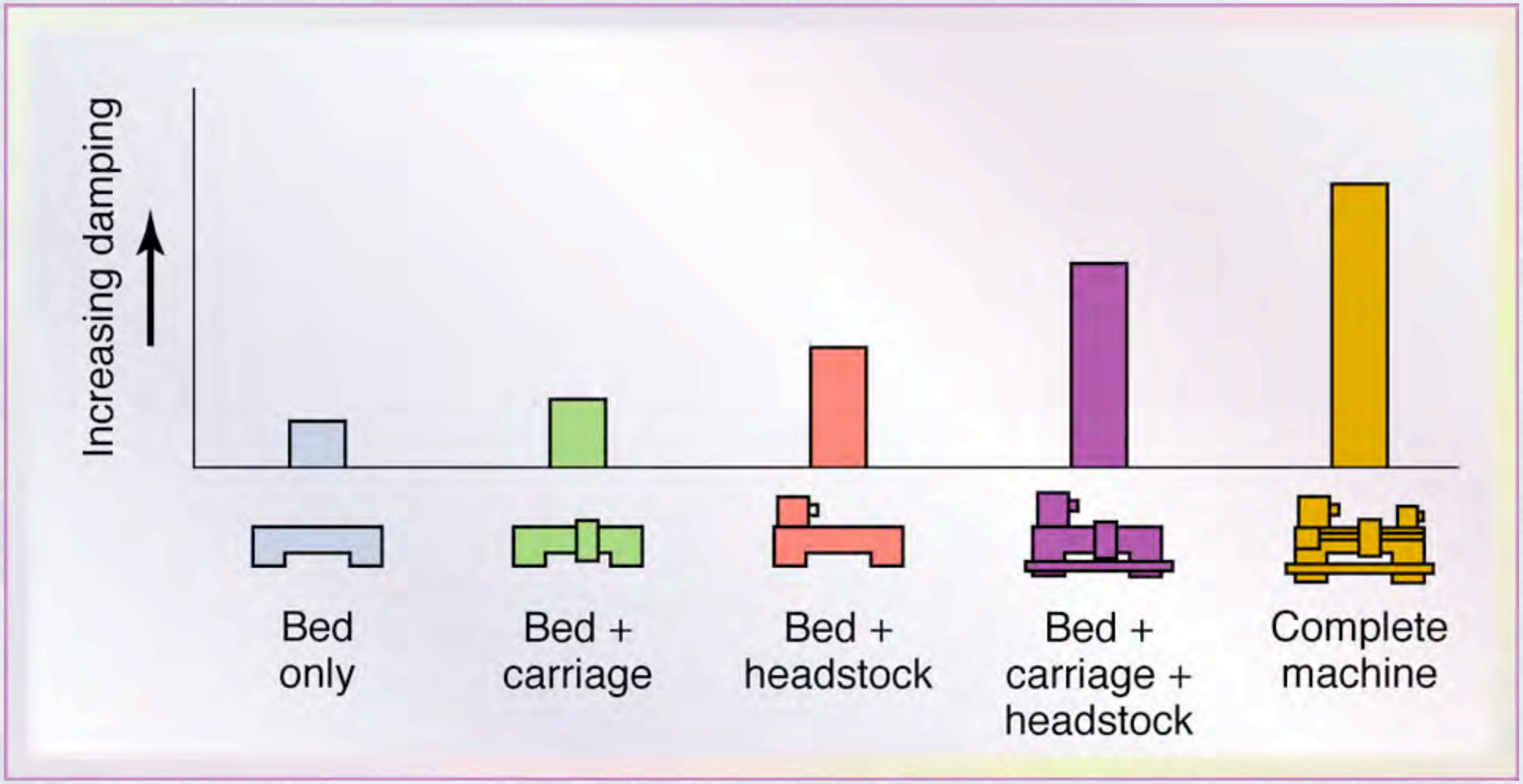

Figure 25.15 The damping of vibrations as a function of the number of components on a lathe. Joints dissipate energy; the greater the number of joints, the higher the damping capacity of the machine. *Source:* After J. Peters.

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Example: Red-Crescent Machining Conditions

TABLE 25.1

Comparison of Conventional versus Red-Crescent Machining Conditions

Parameter	Conventional	Red crescent
Surface speed (ft/min)	250	5000
Spindle speed (rpm)	160	3200
Feed (in./rev)	0.020	0.005
Number of inserts	10	5
Radial thrust force (lb)	4300	262
Metal-removal rate (in^3/min)	43	80

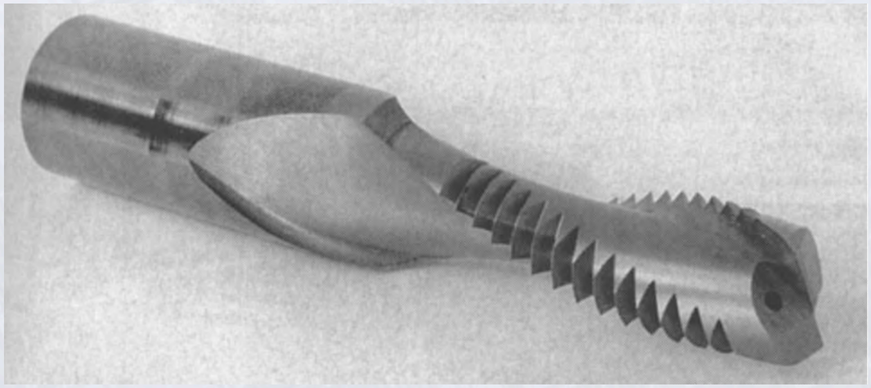

Figure 25.16 A high-speed tool for single-point milling, chamfering, counterboring and threading of holes. *Source:* Courtesy of Makino, Inc.

Machining Accuracy Improvements using Ultraprecision Machining Technologies

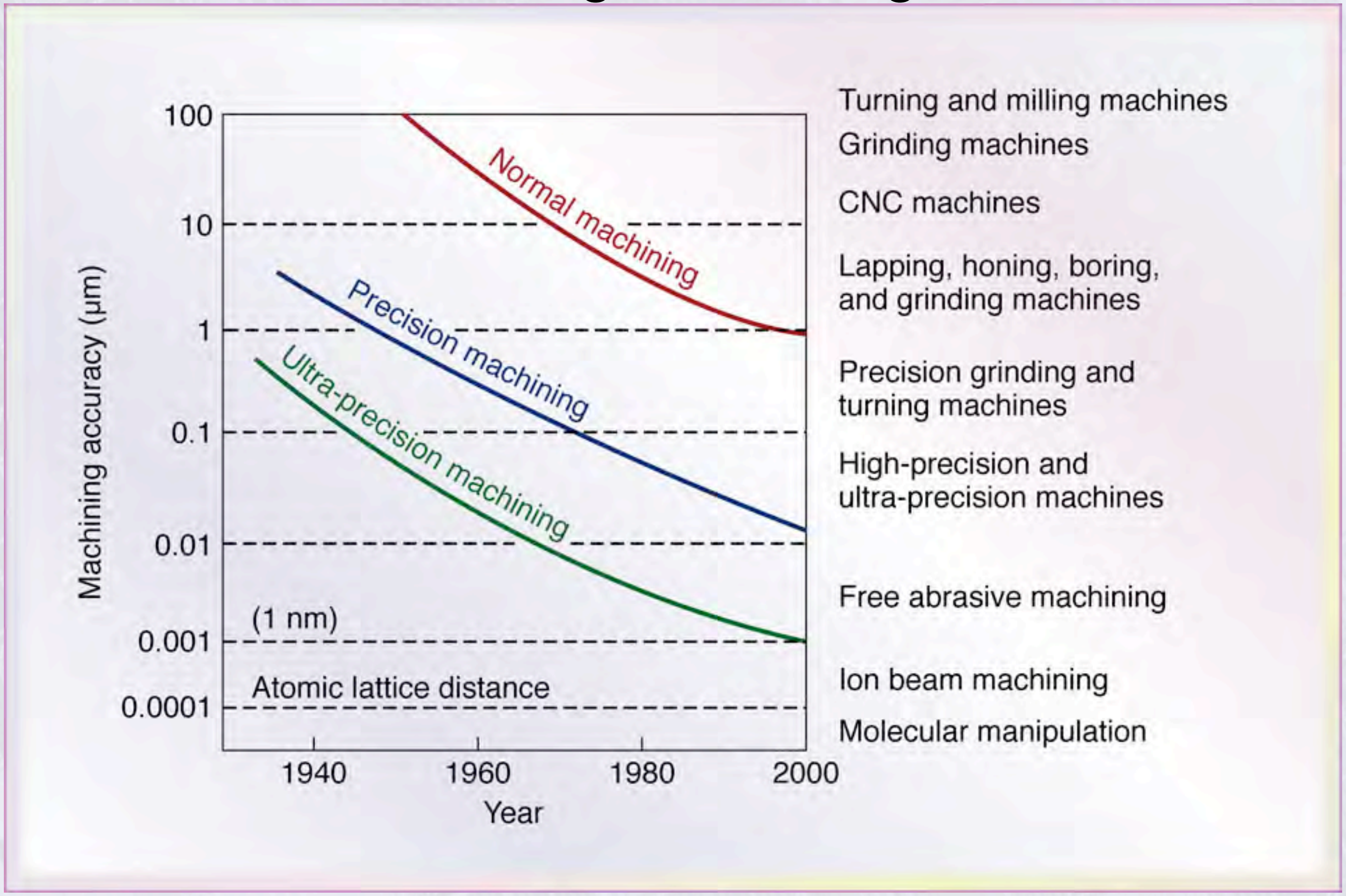

Figure 25.17 Improvements in machining accuracy over the years using ultraprecision machining technologies. *Source:* After C.J. McKeown, N. Taniguchi, G. Byrne, D. Dornfield, and B. Denkena.

Machining Economics

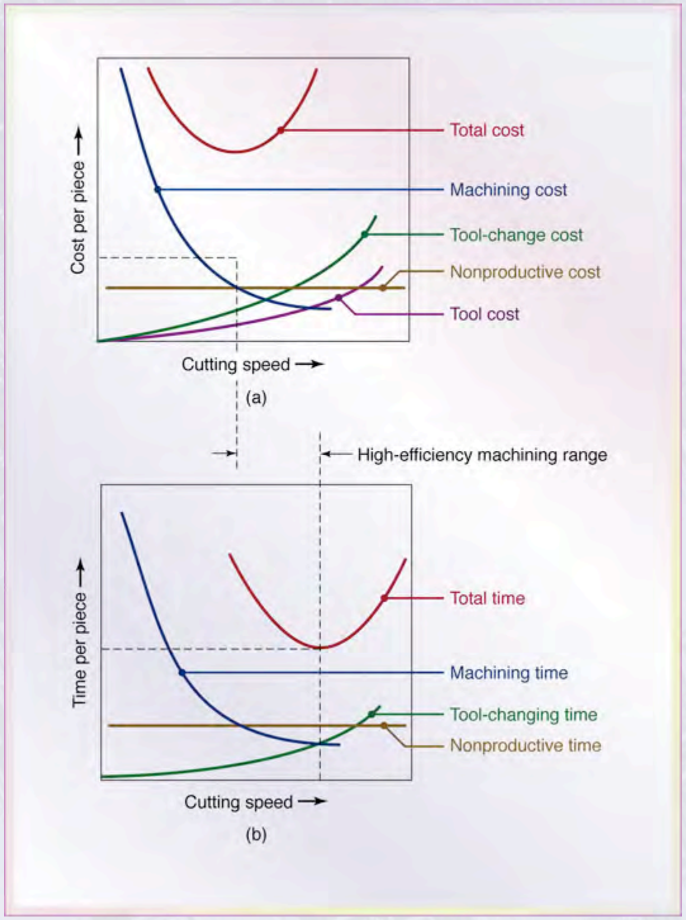

Figure 25.18 Graphs showing (a) cost-per-piece and (b) time-per-piece in machining. Note the optimum speed for both cost and time. The range between the two is known as the high-efficiency machining range.

Minimum Cost :

$$V_o = \frac{C(L_m + B_m)^n}{\left\{\left[\frac{1}{n} - 1\right]\left[T_c(L_m + B_m) + T_g(L_g + B_g) + D_c\right]\right\}^n}$$

Maximum Production :

$$V_o = \frac{C}{\left\{\left[\frac{1}{n} - 1\right]T_c\right\}^n}$$

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