

Chapter 2

Manufacturing Processes and Systems

2.1 An Overview of Discrete Manufacturing Processes

A large number of manufacturing equipment exist for the implementation of basic discrete manufacturing processes into production machinery. Kalpakjian and Schmid (2003) provide a list of discrete manufacturing processes available under different categories of manufacturing, which are used in actual production. These major categories are

1. Metal forming processes
2. Bulk deformation processes
3. Sheet Metal forming processes
4. Metal removal processes
5. Metal joining processes
6. Processing of Polymers and reinforced plastics
7. Processing of Metal Powders, Ceramics, Glasses, Composites and Super Conductors
8. Thermal Treatment of materials
9. Surface Treatment of materials
10. Fabrication of Micro-mechanical and Microelectronic Devices
11. Nonconventional processes

The equipment used under each category of discrete manufacturing is further classified according to¹:

1. Type of manufacturing equipments that are discrete products capable of manufacturing components, assemblies, structure, mechanism and machine (Kalpakjian and Schmid 2003)
2. Size

¹ Extracted with permission from Khan WA, Raouf A (2006) Standards for engineering design and manufacturing, Taylor & Francis/CRC, USA.

3. Accessories
4. Operation parameters, and
5. Type of control

Each manufacturing process for implementation into mechanical artifacts has three distinct features:

1. The inputs to the equipment: raw material type, form, and feeding mechanism; final dimension of the product; energy source; and other auxiliaries.
2. The process implementation allowing transformation of raw material into required size, shape, and surface finish using tools (e.g., tools as used in metal cutting, high-energy beams, or various types of jets); utilizing tool- and work-holding devices; measuring devices and manufacturing instructions. In process supplies such as lubricating oil and coolants may also be used.
3. The output from the equipment comprising a component (the building block of structure, mechanisms or machines); and scrap.

There may be several features present at the production machinery to make the task of manufacturing simpler, easy to control and result in high production rate.

The design of manufacturing equipment relies on a systematic approach to design and considers a few or all of the following special design requirements.

1. Structural consideration for machine frame and assemblies;
2. Thermal effects on the equipment;
3. Noise emission from the equipment;
4. Vibration in the machinery;
5. Environmental effects on the equipment;
6. Geometric and kinematics behaviors of the manufacturing equipment;
7. Static and dynamic behaviors of the equipment;
8. Availability of Computer Numerical Control (CNC) or process control using Programmable Logic Controllers (PLC);
9. Electronic circuitry for implementing control features;
10. Foundation and Installation requirements

Like any other discrete product, the manufacturing equipment commonly utilizes standard mechanical components, machine elements, control elements, electrical and electronic components, and software components.

Special assemblies and other accessories utilized at the construction of manufacturing equipment may also include

1. Tool—Referring to mechanical tool, beams, jets, etc.);
2. Tool-holding devices;
3. Work-holding devices;
4. Lubricating oil pump assembly;
5. Coolant circulation pump assembly;
6. Material handling equipment; and
7. Scrap handling equipment

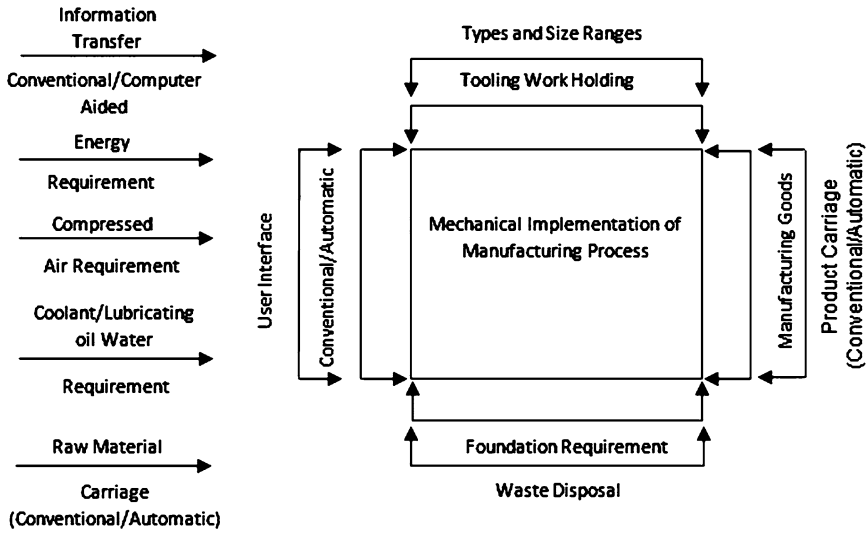


Fig. 2.1 Manufacturing process implementation into equipment

A schematic detail implementation of the manufacturing process into production equipment is presented in Fig. 2.1.²

At present, special consideration is given to the automation, as the use of Computer Numerical Controls and Programmable Logic Controllers have taken firm roots.

2.2 Discrete Manufacturing Systems³

A manufacturing system comprises manufacturing equipment arranged in certain fashion. Tangibly, these manufacturing systems have a physical layout while intangible production control operates on production philosophies. Other important elements of the manufacturing systems are methods of information, energy, and material transfer. The physical layout of the discrete manufacturing systems is normally divided into two areas:

1. Processing area;
2. Assembly area

² Extracted with permission from Khan WA, Raouf A (2006) Standards for engineering design and manufacturing, Taylor & Francis/CRC, USA.

³ Extracted with kind permission of Springer Science + Business Media from 'Manufacturing systems—theory and practice' (1992), pp 223–230; and 'Types of manufacturing systems', Chryssolouris G, Figs. 5.2–5.9 and Tables 5.1 and 5.2, ©1992 Springer Verlag; New York, Inc.

The processing area is used for manufacturing the components, while the assembly area is meant for assembling the product.

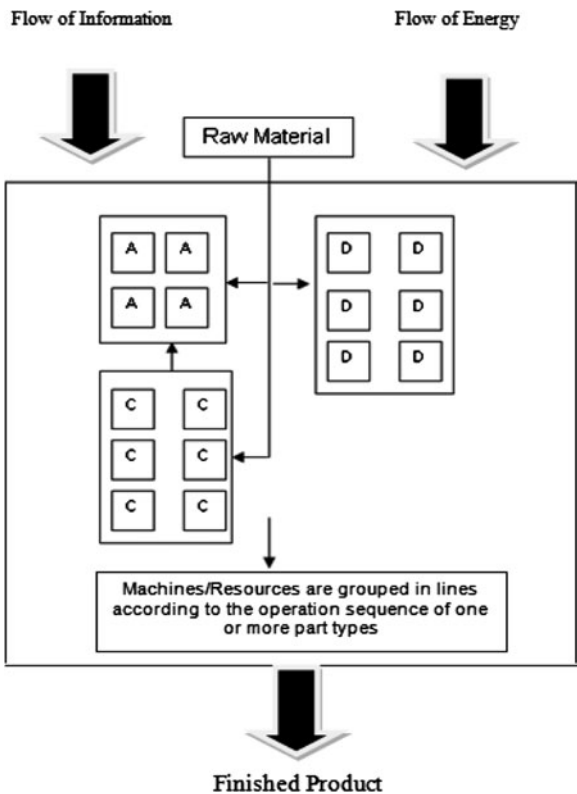
2.2.1 Job Shop

In industrial practice, there are four basic approaches to structuring the processing area for discrete manufacturing [3]: the job shop, project shop, cellular system, and flow line.

In a job shop, Fig. 2.2, machines with the same or similar material processing capabilities are grouped together: the lathes form a turning work center, the milling machines form milling work center, and so forth.

The job shop is characterized by its high flexibility in the production of various types of products while the volume of production in this type of manufacturing system is low—refer to Fig. 2.5.

Fig. 2.2 Schematic of a job shop



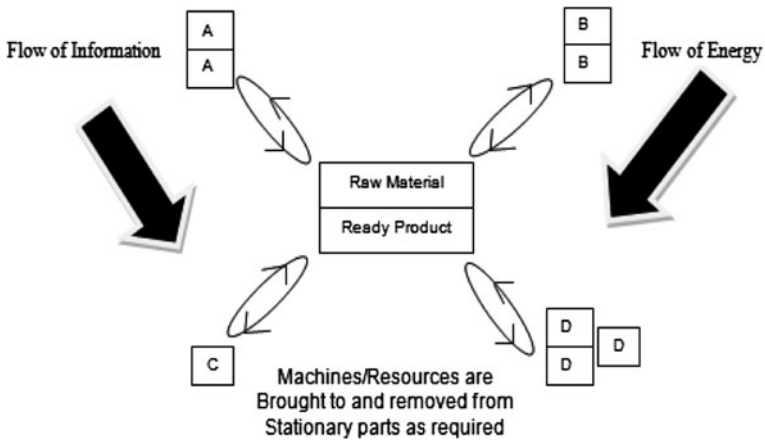


Fig. 2.3 Project shop

2.2.2 Project Shop

In a project shop, a product's position remains fixed during manufacturing because of its size and/or weight. Materials, people, and machines are brought to the product as needed. Facilities organized as project shops can be found in the aircraft and shipbuilding industries and in bridge and building construction. A schematic of project shop is presented in Fig. 2.3 project shop has the lowest lot size production among all type of manufacturing systems.

2.2.3 Cellular Manufacturing

In manufacturing systems organized according to the cellular plan, the equipment or machinery is grouped according to the process combinations that occur in families of parts. Each cell contains machines that can produce a certain family of parts. Figure 2.4 provides arrangement of the equipment in the cellular systems. The cellular manufacturing system is highly automated and flexible. It has low-to-medium lot size production capability.

2.2.4 Flow Line

In flow line, equipments are ordered according to the process sequences of the product to be manufactured. A transfer line consists of a sequence of machines, which are typically dedicated to one particular part or at the most a few very similar parts/products. Only one product is produced at a time (Fig. 2.5).

Fig. 2.4 Schematic of a cellular manufacturing system

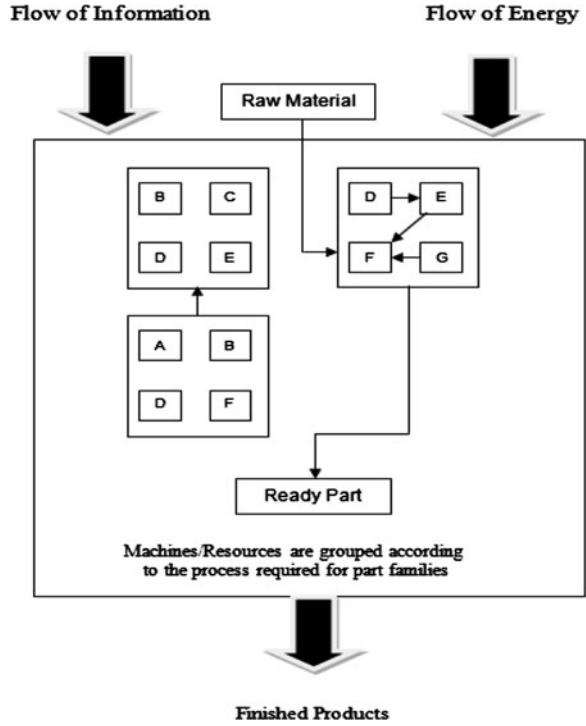
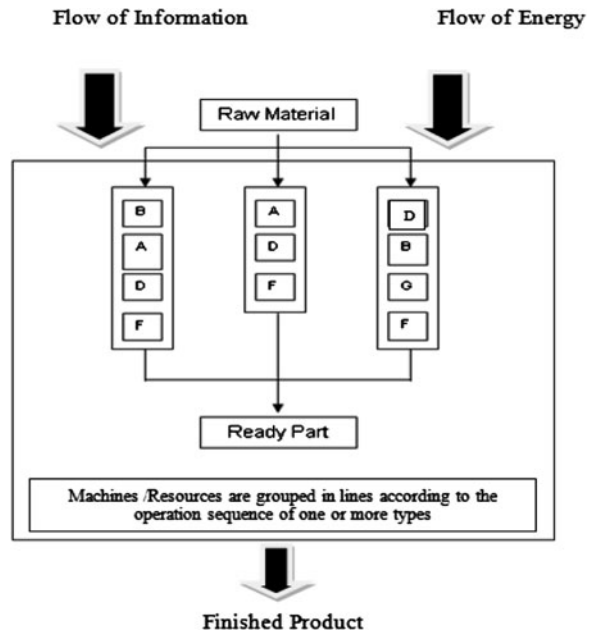


Fig. 2.5 Schematic of a flow line



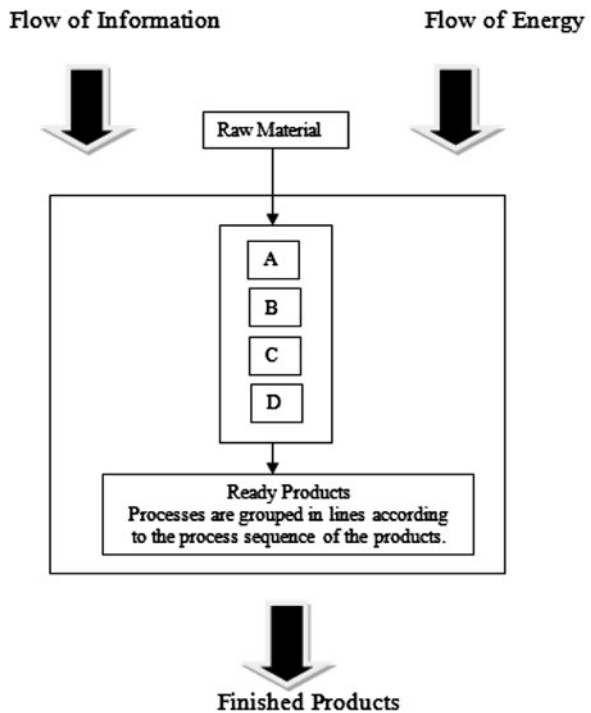
2.2.5 Continuous Manufacturing System

Continuous manufacturing systems produce liquid, gases, or powders. As in flow line, processes are arrayed in the processing sequence of the products. The continuous system is the least flexible of the types of manufacturing systems (Fig. 2.6).

2.2.6 Flexible Manufacturing System

A flexible manufacturing system (FMS) is manufacturing system that comprises the properties of a job shop and a cellular manufacturing system. It has higher flexibility in manufacturing that can produce diverse product ranges as in the case of a job shop, and, can manufacture larger numbers of group of products as in the case in cellular manufacturing. The FMS arranges CNC machines tools through pick and place technology, and conveyors physically such that a group of products can be produced efficiently in small-to-medium batches (Fig. 2.7).

Fig. 2.6 Schematic of a continuous manufacturing system



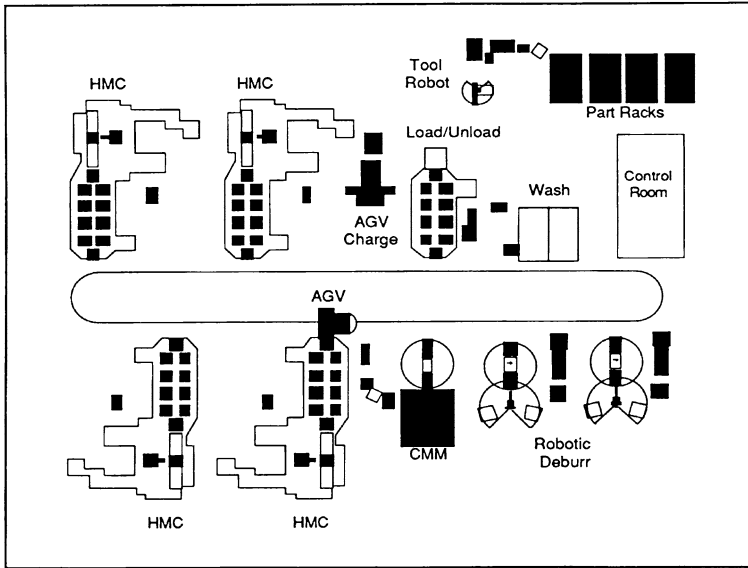


Fig. 2.7 Schematic of a flexible manufacturing system

2.2.7 Assembly System

Another substantial part of a manufacturing company's production facilities is the assembly system. Assembly system can be categorized according to the motion of parts and workplaces. Stationary part systems are usually employed for large assemblies, such as airplanes, which are difficult to be moved around. Moving part systems can be divided into stationary workplace systems, in which parts are brought to stationary workplaces, and moving workplace system, in which the workplaces move along with the parts. Assembly systems with stationary parts tend to have higher floor area requirements. They also tend to have more work at each workplace than moving part systems. Moving part systems are generally more expensive because complicated material handling equipment is required to move parts quickly from workplace to workplace.

In moving part-stationary workplace systems, the assembly operations at each workplace are usually short in duration and are highly repetitive. Moving part-moving workplace systems allow workers to work on each assembly for a longer period of time, making the assembly work less repetitive. The assembly systems are presented in Fig. 2.8. The characteristics of different assembly systems are shown in Table 2.1.

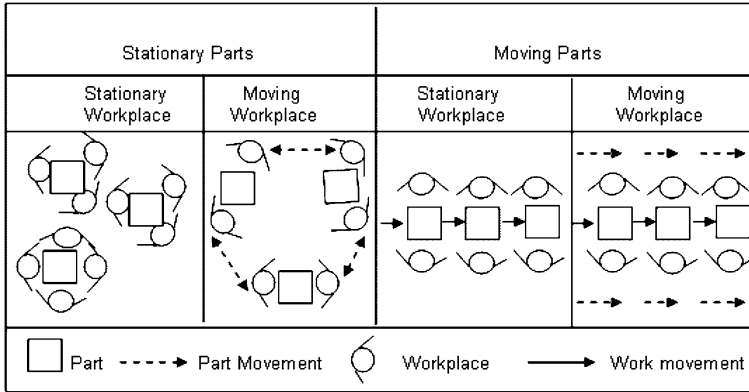


Fig. 2.8 Types of assembly system

Table 2.1 Characteristics of different assembly systems

	Stationary parts		Moving parts	
	Stationary workplace	Moving workplace	Stationary workplace	Moving workplace
Area requirement	High	High	Low	Medium
Work contents at each workplace	High	Medium	Low	Medium
Cost of system	Low	Medium	High	High

In the real-time manufacturing world, these standard manufacturing and assembly system structures often occur in combinations, or with slight changes. The choice of a manufacturing system depends on the design of the parts to be manufactured, the lot sizes of the parts, and market factors such as the required responsiveness. Suitable lot size for each manufacturing system described above is presented in Fig. 2.9.

2.3 Production Planning and Control

Methods and procedures employed in handling materials, parts assemblies, and subassemblies, from their raw or initial stage to the finished product stage in an organized and efficient manner are called production control. It also includes activities such as planning, scheduling, routing dispatching, storage, etc. Production control relies on the experience of the manager to worker level human resources, and algorithms used for efficient control.

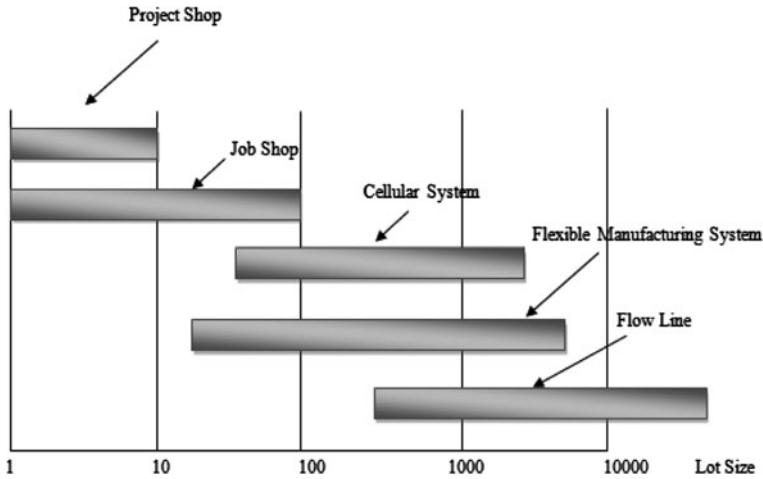


Fig. 2.9 Suitable manufacturing system types as a function of lot size

2.4 Virtual Reality for Manufacturing Systems and Processes

Discrete manufacturing utilizes diverse manufacturing processes and systems for producing wide range of products. It is rare to find similar manufacturing setup for producing same range of products.

Any manufacturing setup implementing Augmented Reality requires that all the production machinery is stored in the form of graphic models, all the decision parameters are stored in forms of variables, and the inference engine is running in a distributed computing environment. The process systems and the inference engine have the interconnectivity among themselves as well as with the vendors and businesses. There should be a mechanism for producing management information system reports so that the manager is capable of taking a simple to an intricate decision. [Section 2.1](#) provides a scope of manufacturing process that may be used in a real Discrete manufacturing system. [Section 2.2](#) details types of manufacturing system that a discrete manufacturing unit may adopt.

2.5 A Survey of the CNC Controller and Their Applications

Computer numerical control controller is used with number of discrete processes. A survey of these controllers is presented to demonstrate the scope of use of AR for CNC-based processes ([Table 2.2](#)).

Table 2.2 A survey of the CNC controllers

No.	CNC control manufacturer	Website, country	Control models	Application
1.	ABA Z&B Schleifmaschinen GmbH	http://www.abazandbusa.com/abamatic1.htm , Germany	(a) ABAMATIC 1	Grinding
2.	Actek, Inc.	http://www.actekinc.com , Seattle, WA, USA	FLEXcnc2-3 Axis PScnc-PMTI	Milling and boring machine Engine lathe conversion Abrasive water jet control table Definite purpose router Fabrication shop punch Profiling router floor mill retrofit Precision lathe retrofit Fabrication shop punch retrofit Vertical turning center Filament winding machine Automatic overhead cranes Press and punch feeders Portable flam-cutting machine Vertical knee mill
3.	Acu-rite	http://www.acu-rite.com/view/millpwr-control-systems.aspx , Schaumburg	MILLPWR	Miscellaneous
4.	Aerotech	http://www.aerotech.com/products/controllers/motion_controllers.html , USA	A3200 ESSEMBLE SOLOIST	Miscellaneous
5.	AjaxCNC	http://www.ajaxcnc.com/ , Howard, PA	Mill kit Lathe kit	Mill/lathe simultaneous motion for up to 4-axis machines
6.	Allen-Bradley	http://www.ab.com/	9 SERIES CNC GRINDER	Grinding
7.	AMK	http://en.amk.antriebe.de , Germany	Modular CNC controllers; CNC 900 Compact CNC controllers; CNC 905 and 903,902	High-quality and individual controllers for multi-axle and multi-machine applications with convenient handling The economical and efficient solution for simpler applications for controlling up to four axles

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
8.	Anilam	http://www.anilam.com , North America	3000 COMMANDO 3000 M 4200 T 5000 M 6000I MACH 3 CNC Upto 6-AXIS CNC CONTROLLER	Boring Milling Turning Milling Milling Lathes Mills Routers Lasers Plasma Engravers Gear cutting Miscellaneous Miscellaneous
9.	ArtSoft Mach3	http://www.machsupport.com , Fayette, ME, USA		
10.	Asia Automation Pvt Ltd	http://www.asiaautomation.com/multi-axis-cnc.htm , India	SINGLE AXIS CNC CONTROLLER MULTI AXIS CNC CONTROLLER PC based CNC CONTROLLERS	
11.	Bevel Cutting	http://www.bevelcutting.com	USB CNC UPI-SERIES USB CNC UP2-SERIES USB CNC UP3-SERIES CNC-P00 series	plasma and oxyfuel metal sheet cutting For machine's having Multi head cutting technologies installed like plasma, oxy-fuel, water-jet cutting, plasma marking, bevel cutting with triple torch or one torch bevel rotators Turning, milling, drilling Turning, milling, grinding, drilling, punching nibbling, shape cutting, reforming
12.	Bosch Rexroth Corporation	http://www.boschrexroth.com/dcc/Vornavigation/Vornavi.cfm?Language=EN&VHisi=g97568&PageID=g96072 , Hoffman Estates, IL	4 SERVO-AXIS 8 SERVO-AXIS, CONTROLLER BASED 8 SERVO-AXIS, PC BASED 64 SERVO-AXIS	

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
13.	Brothers	http://www.brother.com , Mizuho-ku, Nagoya	CNC-B00 CONTROL CNC-A00	Tapping centre Tapping centre
14.	Burny	http://www.burny.com/Cleveland, OH, USA	PC BASED CNC CONTROLS Burny XL Burny 10 LCD Plus Burny Phantom Burny Phantom ST NON-PC BASED CNC CONTROLS Burny 2.5 Plus Burny 2.8 Plus Burny 1250 Plus Burny 1400 Plus	Oxyfuel, plasma, laser, water jet, routers, punches, drills, knives, and markers
15.	Bystronic	http://www.bystronic.com , Hauppauge, NY	BY VISION CNC CONTROL	Laserjet cutting, water cutting, bending
16.	CamSoft Corporation	http://www.cncontrols.com , Lake Elsinore, CA	MS-1500 CNC CONTROL CAMSOFT TOUCH SCREEN WITH SOFTWARE CNC- PROFESSIONAL OR CNC-LITE, CNC-PLUS	Pick and place, robots, welders, grinders, vision, camera systems, wire and sinker EDM, XYZ positioning tables, automatic height control, press brake, shear, bending, circuit board cutting, cut to length profilers, polishers, dispensing-glue, paint, epoxy, precious metals, cut of saws, stone saws, stone cavers, drilling machines, assembly automation, CNC mill, CNC router, CNC lathe, CNC laser, CNC plasma, CNC grinder, CNC EDM and CNC punch presses
17.	Centroid	http://www.centroidcnc.com/ , Howard, PA	M400, M-39 T400	Milling Lathe

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
18.	Chengdu Great Industrial Co. Ltd	http://www.great-cnc.com/index.html , China	GREAT-150iT/Ita GREAT-66T1 GREAT-150ITJ GREAT-150iM/iMA CB-II AUTOFORM-AF AUTOFORM-AS FORM MASTER-FM FORM MASTER-FM II	Turning Lathe Lathe Milling
19.	Cincinnati Incorporated	http://www.e-ci.com/what_new.php#s , Harrison, OH	Deals in BURNY MACHINE CONTROLS	See no. 13 above
20.	Cleveland Motion Controls (CMC)	http://www.cncontrols.com , Cleveland, OH, USA	System M3X/M4X CNC Control	Milling
21.	CNC Automation, Inc.	http://www.cncauto.com , NH, USA	CNC WireCut EDM Controller (X, Y, Z, U, V, 5 axis)	EDM
22.	C-TEK Technologies Corp.	http://www.ctek.com.tw/EN/p06.htm , Taiwan	ZNC EDM Controller (50A, 75A, 100A)	
23.	DACC	http://www.dacc.com/lynx.htm	DACC PICOPATH CNC CONTROL LYNX ProMotion 2000 ProMotion 2000 NT	For all cutting machines, includes oxy-fuel interface, plasma interface and motorized torch lifter control
24.	DMG	http://www.deckel.com/en/controls,dmg-ergoline-control , Germany	DMGERGOLINE® Control with HEIDENHAIN With Fanuc With Siemens	Milling with iTNC 530 Milling with MillPlus iT V600 Turning with Heidenhain Plus iT Turning with Fanuc 3x0i Milling with Fanuc 3x0i Milling with 840D solutionline Turning with 840D solutionline

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
25.	DELECTRON	http://www.delectron.it , Italy	CNC Z32 Z—Star Series/Z32 CNC FZ Series	For milling machines, machining centres, lathes, laser cutting, plasma cutting, special machines
26.	Denford Education and training machines with control and programming software	http://www.denford.com/ , UK	COMPACT 1000/COMPACT 1000 PRO ROUTER 2600/ROUTER 2600 PRO VERTICAL ROUTER PCB ENGRAVER VMC 1300 MICRO MILL TURN 270 MICRO TURN CONTROL SOFTWARE VR CNC MILLING 5 VR CNC TURNING Advantage 900 Advantage 400	CNC routers Engraving Milling Milling Turning Turning
27.	Delta Tau Data Systems, Inc.	http://www.deltatau.com/common/products/cnc.asp?node=id600&connectionStr=release , Chatsworth, CA, USA		Miscellaneous
28.	Diaform	http://www.pgtechnology.co.uk/cnc_diaform.htm , UK	DIA FORM CNC	Profile dressing for CNC controlled grinding machines for both surface and cylindrical grinders
29.	Direct Motion	http://www.directmotion.com , Ontario, CA	Direct Motion CNC 5.0 (PC-based controller)	Milling/lathe
30.	DYNA Mechnronics	http://www.dynamechtronics.com/product.html , San Jose, CA	DYNA 64-Bit Pentium® CONTROL SYSTEM	2-5 axis PC based control for milling and turning
31.	DynaPath Systems, Inc.	http://www.dynapath.com/page_controls.htm , Livonia, MI	Delta 2000M Delta 2000T Delta 2000P	Milling Turning CNC punch
32.	Dynomotion	http://dynomotion.com/Calabasas , CA	K MOTION CNC (PC based)	2-5 axis CNC controller

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
33.	ECKELMANN	http://www2.eckelmann.de , Wiesbaden, Germany	CNC Classic: E-CNC 55 PC-based CNC: E-PNC55 Embedded CNC E-ENC55 Embedded Controller ExC55 Embedded Controller ExC66 Embedded Controller ExC66 compact	Electronics/productronics Control of machines for pc board assembly and production Highly precise axis control during IC conditioning for electronics components CNC controllers for laser systems for wafer processing and solar cell structuring CNC controllers for soldering systems (we will be pleased to provide you with further information on request) Machine tools/production system Drilling: drilling machine, pc board drilling machine, laser drilling machine Gas cutting: gas cutting machine (autogenous, plasma) Turning: lathe, automatic lathe, pipe and processing machine Eroding: eroding machine, wire erosion machine, cavity sinking machine Folding: folding machine, filter folding machine Milling: milling machine, pc board milling machine, wood milling machine, HSC machining Joining: joining machine Thread rolling: rolling machine, thread rolling machine Thread tapping: thread tapping machine

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
				Engraving: engraving machine, pantograph Laser removal: laser removal system Laser cusing: rapid prototyping Laser engraving: laser engraving machine Laser cutting: laser cutting machine Laser welding: laser welding machine Friction welding: friction welding machine Grinding: grinding machine, cylindrical grinding machine, out-of-round grinding machine, flat grinding machine, profile grinding machine Cutting: cutting machine, fabric cutting machine, leather cutting machine, polystyrene cutting machine, plastic cutting machine, foam cutting machine, contour cutting machine, water jet cutting, water jet cutting machine, water jet system Welding: welding machine, welding system, plastic welding machine, ultrasound welding machine Textiles Contour cutting machines CNC sewing machine production and processing of textiles Processing of glass, plastics and wood laser cutting process for flat glass wood and stone cutting

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
34.	ECS (Italian controls)	http://www.ecsitaly.it , Italy	SERIES 800 CNC 1801 & CNC 4801 CNC 1802 & CNC 4802 CNC 1805 SERIES 900 CNC 901 CNC 902 CNC 903 CNC 904 CNC 905 CNC 906 CNC 907	Milling Turning Cutting Milling Turning Turning milling Sheet bending Sheet cutting Pipe bending Pipe cutting CNC welding and cutting (inkjet, water jet, laser, plasma)
35.	ESAB	http://products.esabna.com/Cutting/EN/cutting/cutting_mechanized_cutting/mech_cutting_secondary_1180017524/q/display_id.id4367f4b1c3eb949585191/path.mechanized_cutting_computer_numerical_controls_USA	VISION PC VISION PC R VISION 51 VISION 52 VISION 55	CNC welding and cutting (inkjet, water jet, laser, plasma) Industrial PC based hardware and Windows based software
36.	Fagor Automation	http://www.fagorautomation.com/ , Spain	8070 T CNC 8055 T CNC 8035 T CNC 8070 M CNC	Lathes To control turning centers, vertical lathes, slanted-bed lathes, parallel lathes, dual-turret (TT) lathes, lathes with several turrets and spindles and dual-purpose (mill-lathe) machines To control high-production turning centers, vertical lathes and parallel lathes For lathes and turning centers with 2 axes and 1 spindle Milling

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
37.	FANUC Ltd	http://www.fanuc.co.jp , Japan	8055 M CNC	To control all types of milling machines and machining centers, both horizontal and vertical
			8035 M CNC	For milling machines and machining centers with 3 axes and 1 spindle
			8070 OL CNC	Other applications
			8055 GP CNC	Grinders, saws, press brakes, machines for wood, marble, stone and glass
				laser, plasma cutting machines, etc.
			8035 M CNC	For controlling all types of machines (engraving, cutting, etc.) with 2 or 3 axes and 1 spindle
			0i Model D	High reliable and high cost-performance CNCs
			0i Mate Model D	
			30i /31i/32i-MODEL A	AI nano CNC of high speed and high accuracy machining
			16i/18i/21i-MODEL B	Ultra-compact, ultra-thin CNC integrated LCD and network features
			160i/180i/210i/MODEL B	
			160is/180is/210is-MODEL B	
			18i /180i /180is/-M MODEL B5	
20i MODEL B	For manual milling machines and lathes			
Power Mate i-MODEL D/H	FA network-capable positioning control CNC			
α -T21iFsa/T21iFsb α -T21iFa/ T21iFb α -	ROBODRILL: Spindle taper size no. 30 for milling and boring as well as drilling and tapping			
α -T14iFsa/T14iFsb α -T14iFa/ T14iFb α -				

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
38.	FASTCUT	http://www.fastcutcnc.com/controller.php , Canada	S-2000i series 15B/30B/50B/50BP/100B/ 100BH/150B/250B/300B ROBOCUT α -lid/ROBOCUT α -0iD ROBONANO α -0iB G6 CONTROLLER	ROBOSHOT: electric injection molding machines with advanced control with dedicated servo system AI wire-cut electric discharge machine For super nano precise machining in optical electronics/semiconductors, medical and biometric fields CNC plasma cutting oxy/fuel cutting
39.	FIDIA	http://www.fidia.it/ , Italia	C CLASS CNC CONTROLLER C0 C1 C10 C20 F CLASS CNC CONTROLLER F0	For milling and machining centres Milling machines, machining centres and boring machines
40.	Flash Cut CNC	http://www.flashcutcnc.com/CNC-Controls.php , San Carlos, CA	FLASHCUT CNC CONTROL	Milling and lathes
41.	GSK CNC	http://gskcnc.com/cnc_controller.php , Thailand	218M 983M 980 M 928 MA 980 TD 928 TC	Milling/drilling Turning

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
42.	HAAS	http://www.haascnc.com/lang/ , CA, USA	Haas CNC Lathe Control	Lathe
43.	HEIDENHAIN	www.heidenhain.com , Schaumburg, IL	Haas Mill (VMC/HMC/5-AXIS) Control iTNC 530/TNC 620/TNC 320/TNC 124 MANUAL-plus 620	Milling Milling turning
44.	Hurco	http://www.hurco.com , Indianapolis	Hurco Winmax [®] Lathe Control Hurco Winmax [®] Mill Control EDGE PRO	Turning Milling Plasma cutting
45.	Hyperterm, Inc.	http://www.hyperterm.com/en/Products_and_Services/Computer_Numeric_Controls/index.jsp , Hanover, NH	Micro EDGE EDGE Ti Mariner EDGE II VOYAGER III PC CONTROL	
46.	Integrated Industrial Technologies, Inc.	http://www.isquaredt.com/products/?g=1 , Pittsburgh, PA, USA		Grinding, milling, drilling, boring, grinding, and turning
47.	ISEL	http://www.iselautomation.de/products/product.php?lang=en&ID=p66 , Germany	CNC Controller C 142-4	For any 3-axes cutting machines
48.	Lakshmi Electro Controls & Automation	http://www.leca.in , Karnataka, India	Advantage 400	Universal motion controller for up to 5 axes machines
49.	LNC	http://www.lnc.com.tw , Taiwan	LNC-MS000 six independent path, and control axes can be up to 32 axes	Lathe/milling grinding/engraving machines PCB drilling machine, glass cutting machine, wafer cutting machine, laser cutting machine, printing machines, and another relevant industrial machines

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
50.	Larken Automation	http://www.larkencnc.com , Ottawa, Canada	3 axis micro-step stepper motor controllers	Custom xyz tables, plasma tables, milling machine retrofits
51.	Linatrol Profile & Shape Cutting Solutions	http://www.linatrol.com/products_cnc_picopath.asp , Burlington, Ontario, Canada	PICOPATH CNC Control LYNX CNC SYSTEM Profiler™ CNC Control Profiler Plus CNC Controller Infinity CNC	Plasma and oxy-fuel cutting process
52.	Lubi Electronics	http://www.lubielelectronics.com/new_site/products/drives_&_motion/cnc_controller/cnc_controller.html , Taiwan		CNC lathe machine Milling machine Bending machine Grinding machine Engraving machine Water jet cutting machine Plasma arc cutting machine Induction hardening machine PCD cutting machine
53.	LUMONICS	http://www.lumonics.com/ , Nepean, Ontario, Canada	GadgetMaster Motor Control	3 axes motion control retrofit kit
54.	Mach Motion	http://www.machmotion.com/ , Newburg, MO, USA	MILLING MACHINE CONTROLS X15-250 X15-250-U X15-250-01 X15-250-06 X15-250-5 X15-350-04 X15-350-04ES	CNC mill control—standard CNC mill control—ultimate CNC mil stepper kit Mill kit—TECO CNC mill control analog Mill kit—Mitsubishi Mill kit – Mitsubishi with drive enclosure

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
			LATHE CONTROLS	
			X15-250L	CNC lathe control
			X15-250-5	CNC lathe control with analog drive controller Lathe kit—Mitsubishi
			X15-250-04L	
			Plasma and Oxy Fuel CNC Control	
			X15-250-06	CNC plasma or oxy fuel servo kit—TECO CNC plasma or oxy fuel servo kit—Mitsubishi
			X15-350-04	
			CNC Router Controls	
			X15-350R	CNC router control
			X15-250-01	CNC router stepper kit
			X15-350-06	CNC router kit—TECO
			X15-250-5	CNC router control with analog drive controller
			X15-350-04	CNC router kit—Mitsubishi
			CNC Grinder Controls	
			X15-350	CNC grinder control
			X15-250-5	CNC grinder control with analog drive controller CNC grinder kit
			X15-350-04G	
			CNC tube bender controls	
			X15-250-04T	CNC tube bender control/retrofit
			CNC Controls for Benchtop Machines	

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
55.	Mazak corporation	http://www.mazak.eu , Japan	XI5-250B XI5-250-01 XI5-255 XI5-400s Mazatrol Matrix	CNC control for Benchtop machines CNC stepper kit Mach3 CNC monitor enclosure Compact CNC control W/O switch panel Turning Milling Multi-tasking machines Laser processing machines Drill Grinder Hob Lathe Mill Ream Router Specialty machines Plasma and oxyfuel
56.	MDSI	http://www.mdsi2.com , Dexter, MI	OpenCNC	
57.	Messer Cutting Systems, Inc.	http://www.mg-system-welding.com/Products/CNCcontrols/tabid/63/Default.aspx , Menomonee Falls, WI, USA	Global Control Plus System Metalmaster Plus MPC2000 TMC4500ST Titan II Global Control S Systems EdgeMax EdgeMate EdgeMaster	

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
58.	Microkinetics Corporation	http://www.microkinetics.com/ , Ken-nesaw, GA, USA	MN 400 MOTION CONTROL WITH DRIVE RACK With control software Mill-Master Pro MN 400 MOTION CONTROL WITH DRIVE RACK With control software Turn-Master Pro	Milling Turning
59.	Mikini Mechatronics	http://www.mikinimech.com/products.htm , Watsonville, CA, USA	MIKINI V2.0 CNC CONTROLLER	Featuring 4 axis manual and CNC host operation. Four axis-DRO with feed rate calculation and spindle load monitoring
60.	Milltronics, Inc.	http://www.milltronics.net/index.aspx , Waconia, MN	Milltronics CNC control	Lathe/milling high speed milling
61.	MS-Tech Corporation	http://www.ms-tech.com/ , Corona, CA, USA	7200 SERIES 8000 Series MSTC-800	Machining centers, turning centers, grinders punches,
62.	MSHAK JSC	http://www.mshak.am/ , Armenia	CNC MSH PC-104 CNC MSH TURBO-U MSH TURBO -M MSH GEO Brick	Lathe, milling and other machines with control of up to 6 axes Complex machine tools with up to 16 controllable axes For multi-axis machine tools, machining centres and complex multi-machine tools units with controllable axe up to 32 High-performance hard-ware control unit with integrated in control units digital drives for 4, 6, 8 axes

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
63.	MultiCam, Inc.	http://www.multicam.com/eng/ , Dallas, TX, USA	EZ Control	CNC routers CNC plasma CNC water jet CNC tooling CNC laser
64.	MORISEIKI	http://www.moriseiki.com/english/products/app/index.html , Japan	MAPPS IV MAPPS III for CNC Lathe MAPPS III for Integrated Mill Turn Centers MAPPS III for Machining Center	Turning Milling turning Milling
65.	Numatix CNC Controls, Inc.	http://www.numatix.com/ , Farmington Hills, MI, USA	Numatix CNC Control MAP-3 MAP-3+2	Specifically tailored for any 3-axis CNC machine application This retrofit package is specifically tailored to convert any 3 axis CNC machine to a fully capable 5-axis CNC machine by utilizing a 5-axis spindle attachment
66.	Num. Corporation	http://www.num-usa.com/ , Battenhus- rasse, Teufen	MAP-4 MAP-5 MAP-FADAL CNC control with digital bus	Specifically tailored to any 4-axis CNC machine application Specifically tailored to any 5-axis CNC machine application This retrofit package is specifically tailored to Fadal CNC machines Tool grinding Inline and rotary transfer and multi- spindle machines Any 5 or more axes machines

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
67.	NUTEC Components, Inc	http://www.nutecl.com/index_files/Page506.htm , Deer Park, NY	CNC control with analog interface Num Power 1020–1040–1060–1080: four ultra compact CN MICROMATIC-9 MICROMATIC-3	Woodworking gear manufacturing machines Turning, milling, grinding, or wood, or glass, or stone or control processes such as palletising, handling or cutting For virtually any type of motion control application, including Pick and Place and even robotics with kinematics
68.	OmniTurn CNC	http://www.omniturn.com/bin/Controls.htm , Port Orford, OR	OmniTurn CNC Control	Turning
69.	Omtromix	http://www.omtronix.com/ , Mississauga	TurboCut CNC	High speed milling Motion Control software and hardware for multiple axis control Different machine tools
70.	OKUMA	http://www.okuma.com/products/mechatronics/ , Niwa-gun, Aichi, Japan	THINC PC BASED CNC CONTROLLER USING MICROSOFT WINDOWS PLATFORM MC Models: 10/110 10/110 LIGHT OS-WIRE 10/510 Light 10/510i	Wood working Pantographs/work centres Polishing/painting Profiling Mortising Piercing/perforating/punching pantograph
71.	OSAI	http://www.osai.it/indexb.html , Italy		

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
			T (Lathes) Models	Plastic working
			3 Axes	Moulding
			3-6 Axes WinLink	Modelling
			GP MODELS	Glass working
			10/510 OpLink	Cutting tables
			10/510 WinLink	Bevelling machines
			10/510 Control Unit	Perforating
				Etching machines
				Grinders
				2 Axes Machines
				Stone working
				Machining centres
				Grinding machines
				Sawing machines
				Lathes
				Laser scanning
				Bridge mills
				Metal working
				Lathes
				Mills
				Machining centres
				Special applications
				Turbine cutters
				Water jet
				Laser
				Transfer machines
				Spring bending
				Grinding

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
72.	Power Automation	http://www.powerautomation.com/ , Pleidelsheim, Germany	PC BASED CNC CONTROLS PA 8000 e2 PA 8000 LW PA 8000 EL	Automation system Palletising Robotics Automated warehousing Wire and pipe bending Routing Engraving Milling Turning Grinding Laser cutting Water jet cutting Plasma cutting Oxy-fuel cutting Multi- channel/multi-axes applications High speed applications Machining centers, turning centers and lathes CNC for basic machines
73.	PC Controls, LLC	http://pccontrols.net/ , Arlington, TX	10 SERIES MC CONTROLS 10 SERIES LATHE CONTROLS	
74.	Siemens	http://www.sea.siemens.com/us/Industry_Solution/Machine-tools/Pages/Machine-Tools-Home.aspx , Munich, Germany	SINUMERIK 802C SINUMERIK 802S SINUMERIK 802D SINUMERIK 802D solution line SINUMERIK 810D SINUMERIK 828D (NEW) ACRAMATIC CNC SINUMERIK 840D SINUMERIK 840D solution line	Digital CNC for dynamic machining CNC for high-speed machining

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
75.	Slicer Controls, LLC	http://www.slicercontrols.com/ , Minneapolis, MN	SLICER	Turret Punch Press retrofits Plasma retrofits, hydraulic clutch retrofits, and laser retrofits 2 axes CNC control—for lathe applications
76.	SOFT LOG	http://www.softlogcnc.com/machine-tool-automation-products.html , Pune, Maharashtra, India	Model—2T/2TG	
77.	Taurin Group USA	http://www.tauringroupusa.com/CNC_controls.htm , Ontario, CA	Model—3M/3MG CNC-C CNC-8 CNC-I	3 axes CNC control—for milling applications CNC bending
78.	UERRO	http://www.uerro.com , Taiwan	EPK6 SERIES PC Based CNC Controller 2 Axes EPCIO SERIES PC Based CNC Controller 3 Axes M2000 system PC Based CNC Controller 4 Axes	Tool machine control, semi-conductor position controls industrial lathe, milling, grinding machine and any 2/3/4 axes motion position control system
79.	UNIDEX	http://www.unidexmachinery.com/ , IL, USA	NA	Spring and wire forming
80.	Vega CNC	http://www.isscnc.com/ , Troy, MI	VEGA MX-2 CNC Control Vega SG CNC	CNC s for machine tool and factory automation CNC s for grinding applications
81.	Velocitech CNC LLC	http://www.velocitechcnc.com/ , Florence, KY, USA	Velocitechcnc	Retrofit of different machine tools
82.	VERTEX	http://www.vertex-monaco.com/vertexcnc , Monaco	COMPACT version VSC 1020–1030 UPTO 4 axes CNC Control	Lathe Milling

(continued)

Table 2.2 (continued)

No.	CNC control manufacturer	Website, country	Control models	Application
83.	Weihong CNC System	http://www.naiky.com/Product.asp , Shanghai, China	NK-300 CNC Integrated Machine System NK-200 CNC Integrated Machine System NK-100 CNC Integrated Machine System	Lathe Milling
84.	Yaskawa	http://www.yaskawa.com/site/Products.nsf/products/Multi-Axis%20Motion%20Controllers-MP2000iec_series.html , IL, WI, USA	NC-100 CNC system B Series CNC Controller G Series CNC Controller J100 Series CNC Controller X1 Series CNC Controller X2 Series CNC Controller X3 Series CNC Controller	Variety of machine tools

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