Characteristics and Technologies of Advanced CNC Systems

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INTRODUCTION

Computer Numerical Control (CNC) systems are the "backbones" of modern manufacturing industry for over the last 50 years and the machine tools have evolved from simple machines with controllers that had no memory and were driven by punched tape, to today's highly sophisticated, multiprocess workstations. These CNC systems are still being worked and improved on. The key issues center on autonomous planning, decision making, process monitoring and control systems that can adjust automatically to the changeable requirements.

Introduction of CNC systems has made it possible to produce goods with consistent qualities, apart from enabling the industry to enhance productivity with a high degree of flexibility in a manufacturing system. CNC systems sit at the end of the process starting from product design using Computer Aided Design (CAD) tools to the generation of machining instructions that instruct a CNC machine to produce the final product. This process chain also includes Computer Aided Process Planning (CAPP) and Computer Aided Manufacturing (CAM).

BACKGROUND

The development of an intelligent CNC controller architecture has been one of the main goals for both CNC manufacturers and end users. This new trend comes with a suite of new technologies and concepts. In today's manufacturing world, understanding the true meaning and implication of these technologies and characteristics is the top priority. Extensibility is the ease with which a third party is able to add capabilities to software or hardware. Interoperability is the ability of two or more systems or devices to exchange information and make use of it transparently. Portability is the ease with which application software can be transferred from one environment to another. Scalability is the ease with which an existing system's performance can be increased or decreased to suit different applications of different magnitude. The recent CNC controller development includes a digital signal processor (DSP) (Chang, 2007), virtual CNC (Erkorkmaz & Wong, 2007) and CNC system based on STEP-NC and Function Blocks (Wang, Xu, & Tedford, 2007).

STEP-NC (ISO 14649, 2003) is viewed to be an effective means of documenting task-level information in the CAD/CAPP/CAM/CNC manufacturing chain. The new standard of Function Block (IEC 61499, 1999) has the advantages of generating method-level data for the control unit. The kernel software proposed by Park, Kim, and Cho (2006) organized and managed various control software modules dynamically by using process and resource models. It enabled the CNC controller to be easily reconfigurable because the software modules can be plugged-and-played and be built modularly so that new features or number of control axes could be added easily. Bi, Yu, and Li (2006) introduced a new type of CNC, which is based on Sinumerik 840D and STEP-NC. This is a kernel of Intelligent Integrated Manufacturing System (I^2MS).

Open CNCs

Open CNC architecture can be understood as having standard hardware and software which permit system scalability, and ensure future performance enhancement. The development of an open CNC architecture entails the establishment of a type of software architecture that fits in with a "general" computer which is independent of a control vendor, plus a communication standard among computer hardware, an operation system and application software (Ambra, Oldknow Migliorini, & Yellowley, 2002; Pritschow et al., 2001).

Most of the advanced CNC controllers and supporting hardware have closed architecture designs which make it difficult, if not impossible, to incorporate advanced control schemes within the CNC itself as well as integrate with other manufacturing resources. Open architecture controllers are designed to remove this type of obstacles by creating a flexible control system that can be attached to a wide variety of machine tool systems in such a way that the original axis and spindle drive motors and supporting electronic interfaces can remain intact.

Work concerning open CNC architecture has been one of the main topic areas in CNC research activities since the mid-1980s, but it was not until the early 1990s that a few

Table 1. Some open-architecture controllers

Vendor and location	Product	Computer(s)	Operating systems(s)	Bus and net
Advanced Technology & Research Corp Burtonsville, Md.	RCS	Dual PCs	• Windows NT for GUI • Real-time kernel for control	• Ethernet • Sercos motion bus • Profibus distributed I/O
Bridgeport Machine Inc Bridgeport, Conn.	DX-32	Dual computers	• PC/DOS for GUI • Motorola 68K/real-time kernel for control	• Ethernet • Serial channel I/O
Cimetrix Inc. Provo Utah	CX3000	Single PC	• Window NT or Lynuxs • VMEbus version available	• Ethernet • PMAC motion card • Cognex or Datacube vision cards
Delta Tau Data Systems Inc Nortridge Calif.	PMAC-NC	Single PC	• Window 95	• PMAC motion card
GE Fanuc Inc. Charlottesville, VA.	MMC-4 HSSB	PC front end PC front end	- -	• Through Fanuc F-bus to CNC • Through high speed serial bus to CNC
Hewlett-Packard Co. Santa Clara, Calif.	OAC 500	Dual PCs	• Window NT for GUI • LynxOS for control	• Ethernet • Sercos motion bus • DeviceNet distributed I/O
ICON Industrial Controls Corps. Shreveport, La	MOS	Single PC	• Window 95 with real-time kernel	• Ethernet • Sercos motion bus • DeviceNet distributed I/O
Indramat (Div. of Rexroth Corp.) Hoffman Estates, III	MTC200	CNC coprocessor	• PC bus	• Discrete I/O cards
Manufacturing Data System Inc. Anna Arbor, Mich.	Open CNC	Single PC	• QNX real-time Unix	-
Siemens AG Erlangen, Germany	Sinumerik 840D	Dual PCs	• PC/DOS for Windows for GUI • RISC or PC with real-time kernel for control	• Nurbs for control • Siemens S7-300 PLC for I/O

commercial products were investigated and prototyped by some leading companies in the CNC industry. Table 1 summarizes some of the developed or prototyped open-architecture controllers (OSACA, 2007).

World-wide, three industrial consortiums have been active since the early 1990s. They are the Open System Environment for controllers (OSE) of Japan (Zhang, Wang, & Wang, 2003), OSACA of Europe, and OMAC consortium of the USA. Although different approaches are used, they all share a similar vision of using open-architecture controllers in replacement of the current closed CNC systems.

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