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AN INTEGRATED MANAGEMENT SYSTEMS BASED ON STEP STANDARD

Abstract: *The objective of STEP is to provide the framework for the unambiguous representation and exchange of computer-interpretable product data throughout the life of a product. The framework is independent of any particular computer system. STEP is a modular standard, there is large number of parts in different levels of standardisation. This way of working has been found especially useful when optimizing technological parameters during the setup of a new integrated management programs.*

Keywords: *STEP standard, management, systems*

1. INTRODUCTION

With the development of numerical control (NC) machine, network and information processing technology, the numerical control system tends to be intelligent, open and networked, composing a manufacturing mode that is open, multi-platform, cooperative and meets different needs of the customer flexibly in time. Traditional NC procedure follows international standard of ISO6983 and describes how to process with G, M code, and has the nature of being process-trended and simple NC programming specifications and interface, leading to the difficulty in programming, lower portability, less intelligence, which limits the development of the opening and intelligence of the CNC system. Meanwhile, it forms bottleneck between CNC and CAX technology which hinders the development of mechanical manufacturing industry. STEP-NC, as a new international data interface standards (ISO14649) for NC procedures made in 1996 [1], is the extension of STEP (standard for the exchange of product model data) in the CNC field. It regulated the data interface between CAM and CNC again, described what to process, and included all the required information during the product processing, such as geometry, craft and tolerance information. Besides, it provided a neutral mechanism which is independent of the specific system and a united data model which can describe the whole life cycle of the product. The core is: Work plans containing a sequence of working steps; Each working step associates an operation with a feature somewhere on the work piece; Each operation describes what to do and what strategies and parameter settings to use. By putting forward STEP-NC, it becomes possible to scatter over internet the numerical control program focused on a single computer in various devices in order to create conditions for manufacture mode and technology based on network. The NC system based on STEP-NC is the open and networked direction of NC technology development [2].

2. THE TECHNOLOGY FOR THE REALIZATION OF THE STEP SYSTEM HARDWARE PLATFORM

To finish the coordinate manufacture

of the net work, the system collects all equipment in the network environment and connects them by the network standard hardware interface. The network framework of STEP system will be shown in Figure 1.

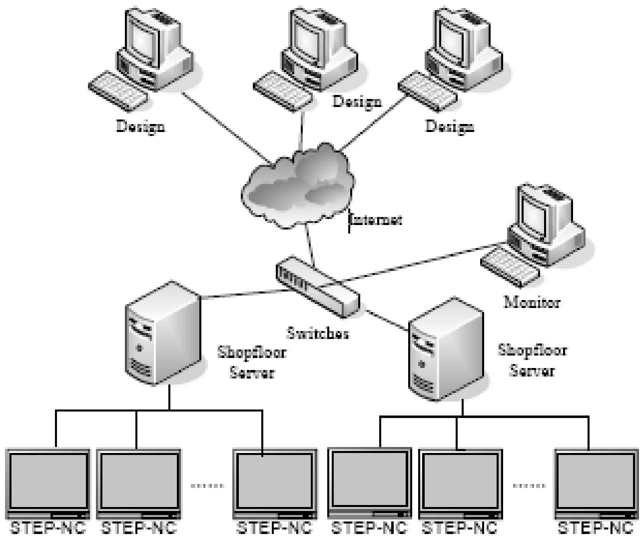


Figure 1. Network framework of STEP system

According to the functions, the whole network framework can be divided into two parts: design part and manufacture part. Because of the existence of the internet, the two parts can work without the restriction of space location. During the design part, every designer can use CAD or CAM to create their own three dimension accessory pictures on their design and output the standard form files directly tally with STEP-NC through their own STEP transformation interface. Early Banding and Late Banding are the current used ways of transformation [3]. Early Banding means the transformation by taking all the same kind of EXPRESS as a whole, and the markers of XML and the data types of EXPRESS data model and their attributes directly mapped: the elements of XML correspond to the entity of EXPRESS, while the attributes of XML element correspond to the attributes of entity. Late Banding means the direct correspondence of XML markers to meta data objects of EXPRESS (including entities, attributes and data types). Obviously, Early Banding is simpler than Later Banding in forms, Later Banding is apt to cause the expansion and explosion of structures. But, when using Early Banding, a label set for each of EXPRESS model has to be found, that is to say, rewritten a schema; While Later Banding permits all EXPRESS models to share a label set, that is to say, permitting them to share the same schema. Therefore, for different structure platforms, the generality and portability can be better reached by taking Later Banding. The transformation of EXPRESS/XML is mainly based on their corresponding relations [4]. No matter what banding is adopted, the corresponding relations in its structures are needed to be defined clearly. Since the mid-1980s, the international community has been developing the ISO 10303 set of standards, well known as STEP (ISO 10303-1 1994), which has its foundations in many of the earlier aforementioned standards [5]. STEP has developed from a group of people popularizing emerging ideas through cycles of consensus, much as do schools of art, literature, and music [6]. The STEP standard is divided into many parts, i.e. Description Methods, Information Models, Application Protocol (AP)s, Implementation Methods, and Conformance Tools. Each part is published separately [7]. The Information Models and Application Protocols describe the data structures and constraints of a complete product model [5]. The use of STEP language can help the enterprises to have to somehow the integration of data for product design activities [8]. The overall objective of STEP is to provide a mechanism that is capable of describing product data throughout the life cycle of a product, independent from any particular system [9]. STEP has led to improvements in exchange and sharing of simple CAD information, product models and complete product structures and Furthermore, STEP has improved communications within the extended enterprise (including suppliers, business partners and customers) and helped to support global collaborations [8]. This standard can manage the design information in an integrated environment. The first parts of STEP publication to achieve International Standard status happened in 1994, but many other parts have since been published or are under development and will eventually be added to the standard [10]. STEP has capabilities that span multiple industries. Those industries driving and actively developing standards today include architecture & construction, aerospace, automotive, electrical & electronic, manufacturing technologies, process plant, and shipbuilding [6]. ISO 10303, also informally known as the Standard for the Exchange of Product model data (STEP), is a family of standards defining a robust and time-tested methodology for describing product data throughout the lifecycle of a product [11]. When the STEP effort began in 1984, it was envisioned as a more encompassing set of standards for the exchange of all product data that included CAD/CAM and Product Data Management (PDM) systems [12]. STEP is widely used in computer-aided design (CAD) and product data/lifecycle management (PDM/PLM) systems [11]. The ISO10303 and ISO14649 Standards (STEP and STEP-NC) have been developed to introduce interoperability into manufacturing enterprises to meet the challenge of responding to production on demand [13]. It is stated that Major aerospace, automotive, and ship building companies have proven the value of STEP through production implementations resulting in actual savings of $150M per year in the US (and potential savings of $928M per year) [11]. STEP is a proactive effort, the focus being placed on developing a standard that caters for various user groups, which are usually associated in an industry or according to a common application such as CAD data, which can be used throughout multiple industries [14]. The STEP standard categorizes the various types of product data around APs. An AP includes at least three formal documents: The Application Activity Model (AAM) describes the activities in the lifecycle of a product. The pieces of product information that are needed for the activities are called the Application Reference Model (ARM) The Application Interpreted Model (AIM) is formed by using an EXPRESS information model to capture everything in the ARM and to tie it to a library of pre-existing definitions [12]. STEP will enable us to iterate designs based on manufacturing suggestions, then evaluate and analyze the results before manufacturing the pieces. It also offers a tremendous benefit for exchange and managing information from several engineering and manufacturing disciplines in an effective way [15]. Some of the most relevant APs used in the CAD/CAM domain include [12], Part 203: Configuration controlled 3D designs of mechanical parts and assemblies (ISO 10303-203 1994), Part 214: Application protocol: Core data for automotive mechanical design processes (ISO 10303-214 1994) and Part 224: Application protocol: Mechanical product definition for process plans using machining features (ISO 10303-224 2001). The objective of STEP is to provide the framework for the unambiguous representation and exchange of computer-interpretable product data throughout the life of a product. The framework is independent of any particular computer system. STEP is a modular standard, there is large number of parts in different levels of standardisation. The parts can be divided into six classes (picture 1.). A brief description of each class is presented below. An Application Protocol (AP) is a definition of information and process model for an engineering domain, i.e., Configuration controlled design (AP203). The structure of an AP information model is defined in terms of a Description method. The standard description method used within STEP is the language EXPRESS [16]. It is based on an extended entity relationship formalism supporting object orientation concepts and specification of constraints on data and relationships. Integrated resources provide a set of generic definition that are shared among application protocols to facilitate interoperability. Data exchange is facilitated via Implementation methods. There are standard implementation methods defined for file based transfers and for specification of repository interfaces. Conformance testing methodology and framework define the validation process for STEP implementations and Abstract test suites provides a comprehensive set of test cases for an AP The service offered by STEP allow for realisation of domain specific data exchange structures as well as domain specific repositories with uniform interfaces. As EXPRESS is a formal language, it is possible to transform EXPRESS models to representations in languages such as C or SQL, which in turn may be used to define the structure of repositories for model data. Compared with the traditional method for data exchange, i.e., manually written interface software for reading/ writing tool specific data formats, an information model driven approach have the following advantages:

- 2n interfaces are required to integrate n tools if a common information model is used compared with n(n-1) interfaces if no standard model is employed.
- The existence of formally defined exchange formats allows for automation of large parts of the interface development process (picture 2.). Those parts not easily automated, i.e., the mapping from entities in the information model to the corresponding entities in a tool’s meta-model are supported by a formal description — in this case the EXPRESS model.

An information model based approach allows users to express their view on important domain information. In this sense the approach not only facilitates information exchange across tool boundaries — it also allows users to express requirements on future tools.

STEP-NC Environment for Manufacturing ISO 14649 is referred to as STEP-NC due to its interaction with ISO 10303 (STEP) and was initiated to provide a data model for a new breed of intelligent CNC controller that is well-structured with workplans and workingsteps. ISO 14649 aims to model the complete information requirement that must exist in a controller to control a machine tool by defining “what-to-make” and plans “how-to-make”. STEPNC has been developed as a result of several research projects carried out by companies and academic institutions. In terms of international research and development into these standards, projects such as OPTIMAL [17]. OPTIMAL is one of the earliest STEP-compliant systems and is based on feature information and machining strategies. The research does not stop there, because the researchers now focus on identifying and defining interoperable manufacturing and STEP-NC compliance in the context of concurrent engineering. In particular, information reviews of STEP-NC, manufacturing processes and manufacturing resources are also major foci in this research area. STEP-NC is aimed at overcoming the problems left from ISO 6983 which focuses on programming the path of the cutter centre location (CL) referred to the machine axes rather then machining tasks. One approach to the problem is to exchange a high level of information between CADCAM systems and NC controllers. STEP-NC works by manufacturing features, operations and the workingsteps. The STEP-Compliant Data programming interface for numerical controls has been introduced and proposed for standardization by the International community, where its higher level of information aims to overcome the shortcomings of contemporary NC programming. The new NC programming data model purports to support a well structured hierarchical interface, and object-oriented and two way communication from the CAD environment down to the shop floor [6]. STEP-NC is an improved interface between the CAD world and the manufacturing arena. It is recognized as such since it provides process information at the time and place of the manufacturing activity. The proposed STEP-NC data format supports accurate and timely adaptive control of the production equipment and provides feedback for information back to the planning activity. The current standard of programming NC namely G & M codes or ISO 6983 has had no significant change since the format of NC machines was developed at MIT in 1952 [16, 18, 19, 20] and the evolution of NC machines since using hardwired configurations to the current fully-integrated systems that can be found almost everywhere, from small job shops in rural communities to multi-national companies in large urban areas. During the pre-Computer-Numerical Control (CNC) epoch the program language had been modified by vendors and controller developers who added their own commands. Since the 1970's significant developments have been made towards more automatic and reliable computer numerically controlled machines with new machining processes. Today's highly sophisticated Computer Numerically Controlled (CNC) machines utilize a variety of cutting technologies such as multi-turret and multi-spindle in complex axial configurations and this machine capability increases the level of flexibility and capability compared to the previous decade [21]. A large number of Computer Aided Systems have been developed and implemented in recent years to support all stages of product life by computer systems and many can simulate virtual CNC machining with the complete machine toolpath [15]. Since the first NC machine was introduced in 1952, various process plan packages have been developed and each system tried to interpret the part data format more reliably. Most of these systems are specialized to support certain applications, and are based on an information model that handles the application specific view of the product. These current trends are aimed at open systems but they are predominantly used in retrofitting applications for conventional NC machines. Review of STEP-Compliant Manufacturing for Turning One of the aims for the next generation of CNC machines is to be interoperable and adaptable so that they can respond quickly to changes in market demand and the manufacturing needs of customized products [22]. As part of this, 2006 was a time when researchers were particularly focused on proposing a framework for turning. Most of the researchers proposed prototype systems to support data interoperability between the varioue systems based on ISO standard 14649 that provided the first data exchange format used in the operation of NC machines. Among these systems, G2STEP is the latest system to cover the machine functioning from pre-processor to STEP-NC part program generation including part program verification [23].

3. STEP-NC PROCESS CHAIN

STEP-NC is a new model of data transfer between CAD/CAM systems and CNC machines, which replaces G-code. It remedies the shortcomings of G-code. by specifying machining processes rather than machine tool motion, using the object-oriented concept of workingsteps. Workingsteps correspond to high-level machining features and associated process parameters. CNCs are responsible for translating workingsteps to axis motion and tool operation. A major benefit of STEP-NC is its use of existing data models from STEP. Basically, the standard is the smooth and seamless exchange of part information between CAD, CAM, and NC programming. STEP-NC provides a comprehensive model of the manufacturing process. It is object and feature oriented and describes the machining operations executed on the workpiece, and not machine dependent axis motions. It will be running on different machine tools or controllers (Figure 2). This compatibility will spare all data adaptations by postprocessors, if the new data model is correctly implemented on the NC controllers. If old NC programs in G-code are to be used on such controllers, the corresponding interpreters shall be able to process the different NC program types in parallel.

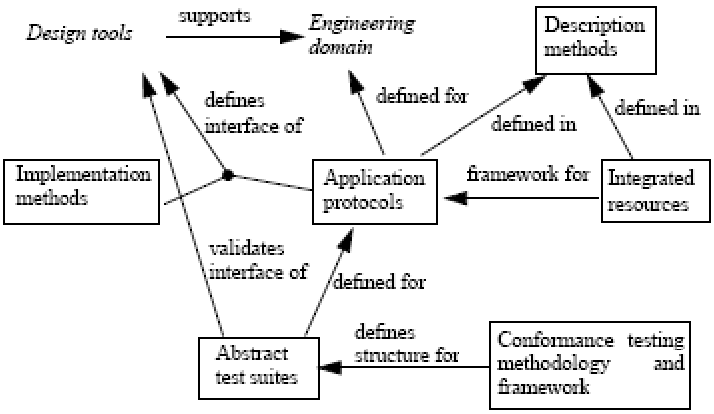


Figure 2. STEP classes and their relationships

The STEP architecture facilitates sharing of common data structures between STEP parts. For instance, a CAD system may output geometry, design features, and product identification data in STEP format. A CAM system may then input that data and use it to develop the detailed process data needed to manufacture the part. The CAM system does not need to redefine the geometry and features because these data structures are shared between STEP parts. The CAM systems output geometry, features, process sequence, and tool requirement data in STEP-NC format. Because STEP-NC data is intended to be processed at run time, specific machine operations (e.g., cutter paths) are left to the machine controller.

This offers some advantages over traditional methods:

- A STEP-NC file contains all data required to produce a part, therefore, manufacturing operations may be adjusted to maximize production efficiency.
- STEP-NC allows for complete safety checking because safety areas for fixtures can be defined as part of the setup.
- Documentation may be easily generated by the CAM or CNC system to show the state of the part before and after each working step.
- STEP-NC is easy to generate; specific tool paths need not to be defined in advance.
- A STEP-NC file is not machine specific; the STEP-NC file can be manufactured on any machine that meets the tooling requirements.

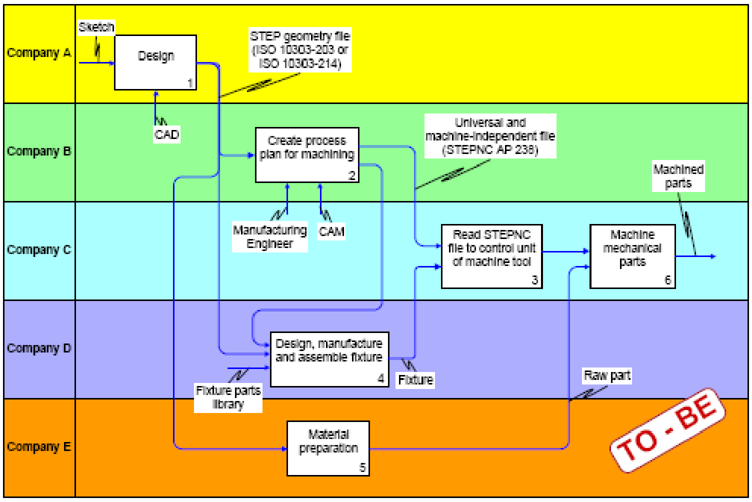
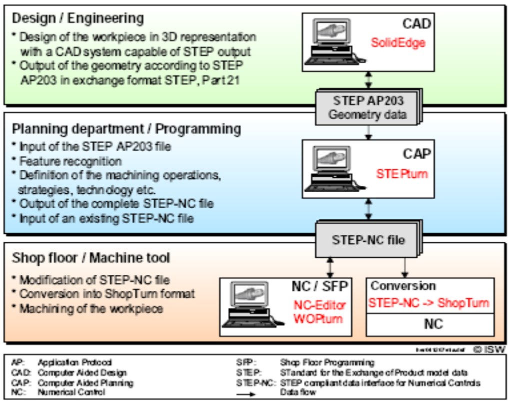


Figure 3. Simulation of STEP-NC cycle

In figure 3 it is shown the new way of action in manufacturing life cycle, from design to fabrication, and how STEP-NC is envisioned to be used within this cycle. The design phase results in STEP data and includes the geometry of the part. It is estimated that more than one million CAD stations contain STEP data translators.In 2002, research and development in terms of manufacturing technology and processes began with a proposal for the conceptual framework for designing and implementing an intelligent CNC system by Suh and Sheon [24], followed by Hardwick providing the first outlook on STEP-NC compliant manufacturing [25]. Lee and Bang have successfully developed and built a five-axis milling machine that is run by STEP-NC in XML [26] and another prototype system has been proposed by Newman et al for a STEP-compliant CAD/CAM system based on one of these frameworks using the new ISO 14649 standard for milling components [27]. Finally test and validation methods have been proposed for testing data for numerical control [28]. It is noticeable that in 2006 researchers were extremely focused on this particular area, and details can be found a special issue edition of the International Journal of Computer Integrated Manufacturing (IJCIM) for STEP-Compliant Process Planning and Manufacturing [29]. Kumar introduced a STEP-compliant framework that makes use of self-learning algorithms that enable the manufacturing system to learn from previous data and results in error elimination and consistent quality products. It has been tested and certified for pocket and hole features for milling [30]. The latest achievement in 2007 is the successful development of a system called ST-FeatCAPP for prismatic parts based on ISO 14649 by [31]. The system maps a STEP AP224 XML data file, without using a complex feature recognition process, and produces the corresponding machining operations to generate the process plan and corresponding STEP-NC in XML format. Liu et al. also proposed a NC programming system for prismatic parts to be machined using STEP-NC machine tools, and the system consisted of three functional modules, namely i) a feature-based modeler, ii) a process planner and iii) a part program generator. The system can read the STEP-NC file and calculate the toolpath automatically compared to current systems that only produce low level control information [32].



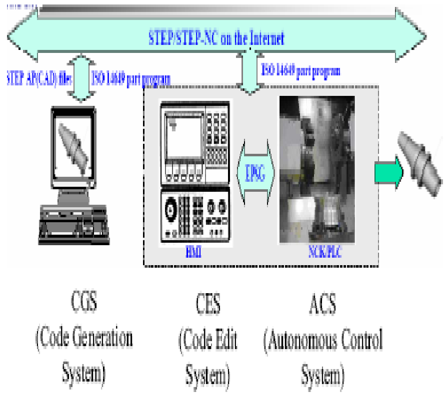


Figure 4. and 5. Implemented STEP-NC process chain

4. SUMMARY

Numerical Control (NC) machines were first introduced in the early 1950s and sparked the research and development of Computer Aided Manufacturing (CAM). In industry, CAD techniques are extensively used to design products, and CAM techniques are used to manufacture the products. Special languages were

developed to translate the shape information from the drawing into computer-controlled machine tools. Current NC programming is based on ISO 6983, called .G-code., where the cutter motion is mainly specified in terms of position and the feedrate of axes.

Even though G-code is a well-accepted standard world-wide it is in fact a bottleneck for today's CNC production chain. Programming with G-code results huge programmes which are difficult to handle; last-minute changes or correction of machining problems on the shop floor are hardly possible and control of programme execution at the machine is severely limited. Even worse, due to many different dialects and vendor-specific additions to the programming language, part programmes are not interchangeable between different controls.

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