INTERNATIONAL STANDARD

ISO 14649-1

First edition
2003-03-01

Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers —

Part 1: Overview and fundamental principles

Systèmes d'automatisation industrielle et intégration — Commande des dispositifs physiques — Modèle de données pour les contrôleurs numériques informatisés —

Partie 1: Aperçu et principes fondamentaux

Reference number
ISO 14649-1:2003(E)

© ISO 2003

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS

Not for Resale

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

© ISO 2003

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Contents

Page

--`,,,`-`-`,,`,,`,`,,`---

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14649-1 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 1, *Physical device control*.

ISO 14649 consists of the following parts, under the general title *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers*:

NOTE Phase numbers below refer to the planned release phases of ISO 14649 which are described in Annex D.

— *Part 1: Overview and fundamental principles* (Phase 1)

— *Part 10: General process data* (Phase 1)

— *Part 11: Process data for milling* (Phase 1)

— *Part 12: Process data for turning* (Phase 2)

— *Part 13: Process data for wire-EDM* (Phase 2)

— *Part 14: Process data for sink-EDM* (Phase 2)

— *Part 111: Tools for milling* (Phase 1)

— *Part 121: Tools for turning* (Phase 2)

Gaps in the numbering were left to allow further additions. ISO 14649-10 is the ISO 10303 Application Reference Model (ARM) for process-independent data. ISO 10303 ARMs for specific technologies are added after part 10.

This part of ISO 14649 has a strong relationship to ISO 10303 AP238, which is a one-to-one 100 % mapping of ISO 14649, where ISO 14649 represents the ARM and AP238 the AIM. This relationship is referenced in this document and in other parts of ISO 14649.

ISO 14649 is harmonized with ISO 10303 in the common field of Product Data over the whole life cycle. Figure D.1 shows the different fields of standardization between ISO 14649, ISO 10303 and CNC manufacturers with respect to implementation and software development.

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Introduction

Modern manufacturing enterprises are built from facilities spread around the globe, which contain equipment from hundreds of different manufacturers. Immense volumes of product information must be transferred between the various facilities and machines. Today's digital communications standards have solved the problem of reliably transferring information across global networks. For mechanical parts, the description of product data has been standardized by ISO 10303. This leads to the possibility of using standard data throughout the entire process chain in the manufacturing enterprise. Impediments to realizing this principle are the data formats used at the machine level. Most computer numerical control (CNC) machines are programmed in the ISO 6983 "G and M code" language. Programs are typically generated by computer-aided manufacturing (CAM) systems that use computer-aided design (CAD) information. However, ISO 6983 limits program portability for three reasons. First, the language focuses on programming the tool center path with respect to machine axes, rather than the machining process with respect to the part. Second, the standard defines the syntax of program statements, but in most cases leaves the semantics ambiguous. Third, vendors usually supplement the language with extensions that are not covered in the limited scope of ISO 6983.

ISO 14649 is a new model of data transfer between CAD/CAM systems and CNC machines. It remedies the shortcomings of ISO 6983 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 ISO 14649 is its use of existing data models from ISO 10303.

ISO/TC 184/SC 1/WG 7 envisions a gradual evolution from ISO 6983 programming to portable feature-based programming. Early adopters of ISO 14649 will certainly support data input of legacy "G and M codes" manually or through programs, just as modern controllers support both command-line interfaces and graphical user interfaces. This will likely be made easier as open-architecture controllers become more prevalent. Therefore, ISO 14649 does not include legacy program statements, which would otherwise dilute the effectiveness of the standard.

ISO 14649 is harmonized with ISO 10303 in the common field of Product Data by the ISO 10303-238 Application Interpreted Model (AIM) over the whole life cycle.

This document, ISO 14649-1, "Overview and fundamental principles," has five informative annexes. Annex A shows the use and assignment of features from ISO 10303-224 in ISO 14649, Annex B is the Application Activity Model that explains the environment and the activities of ISO 14649 in the manufacturing process. Annex C shows an overview of the data model structure as an EXPRESS-G diagram. Annex D describes the relationship of ISO 14649 to ISO 10303 (STEP). Annex E is a hypothetical scenario, intended to illustrate the life cycle application of ISO 14649 to a manufacturing enterprise. It is a vision of the future of manufacturing data transfer as intended by this International Standard.

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

--`,,,`-`-`,,`,,`,`,,`---
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers —

Part 1: Overview and fundamental principles

1 Scope

This part of ISO 14649 provides an introduction and overview of a data model for Computerized Numerical Controllers and explains its advantages and basic principle, based on the concepts of Product Data.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 841:2001, *Industrial automation systems and integration — Numerical control of machines — Coordinate system and motion nomenclature*

ISO 2806:1994, *Industrial automation systems — Numerical control of machines — Vocabulary*

ISO 4342:1985, *Numerical control of machines — NC processor input — Basic part program reference language*

ISO 4343:2000, *Industrial automation systems — Numerical control of machines — NC processor output — Post processor commands*

ISO/TR 6132:1981, *Numerical control of machines — Operational command and data format*

ISO 6983-1:1982, *Numerical control of machines — Program format and definition of address words — Part 1: Data format for positioning, line motion and contouring control systems*

ISO 10303-1:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles*

ISO 10303-11:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual*

ISO 10303-21:2002, *Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Clear text encoding of the exchange structure*

ISO 10303-22:1998, *Industrial automation systems and integration — Product data representation and exchange — Part 22: Implementation methods: Standard data access interface*

ISO 10303-41:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 41: Integrated generic resource: Fundamentals of product description and support*

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS Not for Resale

ISO 10303-42:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 42: Integrated generic resources: Geometric and topological representation*

ISO 10303-43:2000, *Industrial automation systems and integration — Product data representation and exchange — Part 43: Integrated generic resource: Representation structures*

ISO 10303-49:1998, *Industrial automation systems and integration — Product data representation and exchange — Part 49: Integrated generic resources: Process structure and properties*

ISO 10303-203:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 203: Application protocol: Configuration controlled design*

ISO 10303-214:2001, *Industrial automation systems and integration — Product data representation and exchange — Part 214: Application protocol: Core data for automotive mechanical design processes*

ISO 10303-224:2001, *Industrial automation systems and integration — Product data representation and exchange — Part 224: Application protocol: Mechanical product definition for process planning using machining features*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply, some of which are defined in ISO 10303 and other standards.

3.1 Terms defined in ISO 10303-1

application

application activity model

application interpreted model

application protocol

application reference model

data

data exchange

implementation model

information

information model

interpretation

model

product

product data

3.2 Terms defined in ISO 10303-11

attribute

entity

--`,,,`-`-`,,`,,`,`,,`---
© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

entity data type

entity instance

EXPRESS language

3.3 Terms defined in ISO 10303-21

physical file format

3.4 Terms defined in ISO 10303-224

fixture

machining features

manufacturing feature

3.5 Terms defined in ISO 2806

numerical control

computerized numerical control

tool path

3.6 New definitions in ISO 14649

3.6.1
workingstep
machining information for one cutting tool acting on a feature

NOTE It contains a Machining Operation.

3.6.2
machining operation
technological data for a Workingstep that details the operation

NOTE It is composed of cutting tool, toolpath strategy, machining function, cutting depth, finishing allowance, cutting speed, feed rate, retract plane, safety plane, approach strategy, and retract strategy.

3.6.3
workplan
collection of Workingsteps with an execution sequence

NOTE It contains a list of Executables.

3.6.4
executable
one of Workingstep, NC Function, or Program Structure

3.6.5
NC function
one of Display Message, Optional Stop, Program Stop, Exchange Pallet, Index Pallet, Index Table, Set Mark, Unload Tool, or Wait for Mark

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

3.6.6
program structure
one of Workplan, Parallel, If statement, While statement, or Assignment

3.6.7
project
entity which serves as a starting point for program execution

4 Symbols and abbreviated terms

For the purposes of this document, the following abbreviations apply.

AAM Application Activity Model

AIM Application Interpreted Model

AP Application Protocol

ARM Application Reference Model

CNC Computerized Numerical Control

5 Overview of ISO 14649

5.1 Purpose

The purpose of ISO 14649 is to:

— cover the current and expected future needs for data exchange;

— support the direct use of computer-generated product data from ISO 10303;

— create an exchangeable, workpiece-oriented data model for CNC machine tools;

— use standard, modern languages and libraries for the implementation of the data model;

— ensure compatibility of CNC input data.

ISO 14649 is applicable to advanced CNC machine tool and CAM systems.

5.2 The manufacturing cycle

Figure 1 shows the manufacturing life cycle, from design to fabrication, and how ISO 14649 is envisioned to be used within this cycle. The design phase results in CAD data (ISO 10303-203 geometry) and includes the definition of all the part features in ISO 10303-224. The process planning phase generates the resource requirements for part fabrication, using ISO 10303-213, and other results suitable for use in a Manufacturing Execution System (MES). Process planning also splits the ISO 10303-224 manufacturing features into sets suitable for various processes, e.g. milling, turning, electrical discharge machining (EDM), and inspection (which also uses ISO 10303-219). The ISO 10303-224 feature sets are used during the computer-aided manufacturing (CAM) phase. Based on this, ISO 14649 files are generated that are executed by CNC machine tools. At run time, each controller may access ISO 10303 integrated resources via the Standard Data Access Interface (SDAI) or EXPRESS-X queries in extensible markup language (XML), providing tight integration of ISO 10303 data with machining operations.

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

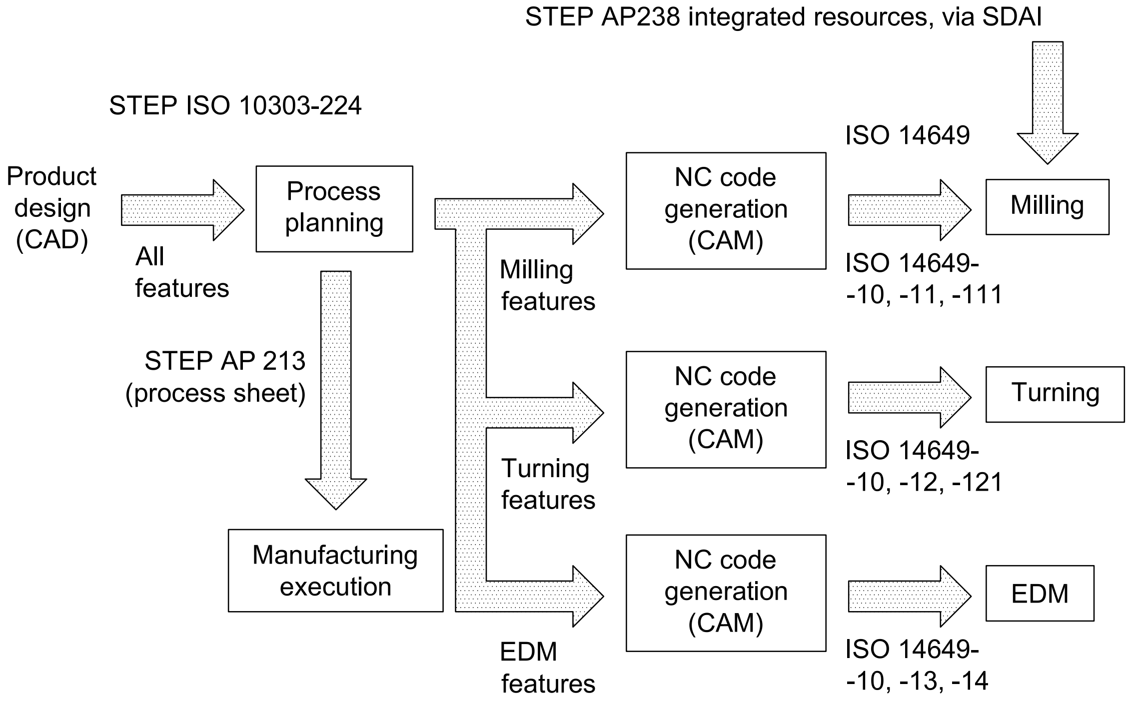


Figure 1 — The manufacturing cycle, from design to fabrication, and how ISO 14649 is envisioned to be used within this cycle

The fundamental principle of the data model is the object-oriented view of programming in terms of manufacturing features, instead of direct coding of sequences of axis motions and tool functions. The objects in this case are manufacturing features and their associated process data. This does not mean that the programming language is object-oriented, in the sense that it provides classes, methods, or inheritance. Rather, the language is a procedural way to link together a sequence of feature objects.

The data model is composed of basic units called *entities*. Entities and the relationships between them are defined in the ISO 10303 EXPRESS data modelling language. Data in a particular ISO 14649 program consists of *instances* of these entities.

The data model contains geometry data, manufacturing feature data, and manufacturing process data. Geometry data typically originates from CAD, and is described in ISO 10303 AP 203. It includes all the information necessary to define the finished geometry of the workpiece. Manufacturing feature data typically originates from CAM. ISO 14649 defines manufacturing features that differ from, but are harmonized with, ISO 10303-224. Manufacturing process data also originates from CAM, and defines the technological parameters to be used during the cutting process such as tool feed and spindle speed, and descriptions of the tooling required for each of the machining operations. Manufacturing process data also includes the definitions of Workingsteps, one for each association of feature, of associated tool and its technological parameters, and the sequence of these Workingsteps. An overall Workplan lists this information. This is shown in Figure 2.

The division of information means that changing the sequence of Workingsteps or optimising tool paths can be done with minimal impact on the rest of the data. Graphical user interfaces are expected to be an excellent help.

Geometry, feature definitions, and process data are described in ISO 14649-10. Milling-specific data is described in ISO 14649-11 and ISO 14649-111. Data models for other technologies, such as turning and EDM, will be described in successive parts as they are completed.

Programming in legacy languages such as ISO 6983 is not part of the data model. CNCs should be able to handle legacy programs in a separate subsystem.

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

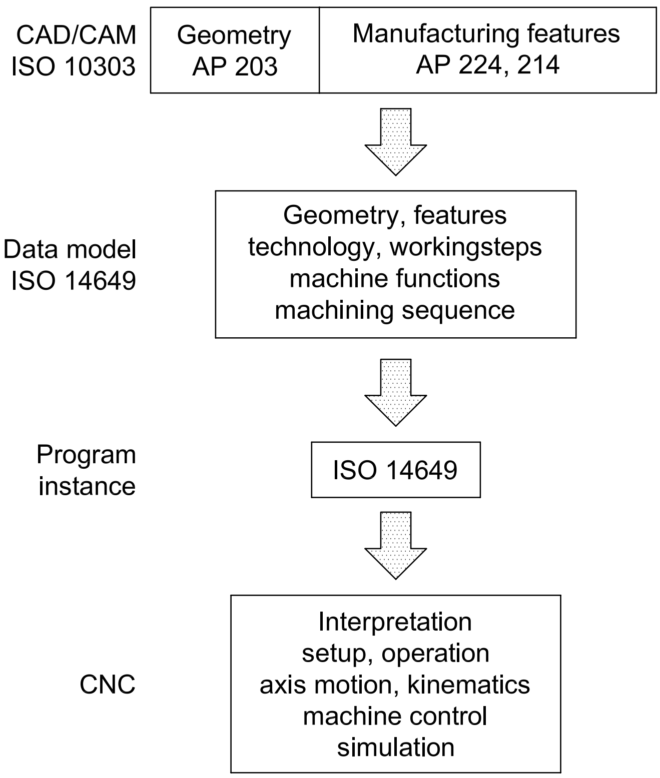


Figure 2 — General description of the data model

5.3 Program organization

A part program is described in a Physical File Format according to ISO 10303-21. The first section of the part program is the header section marked by the keyword "HEADER". In this header, some general information and comments concerning the part program are given, such as filename, author, date, organization, etc.

The second and main section of the program file is the data section marked by the keyword "DATA". This section contains all information about geometry, features, and manufacturing tasks. The content of the data section is divided into three significant parts: Workplan and executables with its technology description, Manufacturing features and Geometry description. A Project entity serves as an explicit reference for the starting point of the manufacturing tasks. Figure 3 shows the relationship between these significant parts of an ISO 14649 data set. The structure and the purpose of the date sets that define features and process data are described in the following sections. (See ISO 14649-10 for more detailed definitions.)

5.4 Project description

The project entity in the DATA section serves as a starting point for executing the part program. This instance should contain a main workplan that contains sequenced subsets of executables (executable manufacturing tasks or commands) and may also include information of workpieces to be machined.

5.5 Executables and the Workplan

Executables initiate actions on a machine and are ordered by the workplan. There are three types of executables: Workingstep, program structure, and NC function. Workingsteps represent the essential building blocks of manufacturing tasks. Each workingstep describes a single manufacturing operation using one cutting tool. An example of a Workingstep is the roughing operation of a pocket or the finishing operation of a region of a freeform surface. The detailed information of workingstep is referenced from the technology description.

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

A program structure is either a workplan or execution flow statements such as “parallel”, “if”, and “while”. A workplan combines several executables in a sequential or parallel order, or depending on given conditions if conditional controls are used.

The order of execution of manufacturing operations is given by the order of executables. In order to change the sequence of operations, only this part of the program file has to be changed. The remaining definitions of geometry and technology are untouched. Intelligent controls may be able to optimise execution ordering, and generate approach and lift movements while guaranteeing a collision-free operation.

Besides Workingsteps, other NC function statements may be included in the sequence of the part program. These include the setting of a workpiece coordinate system or security plane, and auxiliary commands such as program stop, optional stop, or pallet indexing. Workingsteps and NC-functions may appear with conditional statements so that they may depend on run-time conditions. The possible NC function statements are defined in ISO 14649-10.

5.6 Workingstep and machining operation

This part contains a detailed and complete definition of all Workingsteps used in the workplan. The technological description includes tool data, machine functions, machining strategies and other process data. Included in this description are a definition of the workpiece and all features of the finished part. The association between features and Workingsteps is given, i.e. which Workingsteps belong to which feature. A complete technology description includes but is not limited to cutting width and depth, spindle speed, feed, finishing allowance, and tool used.

The description of the tools includes the tool dimensions, tool type, and other data used to identify the usage and conditions of the tool. All tool data for milling is specified in ISO 14649-111.

The technology description will be fairly large for many applications, and is intended to be manipulated by computers. If a human operator intends to manipulate such data, he should be guided through a graphic user interface.

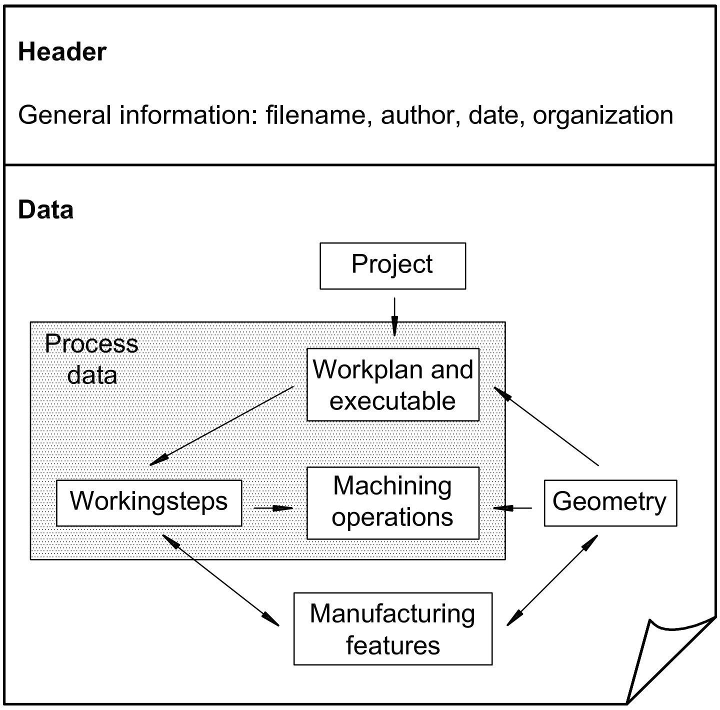


Figure 3 — Data structure of ISO 14649

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS Not for Resale

5.7 Geometric description

CAD systems and CAM systems have standardized their exchange of product data, especially the geometry description, with ISO 10303 data (ISO 10303-21, -42, and -43). All geometrical data for workpieces and manufacturing features are described using this ISO 10303 data format. This data should also be used directly by the CNC to avoid conversions between different data formats that may result in reduced accuracy. To enable an understanding of the part program based on ISO 14649 data model, examples are given in Annex E of ISO 14649-11:2002.

5.8 Manufacturing feature description

ISO 10303-224 (and ISO 10303-214) defines manufacturing features that aid the development of a machining process plan, but which are not necessarily incorporated into the process plan that results. ISO 14649 takes this one step further and defines features that are referenced within the process plan. ISO 14649 features are mapped from those in ISO 10303-224 when features are assigned to the machine tool that will produce them. The relationship is determined between the placement of the manufacturing feature and the axis and tool spindle configuration of the machine.

Annex A shows in more detail and examples how features are used and their relationship.

5.9 Implementation of the program data file

There are two methods for implementing an ISO 14649 program data file. The first is the direct use of the program data in ISO 10303 Part 21 physical file format. With this method, CNC machines must be able to handle the ISO 14649 ARM (Application Reference Model) directly, that is, the EXPRESS models defined in ISO 14649-10, -11, and ISO 14649-111. The second method is to implement the program file using the ISO 10303 AP238 AIM (Application Interpreted Model), which is a mapping of the ARM into the ISO 10303 Integrated Resources. Using this method, data transfers between design, process planning, and CNC can be accomplished using ISO 10303 SDAI (Standard Data Access Interface) or EXPRESS-X queries with data formatted in XML according to ISO 10303-28.

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Annex A
(informative)

Use and assignment of design features for machining geometry

In ISO 14649, features are used to describe the volumes to be removed by machining, to get the final form of the workpiece described by the design features in ISO 10303-224 and ISO 10303-214. This features are recognized by the CAD or the CAM System and contain the final geometry and tolerances.

In many cases the final feature geometry can be used directly, completed with attributes like offsets, the needed technology, tools and machining strategies. However depending on the used technology, planned operations as e.g. number of roughing and finishing cuts, the sequence of Workingsteps, quality targets like surface quality or shape enhancements additional machining features or additional machining features, must be created at the CAM system.

These features are based on the geometry of the raw part and the final geometry derived from the design features. Intelligent CAM systems are able to do this automatically when Operations and Workingsteps are specified by the planning engineer.

Manufacturing and Machining is planned with CAM systems, which add manufacturing information and provide CNC's with executable and interchangeable programs. CAM systems are typically located in the manufacturing planning department but they can be used also on the shop floor, or integrated in modern CNC-Controllers. This is shown in Figures A.1 and A.2.

Figure A.3 shows how machining features or volume removal features may be generated nominally, derived from design features, or created temporarily. Temporary features may arise from relationships between design features and part dimensions, as conveniences to streamline machining. CAM features may also depend on the setups.

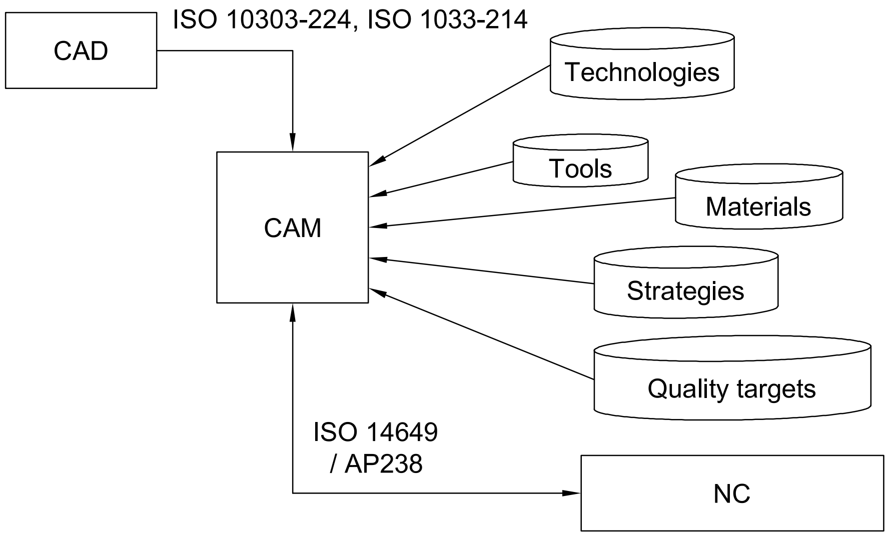


Figure A.1 — Design and process dataflow and associated standards

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

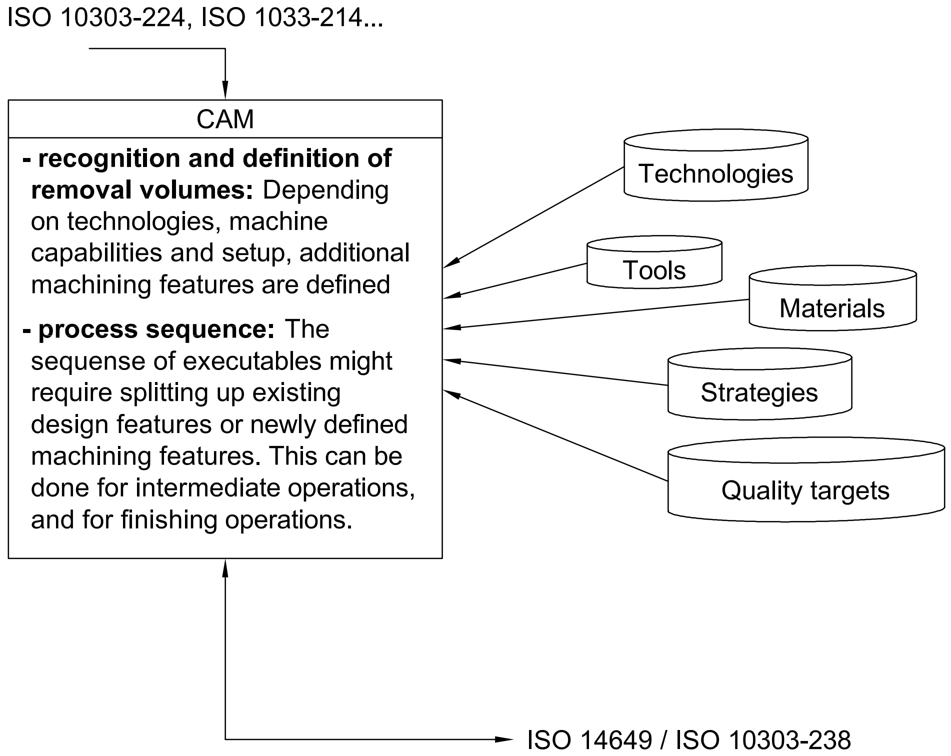
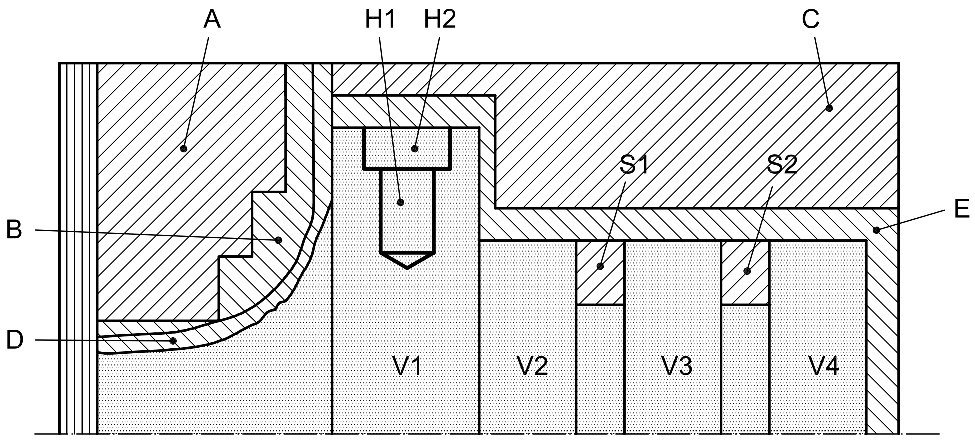


Figure A.2 — The role of the CAM- System in defining features and sequencing their machining

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale



CAM-features depend on the setup

— Left set-up features "**A**", "**B**"; "**D**"
— Right set-up features "**C**", "**E**", "**H1**", "**H2**", "**S1**", "**S2**"

CAM-Features depend on the volume to be removed

— New roughing shape **A** defined in CAM.
— New roughing shape **C** defined in CAM.
— Roughing of **B** can be based on the underlying design feature**.**
— For Finishing **D,** the equivalent design feature can be used.
— Instead of using four single elements for finishing the right setup, based on V1 to V4, only one element "**E**" is used for finishing. For this in CAM the additional element **E** is defined.

CAM-features depend on the design-features

— To realize the features H1, H2, and S1, S2, their equivalent design-features are directly referenced.

Figure A.3 — Example to show the combination and relation of features used for machining

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Annex B
(informative)

Application Activity Model (AAM)

The ISO 14649 Application Activity Model (AAM) describes the relationships between the design, programming, and manufacturing activities in which the standard plays a part. The AAM is informative, not normative. It represents the typical activities assumed by ISO 14649 and shows how this ISO 14649 fits within these typical activities, but does not prescribe these activities.

The AAM uses IDEF-0 nomenclature to represent these activities. A legend for reading IDEF-0 figures is shown in Figure B.1.

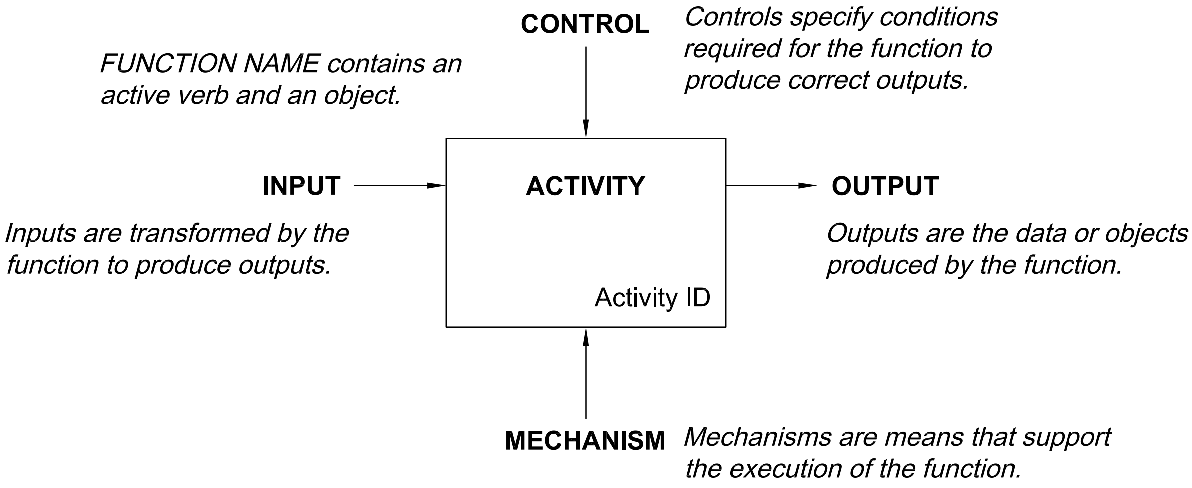


Figure B.1 — IDEF-0 Functional blocks

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

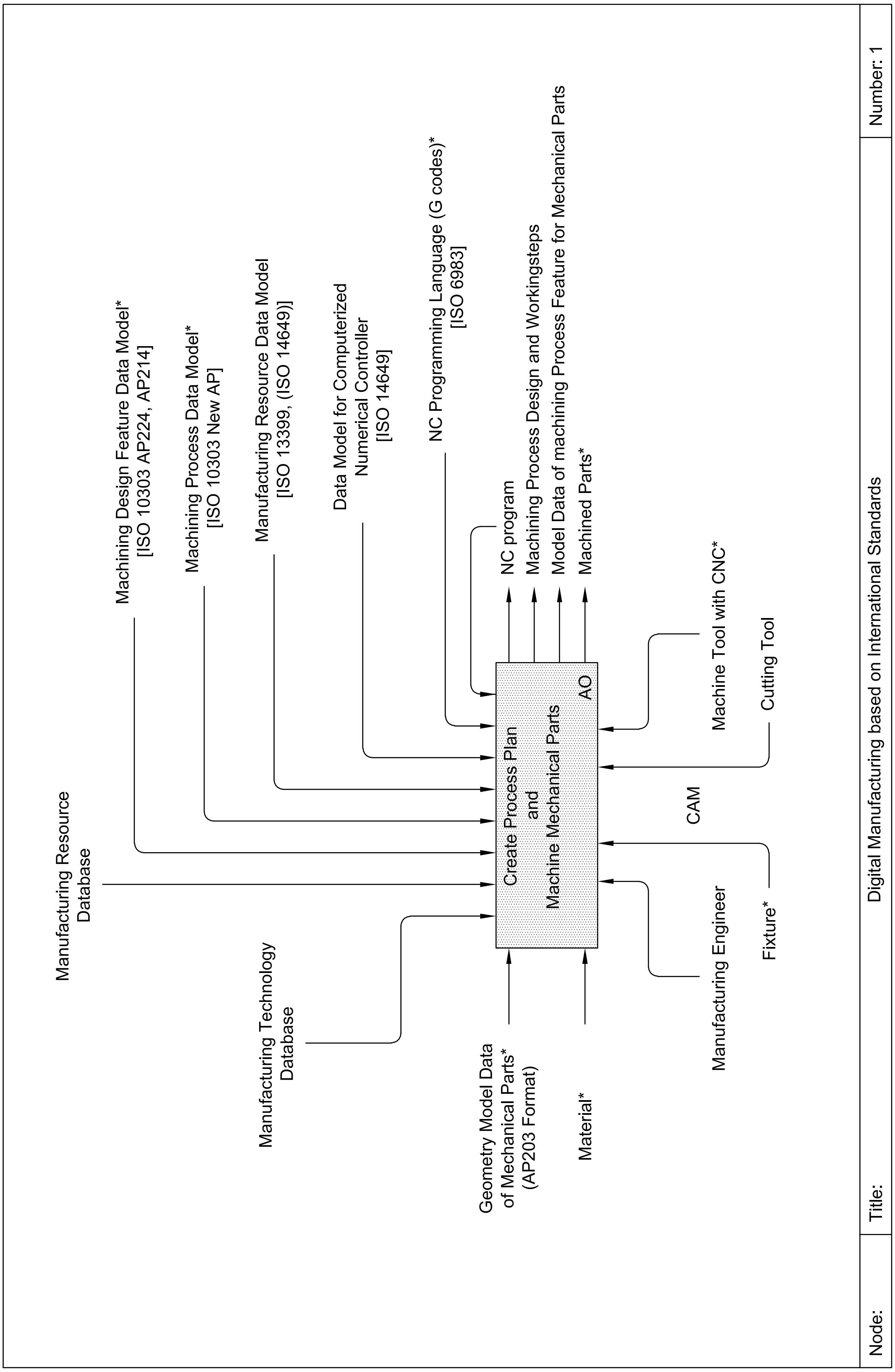


Figure B.2 — Application Activity — Model Overview

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

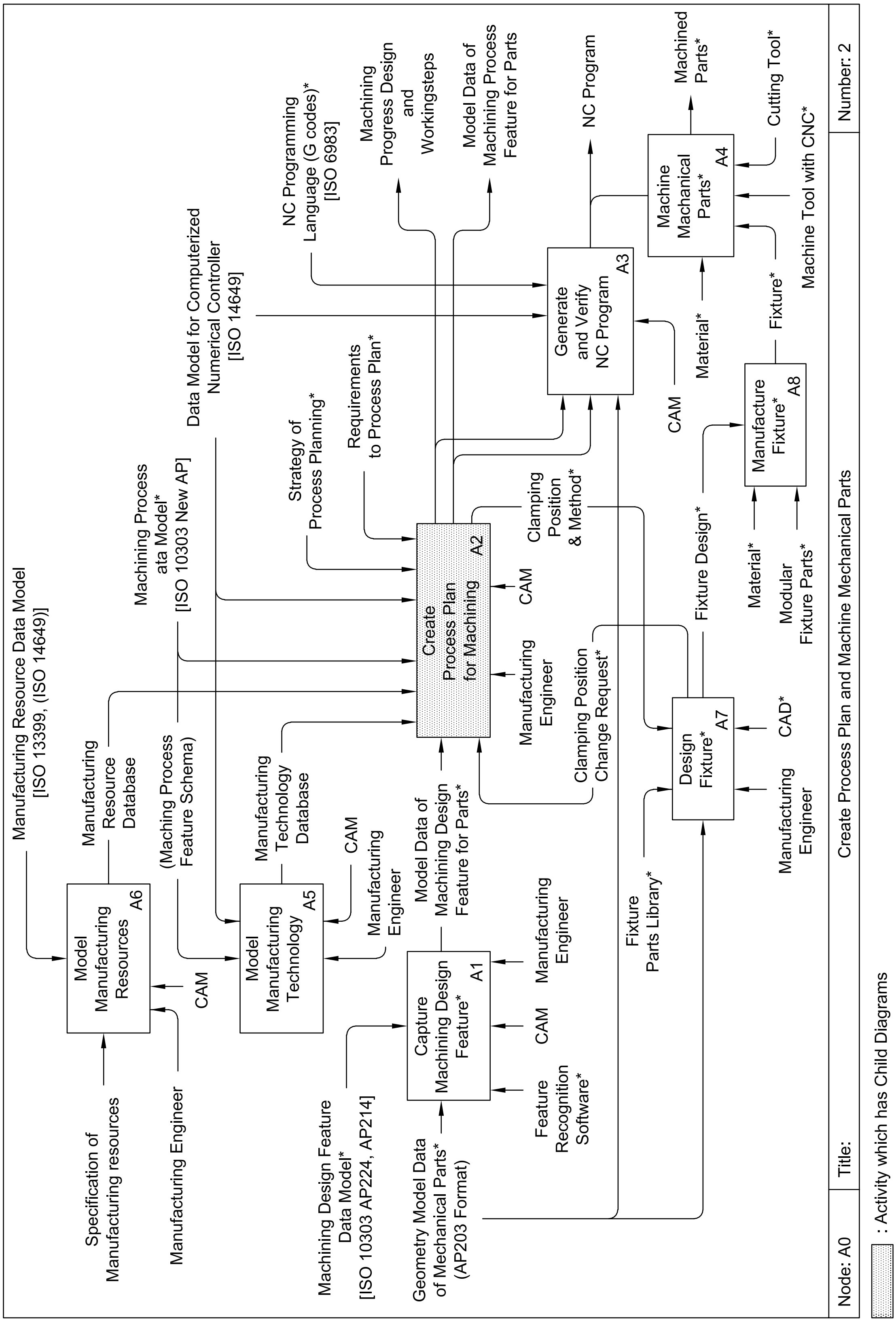


Figure B.3 — Design Process Planning

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

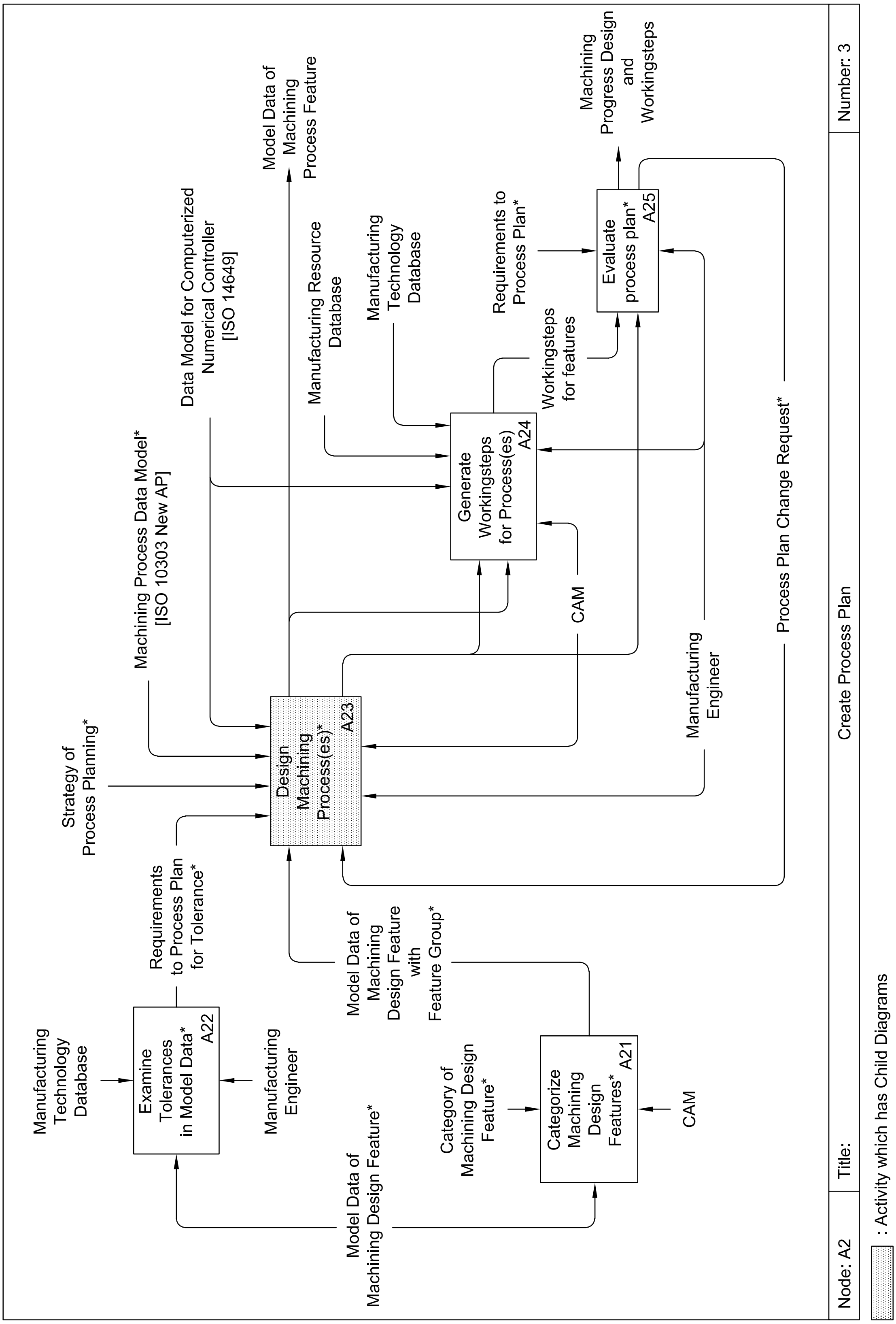


Figure B.4 — Plan Machining Processes

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

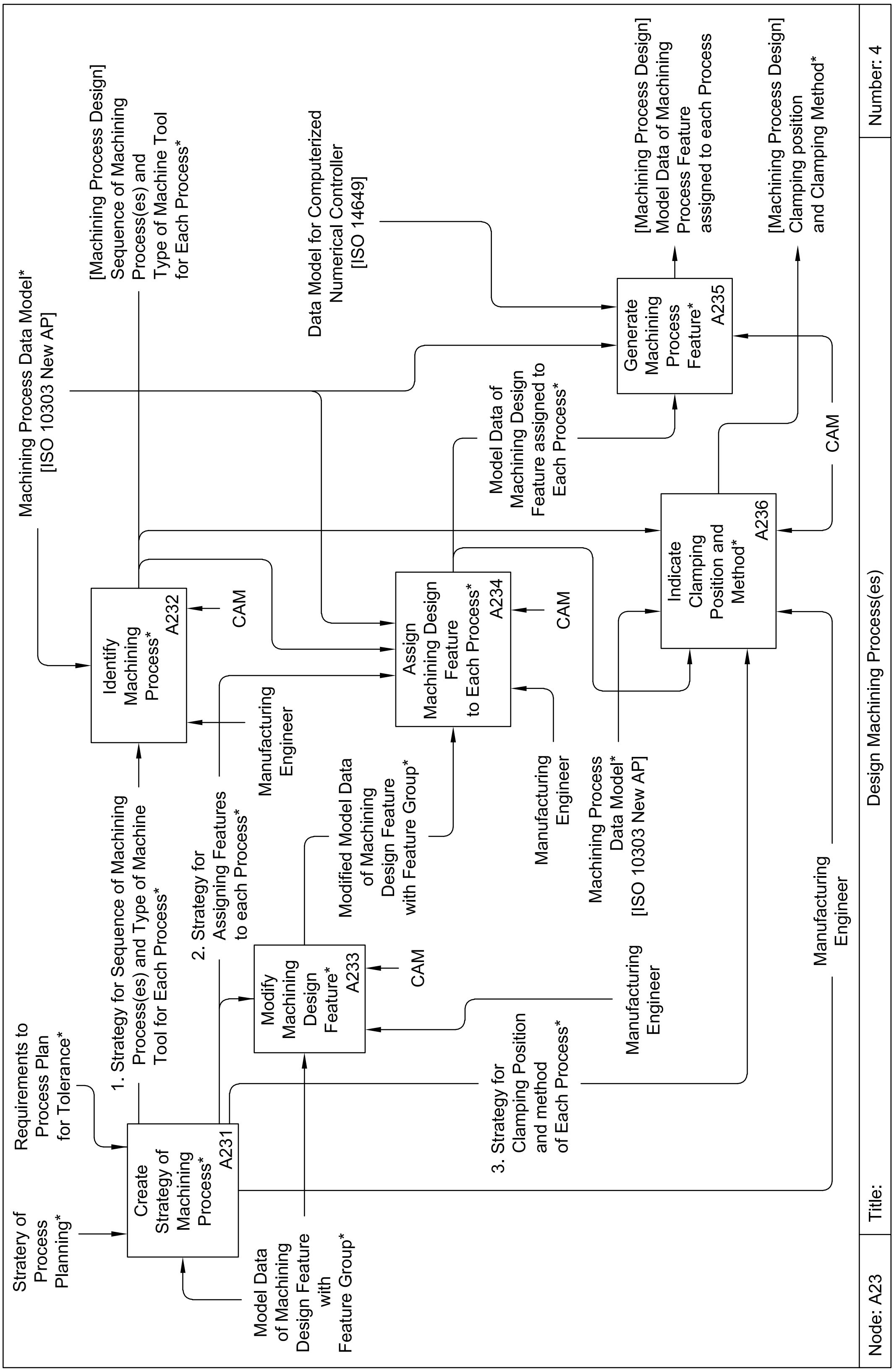


Figure B.5 — Design Machining Operations

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

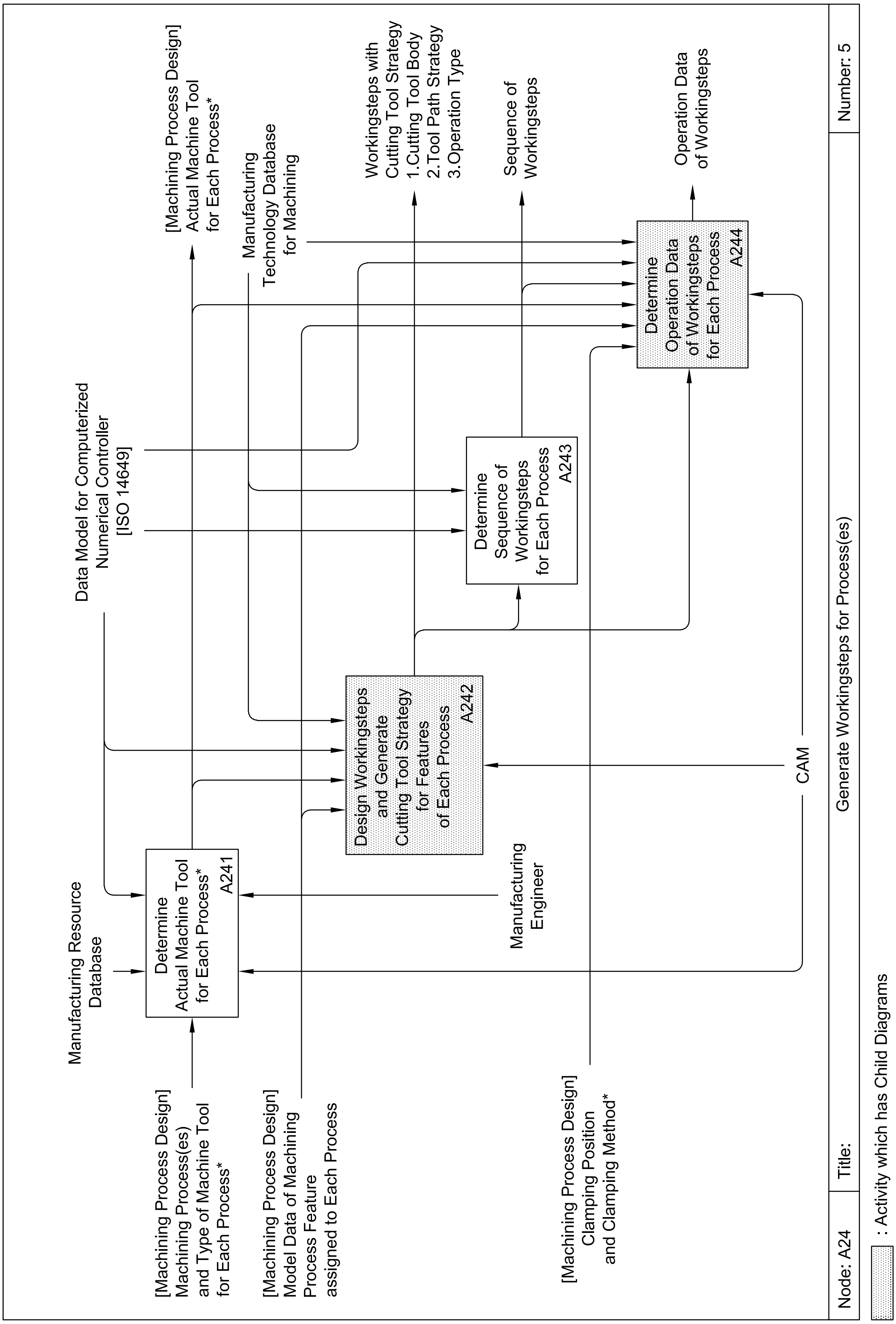


Figure B.6 — Generation of Workingsteps

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

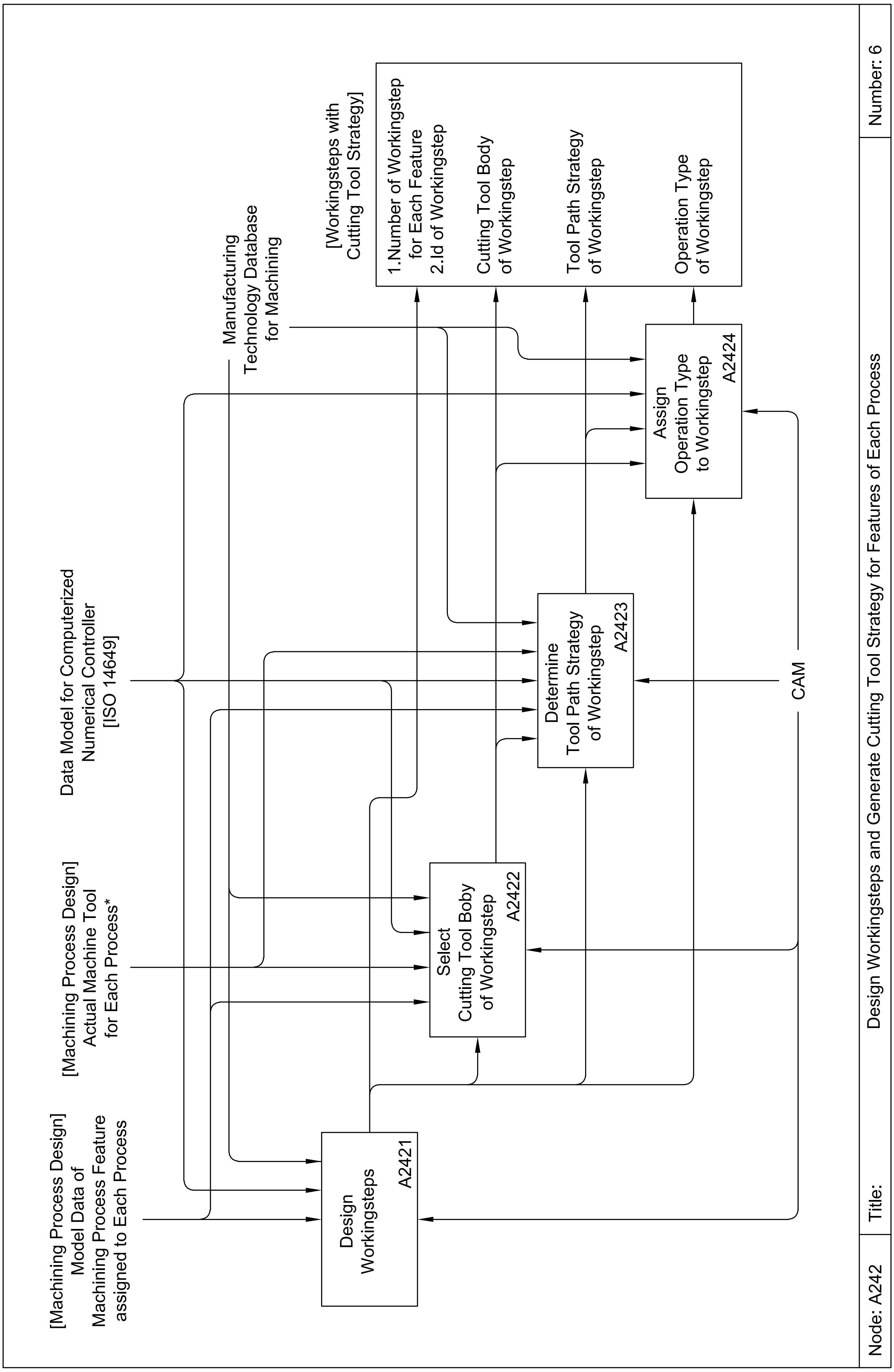


Figure B.7 — Design of Strategies

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS

Not for Resale

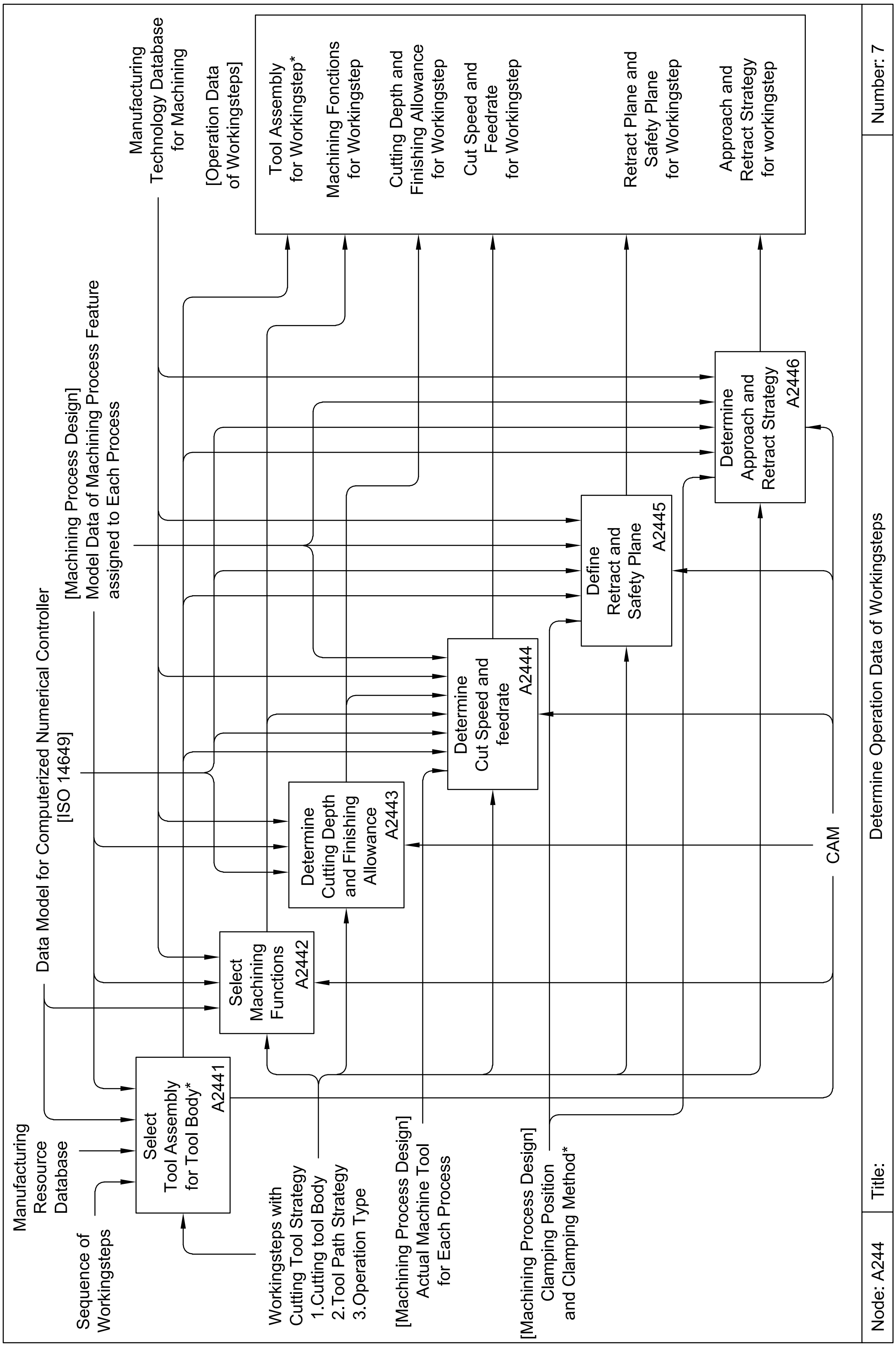


Figure B.8 — Detail Planning of Machining Operations

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Annex C
(informative)

Structure of ISO 14649 data model

An overview of the ISO 14649 data model structure is shown in Figure C.1. This diagram is a summary of the exact EXPRESS_G diagram.

ISO 14649 allows also the direct control of axis motions using a Toolpath, which is an attribute of Machining_operation.

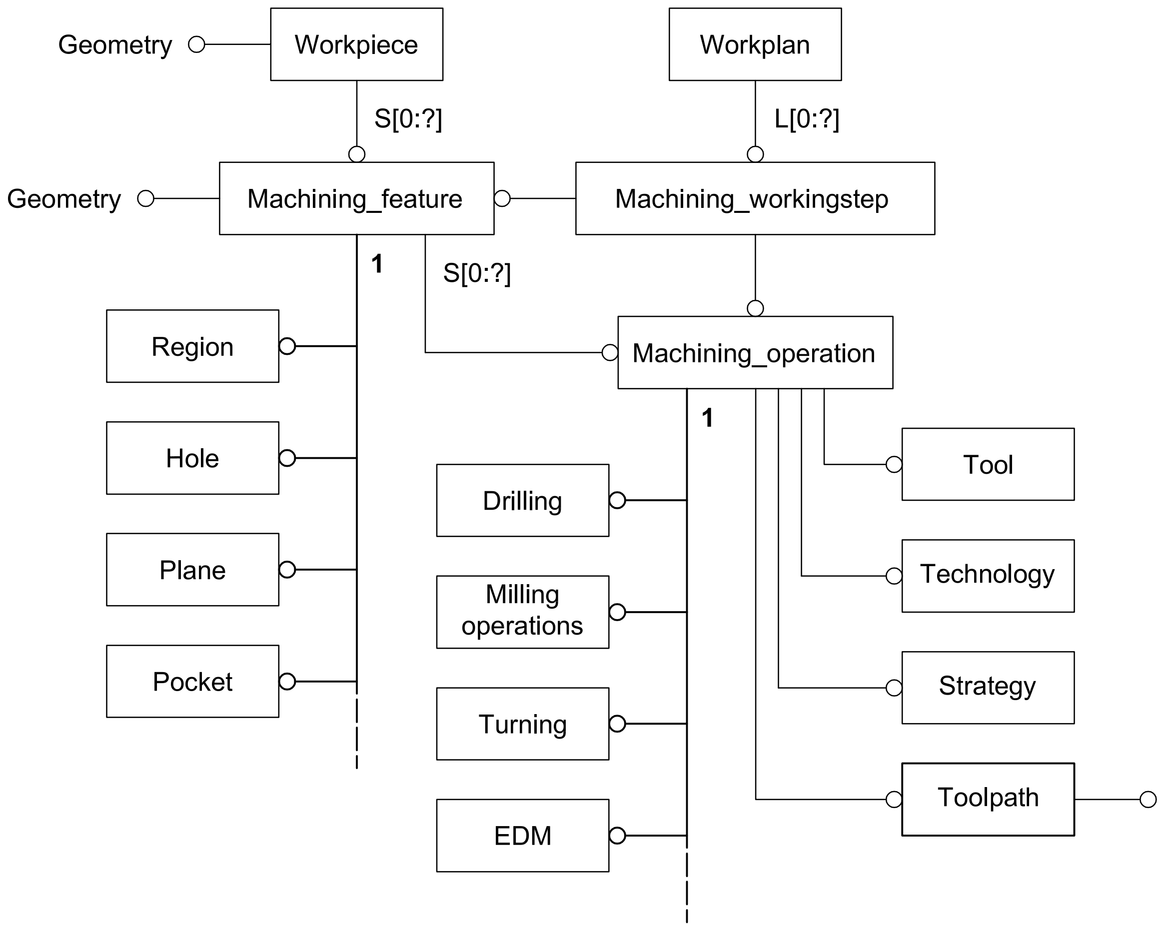


Figure C.1 — Overview of ISO 14649 data model structure

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Annex D
(informative)

Relationship between ISO 14649 and ISO 10303 (STEP)

D.1 General

Both the feature description and the model structures in ISO 14649 are harmonized with ISO 10303.These harmonization's will likely result in future revisions to ISO 14649.

Figure D.1 shows the shares of activities and responsibilities between ISO 14649 and ISO 10303 (STEP).

The data models within ISO 14649 are organized into levels

D.2 Levels for activities and responsibilities

Cooperation between SC 1 and SC 4 in ISO/TC 184 is organized into levels that define activities and responsibilities, as shown in Figure 1.

Level A deals with the modeling of the manufacturing technologies in the Application Reference Models (ARMs) with a precise description in EXPRESS schemas. Level A is the responsibility of ISO/TC184/SC 1/WG 7. Each machining technology will be covered by an individual model in a specific part. General process data valid for all technologies are included in the generic ISO 14649-10.

Level B deals with integration and compatibility in a ISO 10303 environment, based on the Application Interpreted Models (AIMs) that map the ARMs to the set of ISO 10303 integrated resources. Level B is the responsibility of ISO/TC 184/SC 4. For each machining technology a specific AP (Application Protocol, final numbering assigned by SC 4) will be developed. Each AP will contain the relevant General Process Data and the conformance testing as ruled by SC 4.

Level B covers also the data exchange and compatibility needs. Based on actual STEP standards, different data formats can be used in the data bases and to transfer exchangeable data to the CNC controllers, such as ISO 10303-21, ISO 10303 SDAI Database and the most actual and advanced ISO 10303 Data Server with EXPRESS-X queries and data formatted in XML (ISO 10303-28).

Level C deals with adoption software, which is the implementation of Level A or B in controllers. CNC manufacturers or third parties are responsible for implementing Level C. Until the execution of workingsteps and their linear or conditional sequencing is supported by the basic resources of ISO 10303, this will be done with individual adoption software in Level C. Implementation depends on the used interchangeable data formats, mentioned under Level B. The direct implementation from Level A, based on EXPRESS Tools is only intended for first prototyping and testing of the model. It will be replaced by one of the methods of level B when this parts of ISO 14649 will be available.

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

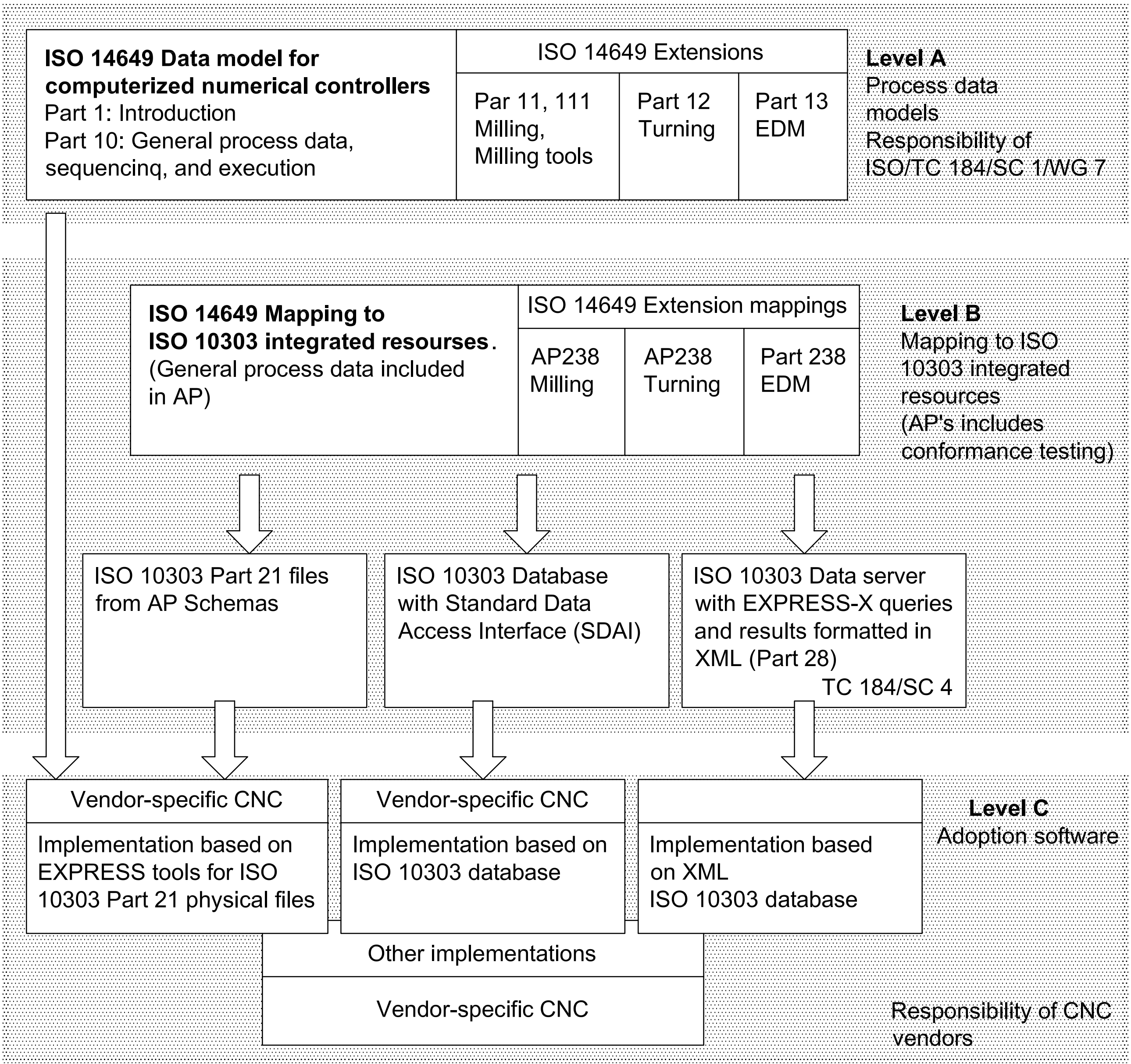


Figure D.1 — Distribution of activities and responsibilities between ISO/TC 184 SC 1 and SC 4

D.3 Publishing phases

The publishing of ISO 14649 will be done in three phases.

Phase 1 includes Part 1, "Overview and fundamental principles," with the Application Activity Model (AAM) and a scenario as informative annexes; ISO 14649-10, "General Process Data," which contains the Application Reference Model (ARM) for process-independent technology data and executables for linear and conditional sequencing; and ISO 14649-11 and ISO 14649-111, "Process Data for Milling," and "Tools for Milling," which contain the ARMs for milling process data and milling tools, with examples as annexes.

Phase 2 includes the AIM schemas corresponding to Parts 10 and 11 and the Application Protocol's for the milling technology.

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Phase 3 includes all other parts for the needed key technologies and the language bindings and libraries for implementation in CAM-systems, Front-end-systems for existing CNC-controllers and new CNC-controllers with full integration of ISO 14649.

D.4 ISO 10303 Application Interpreted Model (AIM) for milling

AP238, as technology specific Application Protocols are based on the ISO 10303 Application Interpreted Model (AIM) for milling and the other main technologies). In ISO 10303, the information model for an application is used by interpreting the concepts of the application in terms of a fixed set of concepts called “generic resources.” This interpreted form of the application's information model is called its “Application Interpreted Model”, or AIM. The use of an AIM makes it feasible to share application information through a database implementing the ISO 10303 generic resources, without having to modify the underlying structure of the database.

D.5 Adoption software

To make implementation of the new data model easier and unique, which warrants unambiguous data exchange and operations, language bindings and libraries are under development and will become part of the standard. At the time being this adoption software is developed by third parties or control manufacturers and lies under their responsibility.

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Annex E
(informative)

Scenario

This hypothetical scenario is intended to illustrate the life cycle application of ISO 14649 to a manufacturing enterprise. It is a vision of the future of manufacturing data transfer as intended by this International Standard.

E.1 Data flow

The General Automotive Corporation (GAC) has facilities in Austria and Brazil that rely heavily on CNC machining centers to produce automotive engine and transmission parts. Parts are designed in Detroit using CAD software that generates ISO 10303 AP 203 output. GAC's process engineers take the resulting AP 203 designs and develop process plans for each part. Some portions of the processes include CNC machining, and ISO 14649 output files are generated for the CNC machines.

The Austrian and Brazilian facilities each will produce some of the target parts, and the ISO 14649 programs are provided electronically to them. Each facility uses machining centers from different manufacturers and with different capabilities, although all of them support ISO 14649 input. During initial production runs, the programs are tested at each facility and the parts are verified to be within the tolerances specified.

E.2 Machine commissioning

One of GAC's suppliers has just purchased new CNCs that will be integrated onto the supplier's three- and four-axis machining centers. Most are identical models from Alphacon, but some supporting more advanced tool control are from Omegacon. All support ISO 14649 input, a GAC requirement.

Since ISO 14649 is relatively new, Alphacon and Omegacon decided to add support for this data transfer standard to an existing line of CNCs instead of building new controllers. The Alphacon CNCs are built from a proprietary software base, and their software engineers were given the task of adding the new data capability. The Omegacon CNCs are based on a published open architecture, and Omegacon contracted with a third party having both ISO 10303 and CNC expertise to add the new data capability to their open-architecture product line.

Both CNC vendors provide tools to tune performance, program auxiliary I/O functions, and calibrate and compensate the machine. Alphacon's CNCs are based on a proprietary platform, but their software tools run on a Windows 98 laptop connected to the CNC via a serial port. Omegacon's software runs directly on the CNC's HMI computer, which is operating under Windows NT. Both systems support the use of IEC 61131 languages for programming discrete I/O control.

Once the initial configuration of each machine is complete, the supplier runs a suite of custom ISO-14649 programs to verify the static and dynamic performance of each machine using laser metrology and ball bar calibration setups. A second suite of ISO 14649 programs is run on each machine, verifying that the controllers properly execute Workingsteps.

E.3 Program download

At GAC's Austrian facility, the CNCs have been delivered and set up in the production area. The Alphacon CNCs are connected to the GAC factory LAN, and ISO 14649 programs can be downloaded using file transfer utilities running on PCs in the shop's CAD/CAM area. The Omegacon CNCs are also connected to the factory LAN, and the built-in Windows NT networking lets the programming staff copy programs to the CNCs as if they were any other computer on the network.

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Both the Alphacon and Omegacon controllers perform performance checks on ISO 14649 input programs. The Alphacon does this checking during the download. On the Omegacon, the checking can be done at any time, initiated by an operator at the machine or by the programming staff remotely. Performance checking ensures that the axes specified in the program are present, that their ranges are within the volume of the machine, and that the required tooling is present.

GAC's facility also includes many older machines equipped with Ycon CNCs that only understand ISO 6983 “G code” programs. These machines have been equipped with postprocessors running on separate PCs since GAC has switched their complete operations to ISO14649. These postprocessor PCs are integrated into the factory LAN, and allow programmers to download ISO 14649 programs. At the PC, these programs are converted into ISO 6983 format and executed using the Ycon serial download feature.

E.4 Machine setup

Prior to running the programs, machine operators load and fixture the part stock and set up coordinate system offsets. The Omegacon CNCs have bar code readers that allow machine operators to scan in the tags on the fixturing and stock. The scanned tags are compared with the ISO 14649 program to verify that the required resources are present. The Alphacon CNCs do not have this feature, so the machinists bring up a window on the CNC that lists the required resources and manually verify them.

With the Alphacon, part coordinate system offsets are determined through a traditional legacy interface, which combines axis jogging using a control panel with manual data input of ISO 6983 G code blocks. The Omegacon provides a portable pendant that allows machine operators to jog axes and use a small touch screen to set coordinate system offsets. Alternatively, the pendant can be used to enter G codes manually. However, the G code interface is provided only for staff used to old-style programming. It is only one of several means for the user to interact with an ISO 14649-compliant system. Internally, the G codes are mapped into the ISO 14649 data model which is typically hidden from the user.

Both vendors' CNCs also allow operators to directly enter ISO 14649 text directly, using any familiar text editor. GAC staff have found this useful when debugging programs or for training, but it is not common practice to use this when running jobs. As the Omegacon provides a comfortable graphical display, capable of rendering 3D workpiece views, the use of text input has virtually disappeared at these controllers.

E.5 Interactive program running

Program verification begins with the machinist running the program entirely in simulation. During simulation, a graphical animation of the tool path is shown superimposed on the working ISO 10303 geometry. The Omegacon simulation also includes solid modeling software from Ultrasim, which allows the machinist to pause the simulation and use the cursor to inspect feature dimensions.

Once the program simulation has completed, the machinist runs the program at a reduced feed rate, set at the CNC console graphically or with a knob, or at the pendant if available. The machinist has the option of viewing the ISO 14649 program while it is running, with the current working step highlighted. At the Omegacon, this highlighting is also mirrored in the 3D workpiece view so that the operator can anticipate which region will be milled next. The graphical simulation of the tool path can be shown simultaneously. Both the execution of the program and its simulation can be paused, stepped, and resumed independently. Typically, the simulation is single stepped at the working step level, while the execution is initially paused. When the machinist is satisfied that the step will proceed as desired, program execution is initiated for that step. The simulation of the next step is run, and the process continues until program execution has finished or is aborted. At any time the CNC can be put into a temporary manual mode, in which the machinist can manually or graphically move axes, enter legacy G codes, or input ISO 14649 statements.

--`,,,`-`-`,,`,,`,`,,`---

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

E.6 Interactive programming

In some cases the input program is insufficient and must be modified. While modifications ultimately need to be reflected back to the designers or process planners, machinists can be given the authorization to interactively test alternatives on the machine. The Omegacon CNC provides a conversational programming utility that uses icons to represent Workingsteps. Icons can be arranged in any order, with conflicts (e.g. a shallow pocketing occurring deep in the material) highlighted. Existing ISO 14649 programs can be shown in their iconic versions, and the machinist can move Workingsteps around to exploit material stiffening or other properties that may be difficult to optimize in simulation during the process planning stage. Workingsteps can also be deleted or inserted, e.g. to add stiffeners or reference datum surfaces for part indication. The iconic program is equivalent in all respects to the downloaded textual program: it can be executed, single stepped, and simulated.

Omegacon's conversational programming can also be applied to legacy machines programmed in ISO 6983. In these systems, feature-based icons can be manipulated graphically, and are converted to blocks of ISO 6983 code making up a complete program that can be saved to disk. This allows businesses to experiment with an iconic representation of ISO 14649 as an alternative to G code programming, while still executing G codes on older machines.

This way of working has been found especially useful when optimizing technological parameters during the setup of a new NC program. ISO 14649 allows both for a rather high-level description of manufacturing features and for a detailed description of tool paths and cutting conditions, if needed. This way, once the parameters have been optimized at the machine, they can be stored in all detail in the very same data model which was handed down from the process planning department.

This mechanism allows to give feedback to the planning department in a consistent manner. At the same time, it allows the planning department to prescribe exact tool paths in cases where the CAD/CAM system's output has been found to be more efficient than Omegacon's internal feature resolution and path generation. Still, each of the individual tool movements can be traced back to the manufacturing feature to which it belongs, thanks to the hierarchical structure of ISO 14649 models. While it may come at different levels of detail, all data is part of one consistent model. This has greatly helped GAC to improve its overall information management and to avoid double work when re-using programs.

E.7 Remote interface to the enterprise

ISO 14649 does not specify the means by which data gets to or is read from CNCs. As described in the preceding section on Program Download, vendors are free to provide whatever means their customers desire, e.g. floppy disks, serial communication, or local area networking. The same is true for remote control of machine operation, uploading of machine data such as tooling information, and access to maintenance information such as coolant and lubrication levels.

The Alphacon file transfer tools provide a means for getting ISO 14649 programs to the machine, but Alphacon does not provide any tools for initiating execution of the program from a remote location. Programs must be run by a machinist at the console. The same is true for the status of consumables such as coolant and lubrication.

The Omegacon controller appears as any other computer in the factory LAN, and files can be copied to the controller as they would any other computer. Additionally, Omegacon provides an application that can be run on any desktop machine that lets an operator select a command file from a browse able list, open it, and run it remotely. The status of the machine is continually updated. GAC policy is that remote operation of a machine can only be done under strictly controlled conditions in the interest of safety. Password protection on the Omegacon software ensures that only authorized staff can initiate remote programs.

Omegacon also builds into each CNC an HTTP server similar to that found in many networked printers. GAC staff can select each Omegacon CNC as the target for their Internet browser, and a page is displayed showing the status of any program that may be executing, the tools that are present in the carousel, and the levels of coolant and lubrication. GAC engineers have supplemented the Omegacon material with their own software that further shows the maintenance history of the machine, and includes digital archival prints of the mechanical and electrical drawings.

© ISO 2003 — All rights reserved
Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

E.8 Extending functionality

The operation of the GAC facility in Brazil is similar in most respects to that in Austria. However, GAC/Brazil also serves as a testing site for new technology. Here, some CNCs are purchased with a development environment that lets programmers modify and extend built-in ISO 14649 Workingsteps. The open-architecture Omegacon used heavily by GAC/Brazil's researchers is based internally on the Open Modular Architecture Controller (OMAC) application programming interfaces (APIs). These APIs are a comprehensive functional interface to all CNC data and operations. Programming in the C language, GAC engineers can call the APIs to effect axis motion, activate tooling, associate data logging functions with internal or external triggers, and access custom sensors to affect process parameters such as feed and speed.

GAC/Brazil recently finished integrating a non-contact probe intended for on-machine inspection. The code for this has been converted into a working step consistent with the ISO 14649 approach, although it is not part of the current standard. The probing working step has been loaded onto the production Omegacons as a “plug in” extension. Now, ISO 14649 programs supplemented with this new working step pass the conformance checking phase and can be run in production.

GAC/Austria would also like the non-contact probing extension. Their Alphacons do not support extensions, but they also have several German Zedcon open-architecture CNCs based on the European Open System Architecture for Controller Applications (OSACA) APIs. The engineers in Brazil have provided their Austrian coworkers with the source code to their Omegacon implementation, and are working together to port the code to the OSACA implementation. This will enable GAC to run the same ISO 14649 programs with non-contact probing extensions at both facilities.

GAC's participation in ISO/TC 184/SC 1/WG 7 has led to the proposed addendum to ISO 14649-11 of the standard, to include this new working step and some others that have proven useful to GAC and other automotive and aerospace manufacturers.

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Bibliography

[1] ISO/IEC TR 10000-1, *Information technology — Framework and taxonomy of International Standardized Profiles — Part 1: General principles and documentation framework*

--`,,,`-`-`,,`,,`,`,,`---

© ISO 2003 — All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS Not for Resale

ICS 25.040.20

Price based on 28 pages

© ISO 2003 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale