Perspective of Machine Tool Data Model for ISO 14649-110

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Overview of the current status of ISO 14649

ISO 14649	Title of documents	Edition	Status
Part 1*	Overview & fundamental principles	1	IS
Part 10*	General process data	1	IS
Part 11*	Process data for milling	1	IS
Part 12*	Process data for turning	1	IS
Part 13	Process data for wire EDM	2	WD
Part 14	Process data for sink EDM	2	WD
Part 16	Process data for inspection	2	WD
Part 17	Process Data for rapid prototyping	2	WD
Part 110	Machine tools for general process	2	NWIP
Part 111*	Cutting Tools for milling	1	FDIS
Part 121*	Cutting Tools for turning	1	IS

Background of Part 110

- ARM: Requirement or Functional Model like Part 111 & 121 compared with catalogue model ISO 13399
  - ASME B5.59-2 is a kind of the catalogue model for machine tools
  - ISO 14649 Part 110 is a kind of the requirement model for machine tools
- Necessities addressed and unanimously agreed in ISO TC184/SC1 Beijing Meeting, October 2005
- Related with Machine Tool *(a kind of catalogue, close to PLIB)* data model under development by ISO TC39, and for *Test codes*, *Modular units*, *Property* by ASME B5.59
- Need to be harmonized with ISO TC39
- Joint Meeting between ISO TC184/SC1/WG7 and ISO TC39/SC2 held in Busan Korea, May 11, 2006
- According to the resolution (Resolution 202)of Hershey meeting, SC 1/WG 7 convener is expected to provide a first draft of the NP 14649-110 for comments by January 2007
- A first draft of NP 14649-110, titled “Machine tool data model for general manufcturing processes,” was distributed for committe at January 25, 2007

Scope of ISO 14649 Part 110 : Machine tools for general process

- Scope & main usage
  - General and functional requirement data model for machine tools to execute a STEP-NC part program
  - To Specify machine tool type and specification to execute STEP-NC part program, which can be used as a means for selecting actual machine tools to be used for executing the STEP-NC part program in the shop floor
- The main interests that might benefit from or be affected
  - Developer side: CAD/CAM Vendors, Machine Tool Builders, CNC vendors,
  - End user side: CAD/CAM system end users, Machine tool end users, CNC users
  - System Integration: SI Software developers
- Others usages
  - Digital manufacturing (STEP-Manufacturing)
    - ✓ Process planning / Machine programming
    - ✓ Virtual machining
    - ✓ Virtual NC
    - ✓ Factory flow simulation
    - ✓ Workspace design
  - Performance verification and tracking/process variability/quality control
  - Machine intelligence (self-knowledge)
  - Education

References for machine tool data model

- Existing standards related to the machine tool
  - Standards from ISO TC39
    - ✓ The standards for interchangeability between components
      - Headstock, spindle, column, base, table, rotary table, etc.
    - ✓ The standards for testing machine tools
      - Test method, Test code, Test condition, etc.
  - ASME B5 : Catalogue model
    - ✓ Draft B5.59-1: "Data Specification for Machine Tool Performance Tests," March 2005
    - ✓ Draft B5.59-2: "Data Specification for Properties of Machine Tools for Milling and Turning", June 2005
- Research for the machine tool kinematics
  - NIST model
  - POSTECH model: Functional model for complex machine
    - ✓ Developed for TurnSTEP, Type 3 STEP-NC system for turning developed by POSTECH
    - ✓ Mainly for configuration (structure, kinematics) of machine tools
  - Suk-Hwan Suh, et al, "Modeling and Implementation of Internet-Based Virtual Machine Tools", IJAMT, 2003
  - H. Shinno and Y. Ito, "Generating method for structural configuration of machine tools (1st paper Generation using variant design using directed graph), Transaction of JSME, 50 (449), pp 213-221, 1984
- Machine tool catalogues from various machine tool builders

ISO standards for modular units for machine tool constructions

ISO No.	Year	Title
ISO 2562	1973	Modular units for machine tool construction -- Slide units
ISO 2727	1973	Modular units for machine tool construction – Headstocks
ISO 2769	1973	Modular units for machine tool construction -- Wing bases for slide units
ISO 2891	1977	Modular units for machine tool construction -- Centre bases and columns
ISO 2905	1985	Modular units for machine tool construction -- Spindle noses and adjustable adaptors for multi-spindle heads
ISO 2912	1973	Modular units for machine tool construction -- Multi-spindle heads -- Casing and input drive shaft dimensions
ISO 2934	1973	Modular units for machine tool construction -- Wing base for columns
ISO 3371	1975	Modular units for machine tool construction -- Rotary tables and multi-sided centre bases for rotary tables
ISO 3476	1975	Tenon drive and flanges for mounting multi- spindle heads
ISO 3589	1975	Modular units for machine tool construction -- Integral way columns
ISO 3590	1976	Modular units for machine tool construction -- Spindle units
ISO 3610	1976	Modular units for machine tool construction -- Support brackets
ISO 3970	1977	Modular units for machine tool construction -- Integral way columns -- Floor-mounted type

ISO Standards for Test code for machine tools

Part	Year	Status	Title
1	1996	IS, Ed.2	Geometric accuracy of machines operating under no-load or finishing conditions
2	2006	IS, Ed.3	Determination of accuracy and repeatability of positioning numerically controlled axes
3	2006	FDIS, Ed.1	Determination of thermal effects
4	2005	IS, Ed.2	Circular tests for numerically controlled machine tools
5	2000	IS, Ed.1	Determination of the noise emission
6	2002	IS, Ed.1	Determination of positioning accuracy on body and face diagonals
7	2006	IS, Ed.1	Geometric accuracy of axes of rotation
8		CD	Determination of vibration levels
9	2005	IS, Ed.1	Estimation of measurement uncertainty for machine tool tests according to series ISO 230, basic equations

ASME B5.59-2

- Purpose of B5.59-2
  - Define an electronic data format and associated information model for *__properties of machine tools for milling and turning__.
  - *Notice: Properties describe the __performance__ and __capabilities__ of a machine at an arbitrary instance in the machine's life-cycle, e.g., during specification, after acceptance testing, or at any time during operation.
- Usage
  - The Standard facilitates the exchange, archiving, and use of unambiguous machine tool data.
  - The specified information model can serve as a basis for generating database schemas and database calls
- Out of scope
  - Kinematics & geometry
- Analysis
  - Too detail model for machine tool and it's part

  → Functional data model for executing STEP-NC part program is necessary
  - Kinematics and geometry information are necessary.
    - ✓ STEP AP203 can be used as a geometry model for machine tool and it's part
    - ✓ Kinematics is necessary for machining simulation with STEP-NC part program
  - Data model for turning and milling machine tool

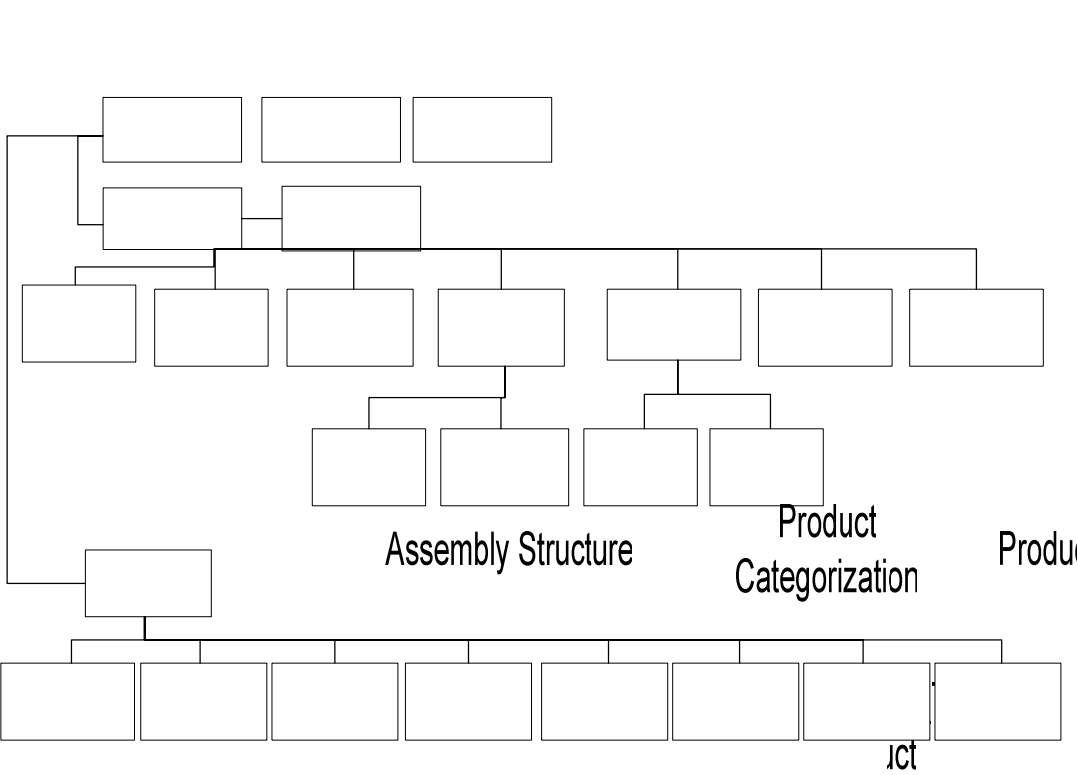
  → Data model must be extended to include other types of machine tools such as complex machine tools

Progress of machine tool data model

- Harmonized with the ASME B5.59-2
  - Machine tool data model at Hershey (2006. 10) meeting was based on the Postech model
  - This version (2007. 03) is harmonized with ASME B5.59-2
    - ✓ Overall structure is similar as ASME B5.59-2
    - ✓ Entity name, attribute name are harmonized with the ASME B5.59-2
  - Currently, data model is limited to the machine tool with cutting tool such as milling machine, turning machine, complex machine tool and so on

- Data model for kinematics added
  - Kinematics information is necessary to NC simulation, process planning, factory flow simulation and so on.
  - Especially for the simulation of the execution of STEP-NC part program, kinematics of the used machine tool is necessary.
  - Geometry information of the part can be represented as simply block, cylinder or STEP AP 203 geometry (advanced_brep_shape_representation)
  - Assembly and kinematics information are added

Overall structure of machine tool

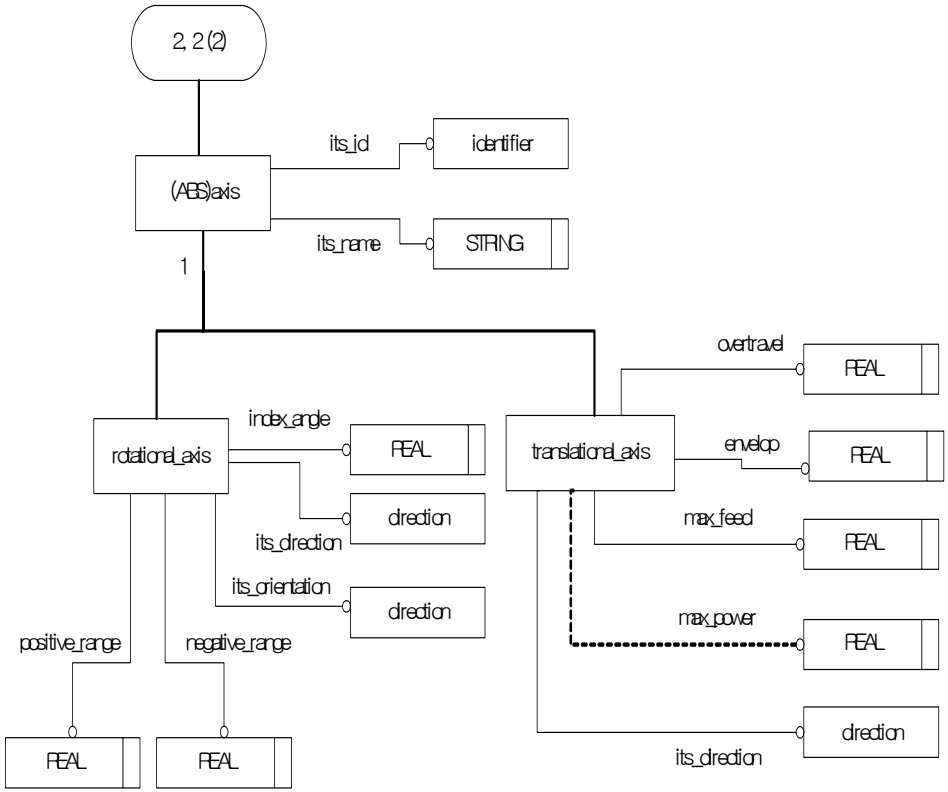


Overall structure of machine tool (2006. 10)

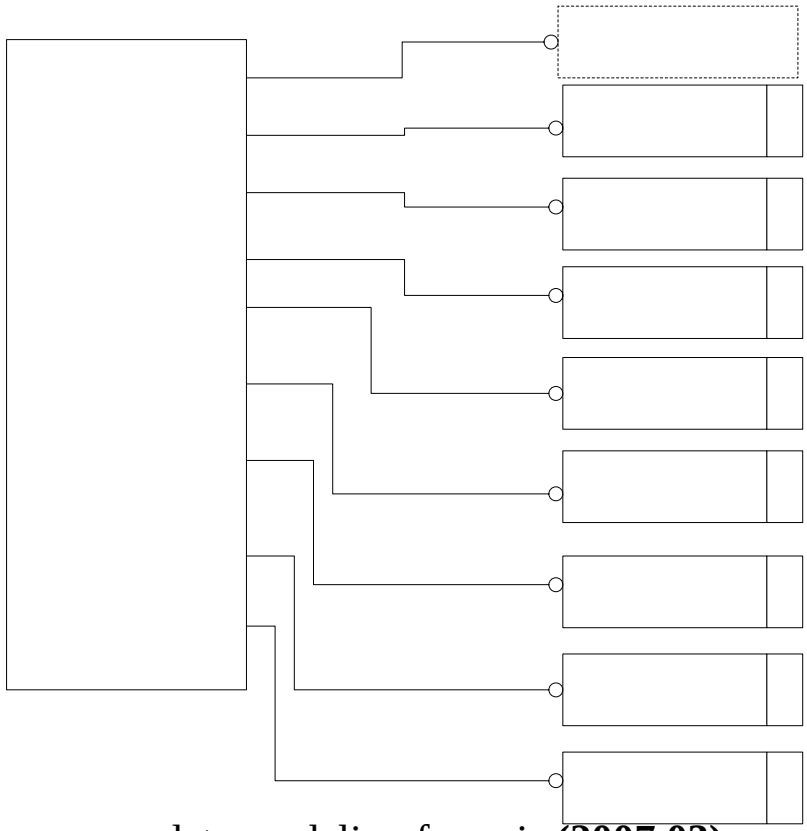
Overall structure of machine tool (2007. 03)

Milling_Machining Turning_Machining Wire_EDM_Mach Sunk_EDM_Mac

Machine tool data model details : Axis

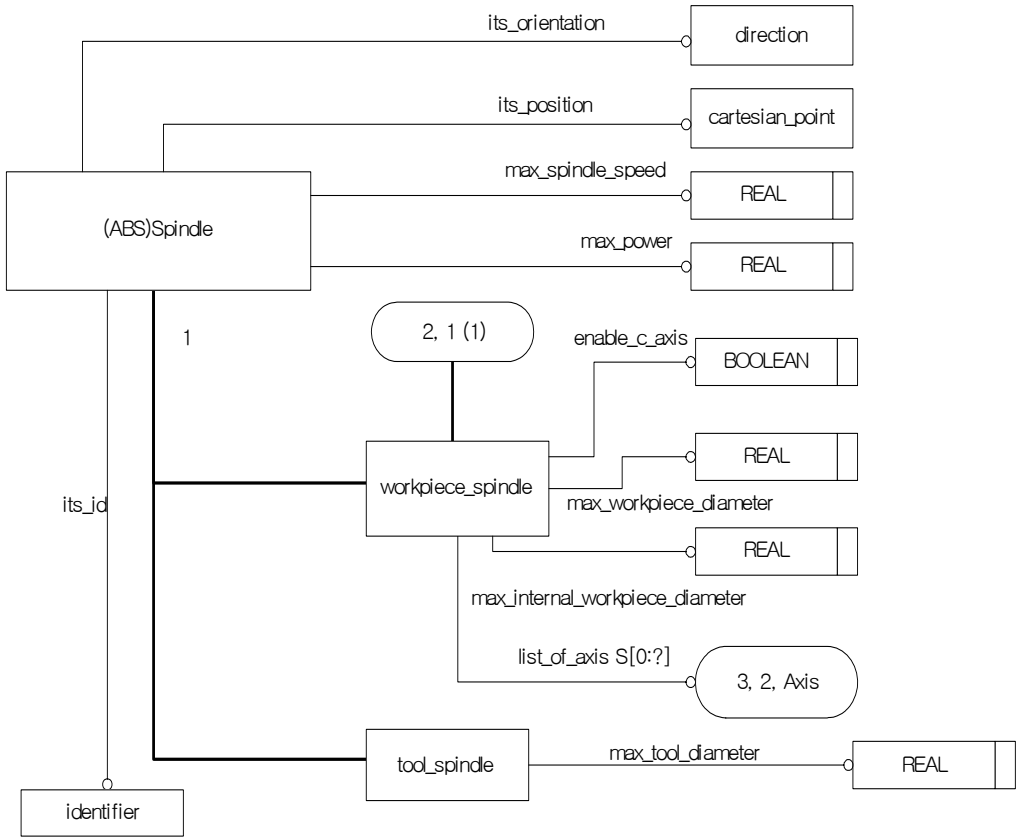


data modeling for axis **(2006.10)**

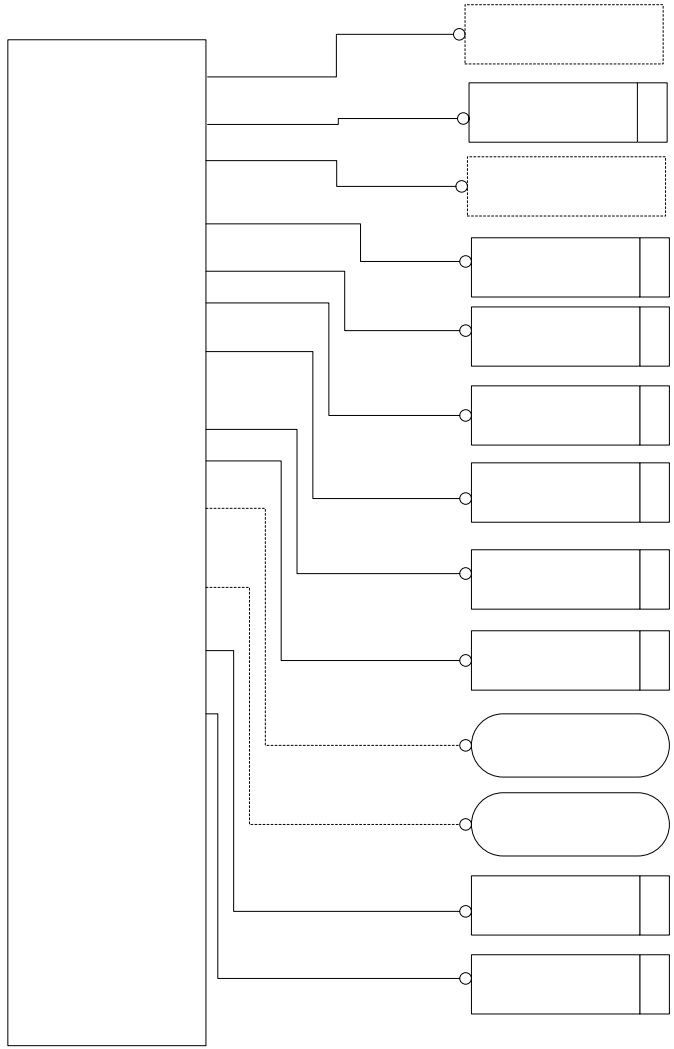


data modeling for axis **(2007.03)**
based on ASME B5.59.2

Machine tool data model details : Spindle



data model for spindle **(2006. 10)**

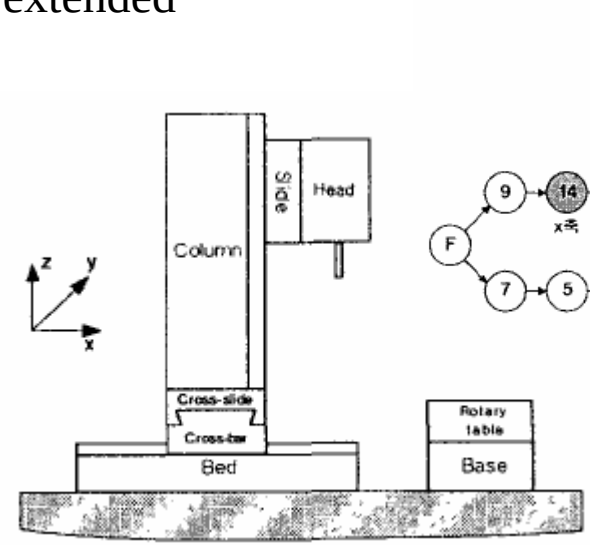


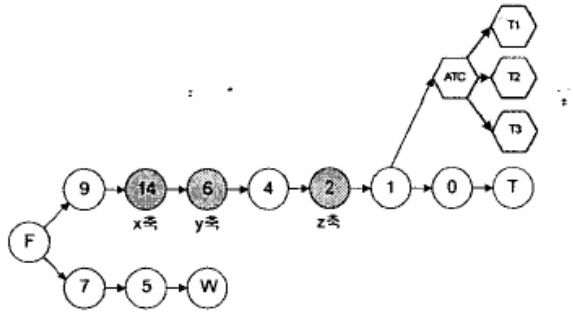
data model for spindle **(2007. 03)**

Assembly model

- Assembly model
  - The machine tool can be built up by assembling the geometrical units.
  - Mechanical units of machine tools can be classified into 9 basic mechanical units: spindle, slide, swivel slide, cross-slide, column, table, base, column base, and bed and they can be combined under specific constraints
  - ➔ a connectivity graph scheme can be used to represent the assembly sequence for the kinematic components.
  - ➔ Basic mechanical units can be extended

	구조모듈	구조모듈명		구조모듈	구조모듈명
1		Spindle	5		Table
2		Slide	6		Cross slide
3		Swivel slide	7		Base
4		Column	8		Column base
			9		Bed

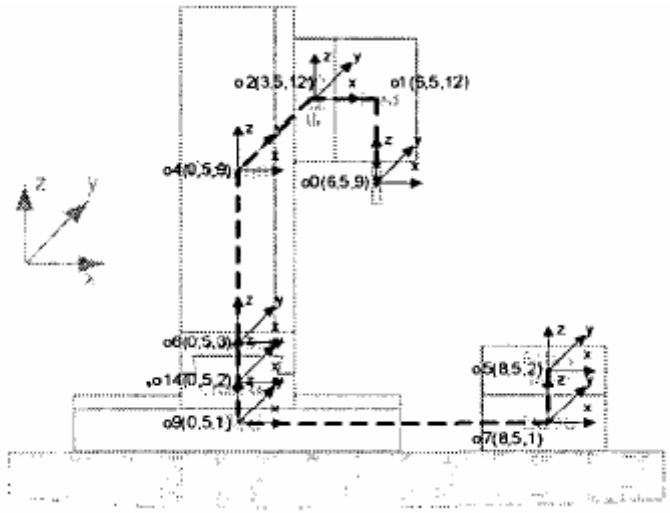




Kinematic model

- Kinematic model
  - The machine tool is structured as a kinematic chain of mechanical components, and functions by the translational and/or rotational movements
  - Using 4x4 homogeneous transformation matrix can be used to represent the kinematics between each components.

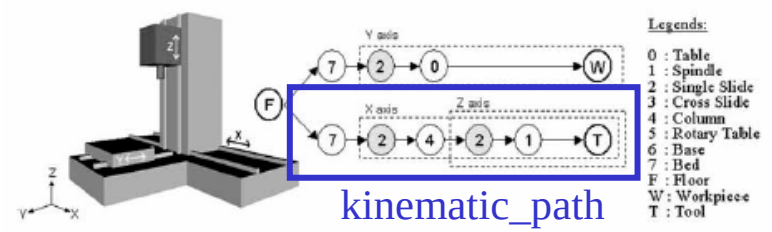
Kinematic chain of TP		Kinematic chain of WP	
$Bed_{(9)}$	$K^9_9 = I$		
$Cross\text{-}bar_{(14)}$	$K^9_{14} = K^9_9 \cdot T_{xx}$		
$Cross\text{-}slide_{(6)}$	$K^9_6 = K^9_{14} \cdot T_{yw}$	$Base_{(7)}$	$K^9_7 = I$
$Column_{(4)}$	$K^9_4 = K^9_6 \cdot I$	$Rotary\ table_{(5)}$	$K^9_5 = K^9_7 \cdot R^5_{zr}$
$Slide_{(2)}$	$K^9_2 = K^9_4 \cdot T_{zw}$		
$Head_{(1)}$	$K^9_1 = K^9_2 \cdot I$		
$Spindle_{(0)}$	$K^9_0 = K^9_1 \cdot I$		

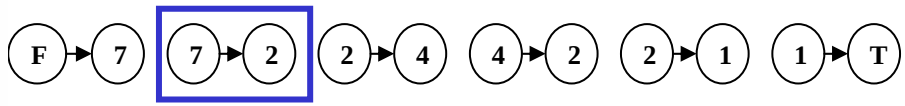


- In STEP AP 203, axis2_placement_3d can be used to represent 4x4 homogeneous transformation matrix to represent the transitional and rotational movements between each components

Data model for kinematics for machine tool product

- Each path of connectivity graph can be divided a directed graph as follows





- Entity for directed graph

```
ENTITY directed_graph
    start_node : part;                  // machining function (true) or positioning function (false)
    end_node : part;                    // character name of axis if axis is used as machining or positioning
    its_kinematics : axis2_placement_3d;            // location of end node with regard to the start node
    geometry_for_sn: OPTIONAL part_geometry_select;             //geometry information of start node part
    geometry_for_en: OPTIONAL part_geometry_select; //geometry information of end node part
END_ENTITY;

TYPE part_geometry_select = SELECT (block, right_circular_cylinder, advanced_brep_shape_representation);
END_TYPE
```

- Entity for kinematics path

```
ENTITY kinematic_path
    path_type : kinematic_type;     // tool oriented or workpiece oriented
    its_graph: LIST [1:?] of directed_graph;        // List of directed_graph
END_ENTITY;

TYPE kinematic_type = SELECT (tool, workpiece);
END_TYPE
```

Future plan

- NWIP for Part 110
- Annex to NWIP
- e-mail from Mr. Wesche (March 23, 2007):

  "I have sent out your (Suh) NWIP and abstract to ISO/CS and we got 'green light' to start a ballot among our SC1 members. This will happen in the beginning of April."