Computer-Aided Manufacturing

NIMs®

Level I
Standards

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Acknowledgements

Introduction to Computer-Aided Manufacturing Standards – Level I

NIMS is pleased to present the first-ever industry-defined skills standards for computer-aided manufacturing (CAM). These standards will enhance education and training programs to meet 21st century demands for skilled CAM programmers, designers, and engineers. Skilled CAM programmers, designers and engineers with extensive education and training are in high demand to plan, manage, and control sophisticated and costly machines. This project will directly support the advancement of CAM training programs by developing industry standards for educating and training CAM programmers.

These standards have been developed by a national Technical Work Group and validated by over 100 subject matter experts in industry and education. Building on their input, these standards outline the basic requirements for a majority of entry-level CAM positions.

Overview

In June 2015, NIMS and Autodesk, Inc. launched an initiative to develop skills standards for CAM. Skills standards refer to the major duties, knowledge, and skills in which individuals must be proficient to meet performance requirements and expectations in the modern workplace. The national basis of these standards refers to the process followed in their development, namely that they be reviewed and reflect employer and employee opinions nationwide. The skills standards are intended to guide workforce development programs in the public and private sectors to build and sustain a globally competitive workforce. The standards also serve as the foundation for industry-recognized certifications offered by NIMS.

Duty Titles

Duty Area 1: Job Preparation

Duty Title 1.1: Process Planning – Milling

Duty:
Develop process plan to program part(s) requiring milling.

Performance Standard:
Given part definitions and equipment/tooling constraints, formulate a strategy to manufacture the parts. Process should include machine selection, tool list, workholding devices, machining operations and operational sequence. Process should identify part features that will be held and/or dimensionally controlled during machining to meet print specifications.

Formulate a process plan for Duty Title 3.1.

Evaluation Criteria:
Implementation of process plan for Duty Title 3.1.

Accuracy Level:
Sufficient strategy to program parts within full compliance of print specifications without adding or modifying process plans.

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: N/A
Measuring Instruments: N/A
References: Machinery's Handbook
Software: Word Processor, Spreadsheet

Duty Area 1: Job Preparation

Duty Title 1.2: Process Planning – Turning

Duty:
Develop process plans to program parts requiring turning.

Performance Standard:
Given part definitions and equipment/tooling constraints, formulate a strategy to manufacture the parts. Process should include machine selection, tool list, workholding devices, machining operations and operational sequence. Process should identify part features that will be held and/or dimensionally controlled during machining to meet print specifications.

Formulate a process plan for Duty Title 3.2.

Evaluation Criteria:
Implementation of process plans for Duty Title 3.2.

Accuracy Level:
Sufficient strategy to program parts within full compliance of print specifications without adding or modifying process plans.

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: N/A
Measuring Instruments: N/A
References: Machinery's Handbook
Software: Word Processor, Spreadsheet

Duty Area 2: Modeling

Duty Title 2.1: 2D Sketching and 3D Modeling – Milling

Duty:
Create and edit 2D model sketches.

Performance Standard:
1. Sketching
    - Given diagrams of 2D geometry and geometric constraints, create 2D sketches. Sketches should include lines, arcs, and circles.
    - Given 2D sketch data files and list of modification requirements, edit/modify the sketches.
2. Modeling
    - Given part definitions and instructions, create 3D models. Models should include islands, pockets, holes, fillets, chamfers, and patterns.
    - Given 3D model data files and list of modification requirements, edit/modify the models.

Evaluation Criteria:
      Requirements checklist.

Accuracy Level:
      Full compliance with requirements checklist.

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: Scientific Calculator
Measuring Instruments: N/A
References: Machinery's Handbook
Software: CAM

Duty Area 2: Modeling

Duty Title 2.2: 2D Sketching and 3D Modeling – Turning

Duty:
Create and edit 2D model sketches.

Performance Standard:
1. Sketching
   - Given diagrams of 2D geometry and geometric constraints, create 2D sketches. Sketch should include lines, arcs, and circles.
   - Given 2D sketch data files and list of modification requirements, edit/modify the sketches.
2. Modeling
   - Given part definitions and instructions, create 3D models. Models should include inside/outside diameters, shoulders, center hole(s), fillets, and chamfers
   - Given 3D model data files and list of modification requirements, edit/modify the models.

Evaluation Criteria:
   Requirements checklist.

Accuracy Level:
   Full compliance with requirements checklist.

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: Scientific Calculator
Measuring Instruments: N/A
References: Machinery's Handbook
Software: CAM

Duty Area 3: Toolpath Generation

Duty Title 3.1: 2D - Milling

Duty:
Generate 2D milling toolpath to 3D models.

Performance Standard:
Given 3D model data files and annotated drawing of models, generate appropriate toolpath and post process. Part designs require a minimum of two setups. Models should require toolpaths for facing, drilling, contouring, pocketing, slotting, and chamfering.

Evaluation Criteria:
- Requirements checklist.
- Machine Verification (Machine verification is an execution of the NC program on a machine tool. Setup and operation of machine tool must be completed independent of candidate).

Accuracy Level:
- Full compliance with requirements checklist
- Print specifications:
  - 125 ra max for all surfaces
  - .003" for profiles
  - .003" for flatness, perpendicularity, and parallelism
  - .005" for position
  - +/- .005" for all limit dimensions

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: Scientific or Machinist Calculator
Measuring Instruments: N/A
References: Machinery Handbook, Manufacturers Tooling Library/Catalog, Machine Tool Manual
Software: CAM

Duty Area 3: Toolpath Generation

Duty Title 3.2: 2D - Turning

Duty:
Generate 2D turning toolpath to geometric (solid) models.

Performance Standard:
Given 3D model data files and annotated drawing of models, generate appropriate toolpath and post process. Part designs require a single setup. Geometric models should require toolpaths for turning, facing, face grooving, outside/inside grooving, and outside/inside threading.

Evaluation Criteria:
- Requirements checklist.
- Machine Verification (Machine verification is an execution of the NC program on a machine tool. Setup and operation of machine tool must be completed independent of candidate).

Accuracy Level:
- Full compliance with requirements checklist
- Print specifications:
    o 125 ra max for all surfaces
    o .003" for profiles
    o .002" for concentricity or total runout
    o +/- .002" for all limit dimensions

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: Scientific or Machinist Calculator
Measuring Instruments: N/A
References: Machinery Handbook, Manufacturers Tooling Library/Catalog, Machine Tool Manual
Software: CAM

Duty Area 4: Documentation

Duty Title 4.1: Setups – Milling

Duty:
Create milling machine operator documentation.

Performance Standard:
Given part definitions and process plans, create documentation required to setup and produce the parts. Documents should include tool lists, setup sheets, and instructions.

Create documentation for Duty Title 3.1.

Evaluation Criteria:
Implementation of documentation for Duty Title 3.1.

Accuracy Level:
Sufficient documentation to setup and produce parts within full compliance of print specifications without adding or modifying documents.

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: N/A
Measuring Instruments: N/A
References: Machinery's Handbook
Software: Word Processor, Spreadsheet, CAM

Duty Area 4: Documentation

Duty Title 4.2: Setups – Turning

Duty:
Create turning machine operator documentation.

Performance Standard:
Given part definitions and process plans, create documentation required to setup and produce the parts. Documents should include tool lists, setup sheets, and instructions.

Create documentation for Duty Title 3.2.

Evaluation Criteria:
Implementation of documentation for Duty Title 3.2.

Accuracy Level:
Sufficient documentation to setup and produce parts within full compliance of print specifications without adding or modifying documents.

Assessment Equipment and Materials:
Workstation: Computer
Materials: N/A
Tooling: N/A
Measuring Instruments: N/A
References: Machinery's Handbook
Software: Word Processor, Spreadsheet, CAM

Knowledge, Skills, Abilities & Other Characteristics (KSAOs)

KSAO Area 1: Written Oral Communication

KSAO Title 1.1: Reading

KSAO Definition:
Locates, understands, and interprets written technical and non-technical information in documents commonly found in the manufacturing industry. These documents contain short and simple sentences, paragraphs and passages, phrases, quantitative information, specialized vocabulary, graphs, charts, schedules, simple instructions, and multi-step directions. All documents are written in standard English.

Performance Requirement:
Given a specific duty to perform and the necessary written information contained on relevant documents and information sheets, locate and read the necessary information and use this information to plan, execute, and evaluate the duty and answer questions about the content or meaning of the written information.

KSAO Area 1: Written Oral Communication

KSAO Title 1.2: Writing

KSAO Definition:
Communicates technical and non-technical information, messages, and ideas in writing using standard English commonly found in the metalworking industry. This writing includes the completion of forms, information sheets, reports, group meeting materials, and short memos.

Performance Requirement:
Given a specific duty to perform and the necessary instructions, forms, and materials to complete the writing requirements for that duty, complete the writing requirement.

KSAO Area 1: Written Oral Communication

KSAO Title 1.3: Speaking

KSAO Definition:
Communicates technical and non-technical detailed information, messages, multi-step directions, and ideas through oral communication using standard English and related cues and communication aids in conversations, discussions, and group meetings. Understands and responds to listener feedback and asks questions when needed in two-way and group conversations.

Performance Requirement:
Given a specific duty to perform and the necessary instructions, written documents, and communication aids and materials to complete the speaking requirements for that duty, complete the speaking requirement.

KSAO Area 1: Written Oral Communication

KSAO Title 1.4: Listening

KSAO Definition:
Listens for, receives, interprets, and recalls specific details, ideas, and multi-step instructions in verbal presentations, conversations, discussions, and group meetings conducted in standard English and supported by written materials and other communication cues and aids. Uses active listening skills in comprehending simple technical and nontechnical verbal information.

Performance Requirement:
Given a specific duty to perform and the necessary written information contained on relevant documents and information sheets, listen for, comprehend, and incorporate oral information in the performance of the duty and answer questions about the content or meaning of the oral information.

KSAO Area 2: Machining Mathematics

KSAO Title 2.1: Number Sense

KSAO Definition:
- Identify positive and negative numbers, and explain the meaning of each.
- Identify whole, fractional, mixed, and decimal numbers.
- Demonstrate understanding of relative scale when comparing numbers.
- Convert numbers represented as fractions and mixed numbers to decimal numbers.
- Recognize decimal numbers that can be easily represented by common fractions and mixed numbers.

Performance Requirement:
Given a specific duty to perform requiring a sense of numbers, perform the required duty and answer questions about the use number sense.

KSAO Area 2: Machining Mathematics

KSAO Title 2.2: Arithmetic Operations

KSAO Definition:
- Apply the order of operations to multi-step arithmetic sequences.
- Perform arithmetic operations of adding, multiplying, subtracting, and dividing of whole and decimal numbers using a calculator.
- Perform arithmetic operations of adding, multiplying, subtracting, and dividing of simple whole, decimal, and fraction numbers mentally without a notepad or calculator.
- Apply arithmetic operations of adding, multiplying, subtracting, and dividing to numbers represented as fractions.
- Calculate percent of a whole and percent difference.
- Estimate numerically-represented quantities such as speed, length, and diameter Rearrange an equation and solve for one unknown.

Performance Requirement:
Given a specific duty to perform requiring arithmetic operations, perform the required duty and answer questions about arithmetic operations.

KSAO Area 2: Machining Mathematics

KSAO Title 2.3: Cartesian Coordinates

KSAO Definition:
- Identify the three axes (X, Y, and Z) and associated planes.
- Understands "the right hand rule" for defining axes and identify positive and negative directions of Cartesian axes.
- Know the difference between absolute and incremental programming.

Performance Requirement:
Given a specific duty to perform requiring the use of Cartesian coordinates, perform the required duty and answer questions about Cartesian coordinates.

KSAO Area 2: Machining Mathematics

KSAO Title 2.4: Units and Conversions

KSAO Definition:
- Understands common units of measure for quantities such as length, angle, mass, weight, and speed.
- Understands linear and angular speed.
- Conversions between imperial and metric units of measure; degrees-minutes-seconds and decimal degrees; diameter and radius.

Performance Requirement:
Given a specific duty to perform requiring the use of units and conversions, perform the required duty and answer questions about units and conversions.

KSAO Area 2: Machining Mathematics

KSAO Title 2.5: Geometry

KSAO Definition:
Determine complementary and supplementary angles given an angle measurement and basic understanding of geometric concepts such as parallel, perpendicular, tangent, and symmetrical.

Performance Requirement:
Given a specific duty to perform requiring the use of geometry, perform the required duty and answer questions about geometry.

KSAO Area 3: Decision Making and Problem Solving

KSAO Title 3.1: Applying Decision Rules

KSAO Definition:
Can follow a set of instructions laid out in a sequence. Can interpret and follow "if....then...." instructions.

Performance Requirement:
Given a specific duty to perform requiring a checklist of sequential instructions, carry out the duty making appropriate entries on the checklist.

KSAO Area 3: Decision Making and Problem Solving

KSAO Title 3.2: Basic Problem Solving

KSAO Definition:
Can establish new responses to unexpected problems of a simple nature. Can formulate the new responses into a sequence of instructions or a set of "if ... then ..." rules.

Performance Requirement:
Given a specific duty to perform and being furnished with a checklist of sequential instructions, carry out the duty according to the checklist responding appropriately to problems. Formulate those responses into "if ... then ..." rules.

KSAO Area 4: Social Skills and Personal Qualities

KSAO Title 4.1: Social Skills

KSAO Definition:
Identify and demonstrate the appropriate social skills and related personal qualities in the performance of major duties requiring cooperative relations with supervisors, team leaders, and team members.

Performance Requirement:
Demonstrates understanding, friendliness, politeness, and empathy toward others including men and women, and with people from a variety of ethnic, social, and educational backgrounds. Works cooperatively with others and contributes to group efforts with ideas, suggestions, and positive feedback to group members. Demonstrates appropriate social and communication skills in resolving conflicts with supervisors, team leaders, and team members.

KSAO Area 4: Social Skills and Personal Qualities

KSAO Title 4.2 Personal Qualities

KSAO Definition:
Identify and demonstrate the appropriate personal qualities in performing major job duties and maintaining positive employment relations.

Performance Requirement:
Recognizes and demonstrates appropriate codes of conduct and values in the workplace and demonstrates honesty and integrity in exhibiting appropriate workplace behaviors. Assumes responsibility and demonstrates strong work ethic by exerting effort and perseverance in doing work tasks according to high standards. Maintains high standards of attendance, punctuality, and involvement in all major work tasks.

KSAO Area 5: Engineering Drawings and Sketches

KSAO Title 5.1: Print Interpretation

KSAO Definition:
- Interpret and understand various line types including geometry lines, hidden lines, dimension lines, center lines, and section lines.
- Spatially visualize a 3D part by referencing 2D drawing views.
- Maintain a basic understanding of ISO and ANSI standard drawing conventions for orthographic projections.
- Understand the differences between third-angle and first-angle orthographic projections, and where orthographic projection views are placed on the drawing sheet.
- Interpret and understand section views and detail views.
- Maintain a basic understanding of ISO and ANSI standard drawing conventions.
- Interpret drawing notes including material type, hardware, surface treatments, surface finish, post-machining processes, etc.

Performance Requirement:
Given a specific duty to perform requiring print interpretation, perform the required duty and answer questions about the use print interpretation.

KSAO Area 5: Engineering Drawings and Sketches

KSAO Title 5.2: Geometric Dimensioning and Tolerancing

KSAO Definition:
Familiarity with Geometric Dimensioning and Tolerancing concepts and symbols as defined by the most commonly recognized version of ASME Y14.5. This includes: datum reference frame (DRF), degrees of freedom (DOF), feature control frame, geometric control symbols, geometric tolerancing categories, geometric tolerancing characteristics, geometric tolerancing zone shapes, and symbols associated with feature control frames.

Performance Requirement:
Given a specific duty to perform requiring understanding of Geometrical Dimensioning and Tolerancing, perform the required duty and answer questions about Geometrical Dimensioning and Tolerancing.

KSAO Area 5: Engineering Drawings and Sketches

KSAO Title 5.3: CAD Files

KSAO Definition:
- Understands various file types used to represent 2D geometry such as EPS and DXF.
- Understands various file types used to represent 3D model data such as STEP, IGES, STL, Parasolid x_t and x_b, SAT and CAD software-specific file types.
- Understands universally-accepted file types in both CAD and CAM software programs for import and export.
- Understand differences between solid, surface, wireframe, and mesh geometry definition types.
- Understand Download Numerical Code (DNC) system.
- Identify part geometry features such as holes, threads, fillets, chamfers, extrusions, lofts, slots, revolutions and patterns.

Performance Requirement:
Given a specific duty to perform requiring understanding of CAD files, perform the required duty and answer questions about CAD files.

KSAO Area 6: Computer Operations

KSAO Title 6.1 Computer Hardware Components and Specifications

KSAO Definition:
- Identify major computer components such as the graphics processing unit, CPU, RAM, and hard disk drive.
- Describe the discrete functions and interrelatedness of major computer components such as the graphics processing unit, CPU, RAM, and hard disk drive, as they pertain to system performance.
- Demonstrate awareness of and basic understanding of current computer technologies, specifications and quantities, such as clock speed (GHz), cores, 32-bit and 64-bit software, and system architecture.
- Identify and interpret software system requirements.

Performance Requirement:
Given a specific duty to perform requiring understanding of hardware components and specification, perform the required duty and answer questions about hardware components and specification.

KSAO Area 6: Computer Operations

KSAO Title 6.2: Organizing and Managing Digital Information

KSAO Definition:
- Understands file naming conventions standards according to industry and workplace.
- Perform cut, copy, and paste functions.
- Utilize digital data storage methods including local, network, and cloud storage.
- Organize electronic files, folders and directory structures, maintaining awareness of both physical and organizational locations of the data.

Performance Requirement:
Given a specific duty to perform requiring organizing and managing digital information, perform the required duty and answer questions about organizing and managing digital information.

KSAO Area 7: Technologies

KSAO Title 7.1: CNC Machines

KSAO Definition:
- Identify and understand types, configurations and applications of various computer numerically controlled cutting equipment, such as vertical and horizontal mills, lathes, EDM, plasma cutters, waterjets, and laser cutters.
- Identify major machine components such as spindles, tables, pallet changers, turrets, and tool changers.
- Identify major machine accessories and options such as chip conveyors, rotary tables and indexers, pallet changers, and live tooling.
- Identify and name the axes of motion for three-axis mills and routers, and two-axis lathes.
- Understand machine kinematics.
- Identify common machine controls such as Siemens, Haas, Fanuc, etc.
- Machine and control capabilities and limitations.

Performance Requirement:
Given a specific duty to perform requiring knowledge of machine types, perform the required duty and answer questions about machine types.

KSAO Area 7: Technologies

KSAO Title 7.2: Workholding

KSAO Definition:
Understands application and operation of fundamental commercially-available workholding devices such as: vises, chucks, collets, step blocks, and toe clamps.

Performance Requirement:
Given a specific duty to perform requiring workholding, perform the required duty and answer questions about workholding.

KSAO Area 7: Technologies

KSAO Title 7.3: Cutting Tools

KSAO Definition:
Understands cutter feeds, speeds, and chip load for efficient programming for both roughing and finishing on various materials. Research tooling technology for efficient machining and select appropriate cutters. Apply manufacturer's recommended parameters and specifications to machining applications.

Performance Requirement:
Given a specific duty to perform requiring cutting tools, perform the required duty and answer questions about cutting tools.

KSAO Area 7: Technologies

KSAO Title 7.4: Machine Codes

KSAO Definition:
- Understanding of common preparatory functions (G-Codes) including codes used to command:
    - Work offset selection
    - Unit selection
    - Absolute and incremental positioning
    - Rapid motion
    - Linear and circular interpolation
    - Modal and non-modal commands
    - Cutter compensation
    - Drilling, tapping, and boring canned cycles (mill and lathe)
    - Lathe roughing and finishing canned cycles
- Understanding of common miscellaneous functions (M-Codes) including codes used to command:
    - Spindle
    - Coolant
    - Program end
    - Optional and force stops
    - Tool change
- Understanding of various canned cycle parameters such as peck amount and R plane selection.

Performance Requirement:
Given a specific duty to perform requiring machine codes, perform the required duty and answer questions about machine codes.

KSAO Area 7: Technologies

KSAO Title 7.5: Offsets and Compensation

KSAO Definition:
Understanding of work and tool length offsets and compensation adjustments of bearing bores, circular bosses, and other critical geometry.

Performance Requirement:
Given a specific duty to perform requiring offsets and compensation, perform the required duty and answer questions about offsets and compensation.

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