MANUFACTURING AND ENGINEERING TECHNOLOGY

Additive Manufacturing

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worldskills

WorldSkills Occupational Standards (WSOS)

Occupation description and WSOS

The name of the occupation is

Additive Manufacturing

Description of the associated work role(s) or occupation(s)

Additive manufacturing is one of the newest and fastest developing branches of engineering. Traditional manufacturing methods, like milling and turning, are "subtractive" methods of manufacture: they start with a solid block of material, normally metal or an alloy, and cut away unwanted material until it forms the desired shape and size. Additive manufacturing adds, or "builds", layer upon layer of material. It is more commonly known as 3D Printing.

Additive manufacturing has several advantages over milling and turning. For example:

- it can enable more complex shapes to be created
- although the materials may be more expensive, it is efficient and economical in their use, because items need be no more solid than is strictly necessary, and weight is minimized
- it can create stronger bonds between different materials
- it can produce complex units as single objects, removing the need for several parts to achieve the overall desired shape and function
- it can use a wider range of materials and composites
- it is especially quick and responsive for manufacturing design and development, including research, prototyping, and trials.

Despite its many strengths, additive manufacturing complements milling and turning; it is not a substitute for them. At least for the foreseeable future, 3D printers and new materials are relatively expensive. The printing process is also slow. Additive manufacturing therefore extends manufacturing's capabilities and applications to a significant extent, especially where customization, lightness, complex shapes and functions, new materials, durability, and reliability are involved. As a result, additive manufacturing is being used very widely, with aerospace an early adopter, followed by medicine, transportation, energy, and consumer products.

Additive manufacturing allows us to redesign many objects around us, and rethink approaches to the design of new ones. In this way it is potentially transformative and disruptive across the manufacturing process. While the layer-on-layer process is relatively slow, additive manufacturing's overall impact on design and manufacture will be to shorten the production cycle, improve quality, and improve customer benefits.

An additive manufacturing technician requires a wide range of knowledge, skill, and generic attributes. In relation to 3D, their role covers 3D scanning, metrology, scan-to-CAD redesigning, CAE, build process analysis, and post-processing. Beyond these, the role requires an appreciation of their properties and characteristics of materials, applied mathematics, and geometry in particular, and the ability to take advantage of the future possibilities of this new technology.

General notes on the WSOS

The WSOS specifies the knowledge, understanding, and specific skills that underpin international best practice in technical and vocational performance. It should reflect a shared global understanding of what the associated work role(s) or occupation(s) represent for industry and business (www.worldskills.org/WSOS).

The skill competition is intended to reflect international best practice as described by the WSOS, and to the extent that it is able to. The Standard is therefore a guide to the required training and preparation for the skill competition.

In the skill competition the assessment of knowledge and understanding will take place through the assessment of performance. There will only be separate tests of knowledge and understanding where there is an overwhelming reason for these.

The Standard is divided into distinct sections with headings and reference numbers added.

Each section is assigned a percentage of the total marks to indicate its relative importance within the Standards. This is often referred to as the "weighting". The sum of all the percentage marks is 100. The weightings determine the distribution of marks within the Marking Scheme.

Through the Test Project, the Marking Scheme will assess only those skills that are set out in the Standards Specification. They will reflect the Standards as comprehensively as possible within the constraints of the skill competition.

The Marking Scheme will follow the allocation of marks within the Standards to the extent practically possible. A variation of up to five percent is allowed, provided that this does not distort the weightings assigned by the Standards.

WorldSkills Occupational Standards

Section		Relative importance (%)
1	**Work organization and management**	**5**

The individual needs to know and understand:

- Standards for environmental protection, safety, hygiene and accident prevention related to the use of
  - optical and laser 3D scanners
  - graphic work stations
  - additive machines
  - other machines, and post-processing equipment
- The principles and applications of additive manufacturing (AM)
- The principles and applications of related and replacement technologies
- The importance of planning and time management during work
- The importance of prioritizing
- The importance of cost accounting and analysis
- Current internationally recognized standards (ISO), and standards currently used and recognized by industry
- The role and significance of providing innovative and creative solutions to technical and design problems and challenges
- The importance of maintaining a productive and professional demeanour
- The importance of efficient, economical, and data rational work habits and performance.

The individual shall be able to:

- Provide and maintain a safe, tidy, and efficient work area
- Promote health and safety legislation, best working practice, and environmental protection
- Apply the internationally recognized standards (ISO) and standards currently used and recognized by industry;
- Use planning and time management during the work;
- Prioritize between work demands on a rational basis
- Independently Interpret technical tasks
- Estimate and plan the time, sequence, and duration of tasks and steps
- Produce work that fully meets the technical specifications and standards;
- Create and apply innovative and creative solutions to problems and challenges of AM
- Maintain a productive appearance and demeanour
- Work efficiently, economically, and data rationally.

Section		Relative importance (%)
2	**Communication and interpersonal skills**	**5**
	The individual needs to know and understand: • The importance of effective communication and inter-personal skills between co-workers, customers and other related professionals • The range of purposes of documentation in both paper and electronic forms as well as instructions in any forms • Technical terminology and symbols • The importance of technical specifications • The importance of resolving misunderstandings and conflicting demands • The importance of gaining, retaining, and developing knowledge through log books, exhibitions, articles, and specialist internet resources.	
	The individual shall be able to: • communicate effectively, using strong inter-personal skills with co-workers, clients, and other related professionals to ensure that developing projects meet requirements • Read, interpret, and extract technical data and instructions from any available sources • Use discretion and confidentiality when dealing with clients • Clarify terms of reference, specifications, and instructions, for the most accurate implementation of requirements • Maintain proactive continuous professional development in order to sustain knowledge and skill in new and developing technologies and practices.	•
3	**3D digitizing**	**20**
	The individual needs to know and understand: • The principles of equipment operation for 3D digitizing • The advantages and disadvantages of various types of equipment for 3D digitizing, and the technologies on which they are based; • The technical characteristics of equipment for accuracy and speed of optical 3D digitizing • The requirements for ensuring the feasibility of work and its required quality and accuracy relative to dust, base vibration, stray light sources, mobility of objects, thermal expansion, etc • The importance of calibration of equipment, and the requirements for calibration and digitizing conditions • The requirements of each item's surface characteristics for optical 3D digitizing, relative to its purposes and uses such as fit, smoothness, transparency, translucence, glossiness • Methods and techniques for surface preparation for optical 3D digitizing, such as washing, sandblasting, and matting • The requirements for polygon models for subsequent scan-to-CAD processes • The types of rejection of 3D digitizing, their sources, and ways to eliminate them.	

Section		Relative importance (%)

	The individual shall be able to:
	• Perform equipment's adjustment and calibration
	• Make decisions regarding the possibility of optical 3D digitizing, for technical reasons:
	  • Possible or impossible to perform
	  • The accuracy it is possible to attain for the object
	  • The required conditions for digitizing
	• Make decisions regarding pre-process works such as disassembly, washing, and painting
	• Perform pre-process actions for applying matting coating
	• Apply matting coating
	• Apply optical marks
	• Fix objects for subsequent digitization
	• Perform 3D digitizing for various objects with:
	  • different materials
	  • different surface characteristics
	  • different geometrical complexity
	• Save results in the required form.	

4	**Metrology**	**5**

	The individual needs to know and understand:
	• The types and range of measuring instruments and devices (probes, sensors, fixing devices, etc.)
	• Constructive and metrological characteristics of measuring instruments, including special ones (for measuring narrow grooves, gears, threads, etc.)
	• Factors influencing the reliability of the results of measurement (surface contamination, temperature imbalance, incorrect measuring force, etc.)
	• The classes of accuracy, tolerances, linear and angular dimensions, and geometric tolerances
	• Distribution laws relating to statistical process control, such as:
	  • the scope of the process
	  • the scope of the tolerances
	  • potential suitability
	  • confirmed quality
	• Measurements making methods
	• How to use specialized reference books, tables, or diagrams
	• Process Capability and Performance (Cp, Cpk, Pp, Ppk).	

Section		Relative importance (%)
	The individual shall be able to: • Prepare objects and measuring instruments for measurements • Calibrate, adjust, and align measuring instruments • Select correct measuring instruments and devices (styluses, probes, etc.), auxiliary and fixing devices (vices, V-blocks, clamps, etc.), relating to measurement strategy • Perform measurements using various control and measuring instruments • Read the indications of measuring instruments • Identify and estimate the correctness of measurements and the reliability of the data obtained, to minimize associated human factor errors • Find the required information in specialized reference books, tables, or diagrams • Carry out routine maintenance of measuring instruments.	
5	**Scan-to-CAD and optimization**	**33**
	The individual needs to know and understand: • The purposes of Scan-to-CAD processes in relation to additive technologies (the number of parts reducing, weight reducing, functions optimizing, etc) • Scan-to-CAD software applications; CAD, CAE, and optimization software • Mathematics, especially geometry related to additive technologies • Polygonal models requirements for Scan-to-CAD purposes • Methods of extracting primitives from polygonal models for the purpose of restoring CAD models and their optimization • Mechanical systems and operational principles • Fundamentals of technical drafts and drawings • The basics of component assembly • Comparative methods for CAD and polygonal modelling • The requirements for CAD models for AM purposes, post-processing, and subsequent use • AM and mechanical engineering materials' properties.	

	The individual shall be able to:
	• Create editable CAD models by digitized data (polygonal models)
	• Apply mathematics to additive technologies
	• Restore missing data of the elements of objects to be redesigned, from available data:
	  • of polygonal models (for example, the gear wheel has only one preserved tooth, the worm has only one turn, or there is only one-third of the flange)
	  • taken from connected parts
	  • taken from existing objects by manual measuring (for example, the depth of a blind hole)
	• Change the geometry of created models according to task
	• Consider the features of AM and subsequent finishing processing
	• Analyse and optimize the structure of the model in accordance with the terms of reference	

Section		Relative importance (%)
	• Analyse the deviation of created models from the results of 3D scanning • Provide lattices' and surfaces' topology, with analysis and optimization according to task • Apply standards for conventional dimensioning and tolerances, and geometric dimensioning and tolerance appropriate to the ISO standard.	
6	**Preparation and forming**	**27**
	The individual needs to know and understand: • Physics and chemistry related to additive technologies • Model preparation, simulation and analysis software • The advantages and disadvantages of the most common additive technologies (SLS, SLM, SLA/DLP, FDM/FFF and MJ) • Properties, advantages and disadvantages of industrial materials for 3D printing • Requirements for models in accordance with technologies and materials • Post-processing technologies, their capabilities and requirements for built models (fastening requirements, binding elements, post-processing allowances, stresses relieve operations sequence) • Technologies and processes that can used for AM parts (casting in SPF, burned or lost wax models casting, polymers moulding, etc.).	
	The individual shall be able to: • Choose the technology that best suits the task • Choose material that best suits the task • Prepare models for forming according to the selected technology and material (placement, orientation, supports, shrinkage) • Apply physics and chemistry as they relate to additive technologies • Simulate and analyse forming processes • Start and control the build process • Assign necessary post-processing processes and define their complexity.	
7	**Finalize and deliver work pieces**	**5**
	The individual needs to know and understand: • The processes and procedures of post processing • The importance of completing work pieces to the required standard to the extent of their responsibilities The circumstances in which referral should be made to other appropriate personnel.	

Section	Relative importance (%)
The individual shall be able to: • Clean parts • Deliver parts to the appropriate locations and/or personnel as required by the organization • Evaluate and report on factors and outcomes relevant to requirements and expectations.	
Total	**100**

References for industry consultation

WorldSkills is committed to ensuring that the WorldSkills Occupational Standards fully reflect the dynamism of internationally recognized best practice in industry and business. To do this WorldSkills approaches a number of organizations across the world that can offer feedback on the draft Description of the Associated Role and WorldSkills Occupational Standards on a two-yearly cycle.

In parallel to this, WSI consults three international occupational classifications and databases:

- ISCO-08: (http://www.ilo.org/public/english/bureau/stat/isco/isco08/)
- ESCO: (https://ec.europa.eu/esco/portal/home)
- O*NET OnLine (www.**onet**online.org/)

The following table indicates which organizations were approached and provided valuable feedback for the Description of the Associated Role and WorldSkills Occupational Standards in place for WorldSkills Shanghai 2022.

There were no responses to the requests for feedback this cycle.