METALS
MachinE Tool ALliance for Skills

Co-funded by the Erasmus+ Programme of the European Union

Analytical Highlight

The European Machine Tool Industry Skills Panorama

Focus on Additive Manufacturing

This panorama focuses on skills required to use additive manufacturing technologies based on the findings of the METALS project, funded by the European Commission's Erasmus+ Programme. It shows how the AM workforce will be characterized by a **hybrid skills pool** comprising typical skills in subtractive manufacturing, new emerging skills specific to additive machines, as well as heightened soft skills in communication and presentation over the next decade.

The European machine tool sector recorded a strong recovery in 2016 after the 2009 economic and financial crisis, mainly due to the rise in exports. As a result of focusing on advanced and sophisticated products, the combined output of a leading club of European countries[1] amounted to 24.2 billion euros in 2016. The figure for 2017 is forecast to be above this level. The machine tool sector has entered a new era, characterized by the emergence of new industrial technologies, and one of the most important is **additive manufacturing (AM), otherwise known as 3D Printing**. Several reasons account for the rising attention of machine tool builders on AM: the opportunity to better customize final products, localize the manufacturing process, minimize waste in production and bring down inventory costs. While such technology is not yet at the level of widespread industrialization, it is part of a continuously expanding industry. Indeed, the global value of the AM market is set to rise three-fold between 2004 and 2018, and hit 21 billion USD by 2021[2]. This trend highlights the need to address possible implications in several aspects of AM, including skills. This is a particularly important variable for **key application industries of AM systems such as aircraft, medical devices and automotive**. A workforce of world-class standards represents one of the cornerstones of Europe's leading position in advanced manufacturing.

The analysis conducted by the METALS project on skills requirements in AM technologies yielded a clear conclusion. As AM will move closer to series production in the period leading to 2025, the relevance of workforce competent in additive production methods is set to rise in the European machine tool sector. The skill set will gradually evolve into a hybrid one, where conventional competences in subtractive manufacturing will be coupled with new skills specific to the manufacturing process with additive machines. These new competences will be in particular concentrated in stages such as design, STL[3] conversion and file manipulation, post-processing, testing and maintenance. Moreover, greater soft skills in communication and presentation will be part of this evolved skill set. They will become more acute as growing competition in manufacturing will put greater and greater emphasis on marketing opportunities.

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New competences needed to enable AM's design freedom

The production of the part needed begins with virtual **design**. Current practice in this stage of the AM process is to create an optimized design of the 3D model by using conventional CAD tools and topology optimization software. An initial design space is created, based on a range of loads and boundary conditions given by the software user. Topology optimization is then applied to this initial model. It allows for the identification of irrelevant material for the part to be produced, leading to an optimized distribution of material in the design space generated.
The improvement of the part's performance through topological optimization paves the way for the final design of the part. This requires the conversion of optimization results into a mathematical CAD representation.
The opportunities that are opened up thanks to design methods in AM are multiple. Although software technology is still under development, the advantages it offers in reducing the type of geometry restrictions that conventional, subtractive machines face in design are clear. For these reasons, **skills in proper design** will be increasingly in demand. They will be possessed by **specialized designers** who will surge in importance in the AM workforce. They will need to possess **knowledge of AM materials and processes**, and have competences in **free surface modelling, structural calculus, topography optimization and computational thermal fluid dynamics**. These will be skills employed for conducting activities such as understanding the needs of the client by identifying requests of the part to be designed, as well as choosing the appropriate AM material for production.

New phase of the manufacturing process: STL conversion and file manipulation

The occupation of the AM specialized designer will rise together with that of the **worker in application engineering**, with whom it will coordinate closely. The latter's main activities will focus on the stage of STL conversion and file manipulation. They will entail exporting the CAD model to STL file format by triangulation. This will be followed by part positioning and orientation, as well as setting parameters. If needed, support structures on the build plate will be generated and added. Afterwards, slicing software will convert the file into a specific code with commands for the machine to read and execute.
The worker in application engineering will then be an occupation requiring knowledge of **AM materials and understanding of features of Computer-aided manufacturing (CAM) software**. This occupational profile will be characterized by individuals with extensive soft skills in decision-making and problem-solving and, crucially, with sufficient practical experience to **oversee the whole production process**.

Safety will be critical in vocational operation skills, a certain extent of which will be retained in the transition from subtractive to additive

Centered on the activities of software and hardware set-up, monitoring of process parameters and extraction of the workpiece, the operation stage will be characterized by **enhanced safety standards**.
Safety procedures during loading and unloading operations will need to be strictly observed. The AM operator will be a safety-minded **specialized worker with basic knowledge of materials, competent in emergency management and capable to handle minor deviations of the process parameters**. Operation is also a stage where AM-driven automation is set to make redundant certain competences. The fact that today software is well-developed at this stage of AM technology, as it is wired into the machine and managed remotely, will make knowledge of software a less central need for operators. The additive machine functions independently in production, with little need of manufacturing process monitoring.

Changes in skills for post-processing are concentrated mostly on a specific aspect

Post-processing, which takes place once operation is completed, is another area of the manufacturing process where skills will evolve between now and 2025. To this extent, workers in AM will need new vocational skills for removing and recycling redundant metal powder around the part fabricated, a task peculiar of the AM process. Metal cutting, surface finishing and heat treatment, other activities to which the part produced is subjected in post-processing, are activities relatively common also among conventional machines.

Knowledge of AM materials fundamental in the testing stage

The identification of defects of the fabrication process in the stage of testing product and production cycle will become more important over the next years. This activity will require expertise specific to additive machines, and is conducted by using computed tomography. **Knowledge of AM materials and processes is essential in this respect**. Controls of the fabricated part, instead, generally follow the path delineated in subtractive manufacturing. As a consequence, the occupation of the **metrologist**, in charge of these tasks, will remain equally important between now and 2025.

Maintenance skills will be distributed along two core areas

Concerning the **maintenance stage**, the time frame analyzed by this project will be long enough to capture the evolution of maintenance practices as a result of the gradual deployment of AM at industrial level. For the additive machine to be used on the shop floor, one has to routinely clean it up and upkeep it. The machine is also subjected, approximatively every six months, to extraordinary diagnostic work in order to solve any potential non-functioning or failure. All these tasks require knowledge and competences specific to the AM space. Alongside operation, maintenance will be a stage of the AM process where **safety standards** in the workplace will play a prominent role. Indeed, there are risks linked to the use of metal powders, such as powder particles' inhalation and the reaction with oxygen and subsequent combustion of materials like titanium. These add a **new specific dimension** to maintenance of additive machines, which translates into an evolved set of competences. Keeping high safety levels is especially relevant in maintenance tasks such as changing filters used during production to capture gases potentially harmful for human health and detrimental to the process efficiency. Similarly, safety is the main driver for carefully handling and storing feed materials, and guaranteeing a safe and clean work environment. In the case of extraordinary maintenance, the end-user of the machine will need to rely on **specialized AM maintenance personnel** sent by the supplier to the manufacturing facility where the machine is located. About ordinary maintenance, tasks will instead be conducted directly by the **specialized technicians** of the end-user company. The role of the additive system supplier, and particularly the vocational skill set of its shop-floor level workforce in maintenance, will therefore be crucial. Needed training and specific instruction on ordinary maintenance of the machine will need to come from the supplier.

Not only hard skills are set to evolve with the emergence of AM techniques: certain soft skills will be equally affected

Between now and 2025, predictions of growing market competition are expected to trigger greater emphasis on the marketing dimension of the business. Manufacturers will pursue more and more opportunities to showcase and demonstrate their latest products. To foster the use of AM technologies, machine demonstrations will multiply in trade fairs. Workforce in AM will therefore improve abilities in showcasing the machine in the exhibition's premises. This will entail interaction with potential users interested in it, and coordination when answering questions from potential customers. Competences of this sort will also be essential when reporting customers' inputs at the end of exhibiting activities. **Better soft skills in communication and presentation** will thus be needed by the AM workforce to successfully cope with more developed and exhibition-oriented marketing strategies.

Notes

1. Figure taken from CECIMO. The countries included are: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden Switzerland, Turkey and the United Kingdom.
2. Accounting for products & services (all materials). Source: Wohlers Report 2015.
3. Acronym for Stereolithography.

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The METALS consortium

The organisations involved in the Erasmus+ METALS project are:

Project leader

CECIMO - European Association of the Machine Tool Industries
www.cecimo.eu

AFM - Advanced Manufacturing Technologies
www.afm.es

Afol Metropolitana
www.cittametropolitana.mi.it/afolmilano

Detmold Government Department 45
www.bezreg-detmold.nrw.de

DETMOLD

ECOLE - Enti COnfindustriali Lombardi per l'Education
www.myecole.it

IMH - Machine Tool Institute
www.imh.eus

ITB - Institute of Technology and Education of the University of Bremen
www.itb.uni-bremen.de

TKNIKA
www.tknika.eus

UCIMU-SISTEMI PER PRODURRE
www.ucimu.it

VDW YF - German Machine Tool Builders' Association Youth Foundation
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