Industry 4.0 Human-Oriented Challenges using the example of Additive Manufacturing Technologies

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***Abstract*—Digitalization of the industry opens new possibilities to fulfill customer requirements such as individualized products. Additive Manufacturing is an example of a technology to do so and is part of a development towards Systems Engineering. Adapting the qualification of the workforce is a decisive factor to use successfully new technologies within the broad field of industry 4.0. This paper addresses the issue of how to integrate workforce in the changing process of digitalization based on providing examples from the Additive Manufacturing technology. It shows that work content will change and generally higher skill levels are required. Subsequently, continuous learning and the determination to do so are necessary. Implementing this is a major task for workforce and employers.**

Keywords - Industry 4.0; Digitalization; Additive Manufacturing; Workplace Change; Job Content; Qualification Needs.

I. INTRODUCTION

Industry 4.0 stands for the current revolution of the industrial production, driven by the internet technologies, and describes the technological change of today's production technology to cyber-physical production systems, so-called Smart Factories [1]. In the Smart factories environment, the manufacturing will completely be equipped with sensors, actors, and autonomous systems [2]. The term "Industry 4.0" was first presented at the 2011 Hannover Fair and describes the fourth development stage of the industrial production. The three previous stages started with the invention of the steam engine in the eighteenth century, which supported the working people in energy-intensive activities. Subsequently, the division of labor was introduced in the late nineteenth century and allowed for mass production by means of the assembly line. The use of electronic control systems, such as Numeric Control (NC) and Computer Numeric Control (CNC) machines, since the 1970s allowed faster and more precise production of goods [3]. Since the introduction of Industry 4.0, much research has been focused on it generating an extensive number of scientific, as well as practically oriented papers and contributions to this field [4].

The historical development of production techniques shows that the desire to automate production is nothing new [5], however, computational power and technical equipment was previously not as developed as it is nowadays. Decades ago, the example of "Hall 54" of the Volkswagen AG showed the practical problems of the past associated to the relation between human and machining development in the industrial production environment [6]. On top, there have been considerable problems with the operational implementation [7]. With the technological development of the last few years, a clearly improved technical infrastructure is now available, especially regarding the information technology aspect, with which many ideas of the connected industry can now be realized.

This paper focuses on additive manufacturing as an example of a part of industry 4.0. Additive manufacturing was first introduced in the 1980s and is becoming more important nowadays with the development of industry 4.0. We will exemplify human-related challenges for the use of this technology based on a qualitative description of changes. Additive manufacturing describes production of tools and products based on the computer-internal data models from formless material – such as powder – or form-neutral material – such as fiber and wires – by means of chemical or physical processes. Within additive manufacturing, different technologies are combined whose common feature consists in the fact that components are layered and material is only connected where the final product should be produced [8]. For all people using additive manufacturing, skills required will change compared to the ones necessary for “traditional” production. This covers knowledge about different types of additive manufacturing, their machine and process parameters as well as properties of the goods produced.

In Section 2, the human-oriented challenges in industry 4.0 are discussed based on the features identified in the industry 4.0 framework. In Section 3, the additive manufacturing is presented as example of industry 4.0 and changes in the way of working entailed by this technological evolution are described. In Section 4, conclusions on the major changes induced by industry 4.0 within work relations are presented.

II. Human-Oriented Challenges in Industry 4.0

The issue of what will happen to the working people is nowadays critically discussed as it had been in time of the third industrial revolution of the 1970s [9][10]. If job losses or workplace growth is predicted, is not only a question of the time horizon taken into regard and the specific type of industry in scope, but also of the political thinking and attitude of the forecasting institution. It is a question of "which type" of industry 4.0 is regarded as well, as industry 4.0 covers several topics from using a tablet computer for work up to collaboration with robots. What can be taken as given is that work itself changes by industry 4.0, and this will also lead to a change in work skill requirements on the one hand and how work will be performed in future on the other hand.

In a process inside industry 4.0, the identification of seven features as shown in Figure 1 is normally expected. It is important to note that the human is a central actor in this revolution. All other features, such as self-organized and distributed artificial intelligence, fast and automatic network integration with high flexibility, open standards, virtual real-time picture of the process, digital integrated life-cycle-management and safe and secure added-value networks have their outcomes established to achieve the requirements and needs of the central actor.

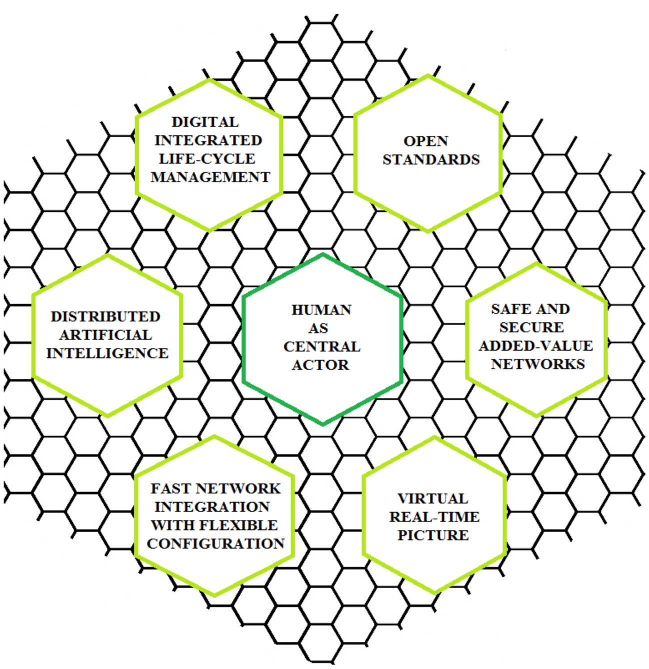

Figure 1. Industry 4.0 and its features - the human in the center.

The companies are transforming themselves by combining investments in information technology with changes in work practices, strategy, products and services. They are carrying on changes not only in their own company, but also in supplier relations and customer relationship [11]. This brings major challenges like changes in the decision rights, in the authority and responsibilities of the workers as well as in the process and workflow. The intensity of interactions with customers and suppliers will significantly increase, and so will augmented lateral communication. Among others, there might be further reductions in the management layers, and products and processes will undergo a concurrent engineering. All these factors will bring changes to the companies, and they need to find strategies of how successfully cope with those changes.

There are some general recommendations that can be given. When implementing industry 4.0, employees should be involved as early as in the planning stage, and their wishes and concerns should be taken into regard by management. It is of great use to have practical test spaces where employees can gain their own experiences with new technologies. Such pilot test environments can illustrate the benefits of digital change and may lead to a high identification with it, and finally to the recognition of its benefits. The fast development of digital technologies requires a high level of learning and change attitude as well. The management of the company plays a critical role in implementing this attitude. Only by good leadership and an appropriate fault culture, a change in thinking can be achieved [3].

Maybe it will be the case that some workers tend to retain elements of the now almost outdated work practices. Some believes, as the key for productivity is to avoid stopping the machine as long as possible and produce goods in large quantities at low rates of variety, negates the chances of flexibility offered by new production processes in industry 4.0.

III. Additive Manufacturing as Example

Additive manufacturing, as example of industry 4.0, offers the chance to produce individualized products at lot size one. Therefore, it is necessary for the workers to set their mind on each new product and machine parameters required to the specific needs for these products. Although the main process will be additive manufacturing, in detail it will make a big change if the product consists of metal or plastic, and the type of metal or plastic requires further knowledge about how to process it. The thickness of layers, therefore the number of layers, the distance of melting points next to each other and temperature are some examples that need to be taken into regard. The workers using additive manufacturing may also need knowledge for product designing, especially if the need of supporting structures for production is required. The latter shows that successful production of a product using additive manufacturing begins at the design stage when computer-aided design (CAD) models are created, therefore designers need to understand the production process and the workforce printing the products should be able to adjust data files with the designers.

To handle with the identified conditions – based on the fact that products will generally be less produced in large quantities by using additive manufacturing but at a higher

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level of customer individuality – the workers should be able to make decisions that were not required in their job functions before. This example shows that industry 4.0 increases the demand for skilled labor, which may in return reduce the need for low-skilled workers. It is important especially for low-skilled workers, in order to be able to work in these more complex highly skilled jobs, to undergo intense learning and a process of continuous education.

There is a consensus that industry 4.0 may not only have consequences for low-skilled workers and their operational shop floor activities, leading generally to a replacement of simple and repetitive jobs in production assembly and quality control, but also for high-skilled management representatives in administration and planning. Figure 2 shows the changes in the way of working in the industries caused by technological evolution over the last decades. In the 1960s, the industry was almost totally composed of mechanical equipment and processes with a small use of electrical systems and equipment. This reality had been changing over the years with an increasing participation of electrical systems and equipment and with the gradual introduction of software engineering and – at a later stage – of systems engineering. The trend is that by 2020 software and systems engineering will have almost as great a share as mechanical and electrical construction in the constitution of industrial production systems.

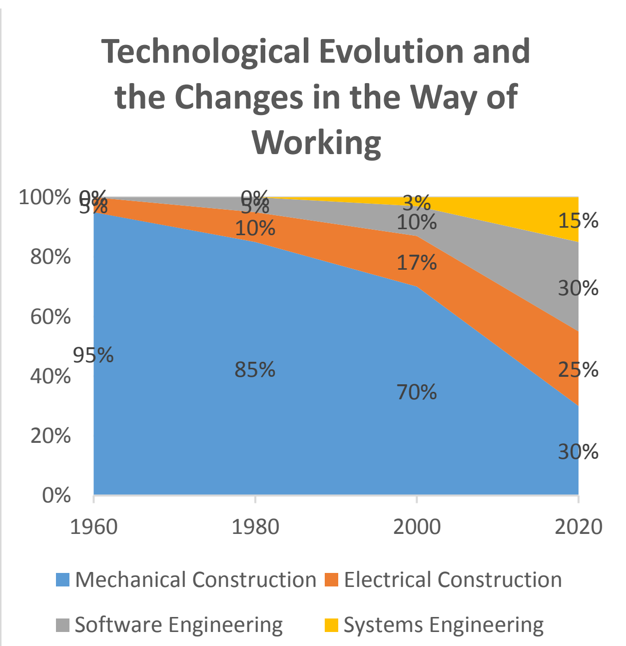

Figure 2. Technological evolution and changes in the way of working

Nevertheless, if the overall number of jobs will decline or improve is a question that cannot be answered now. However, it can be noted that – as in previous industrial revolutions – new jobs and needs for qualification are emerging and will continue to emerge. It is a task for each company on the one hand and for designing new governmental policies on the other hand, that will be required in future to help to balance the effects of industry 4.0 on the labor market.

The changes driven by industry 4.0 on the labor market are derived of the changes of the consumer markets on the one hand and of the changes of the technologies available for production on the other hand. As consumers require more individuality of products and additive manufacturing offers the possibility to do so, each industry and every company need to think of what are specific consequences they need to cope with. Digitalization affects the entire company, therefore prerequisites for a successful digitalization of the own company needs to be established both in production as in supporting indirect areas. To succeed, it is necessary to involve all people at hand and to establish standardization of processes taking into regard the principles of lean management. The change to industry 4.0 requires fundamentally questioning the existing structures and processes, and adapting them as far as necessary and possible. This includes qualification and skills as well.

A practical example is the Smart production of Microsystems based in laminated polymer films research project (SMARTLAM) research project, which was carried out under the European Union program FP7 - Factories of the Future. The main aim was to create a new concept for the manufacturing of functional micro devices based on a modular, flexible and scalable 3D integration scenario. Combining state-of-the-art 3D-compatible technologies, such as aerosol-jet printing, and laser technologies, which are capable of manufacturing three-dimensional structures and parts, with modules for handling and inspection together with a recipe-based control software, as shown in Figure 3, allowed for the successful development of a modular, scalable and easy-to-synchronise manufacturing environment for the production of complete 3D-Microsystems.

Figure 3. SMARTLAN Integrated Modules

It has shown that the 3D integration approach proposed is capable of creating the flexibility and scalability that is necessary to take the manufacturing of micro devices to another level by making it profitable outside of the area of mass production. It became clear to the project partners the need for changes in the business model and in the requirements and qualification of employees in order to face and adapt themselves to the new production paradigms from the Industry 4.0.

IV. CONCLUSION

We have shown by means of the descriptive example of additive manufacturing that industry 4.0 leads to significant changes of the industry. This is mainly driven by two developments, the wish of customers for individualized products and the upcoming of technologies that enable the companies to produce individualized products at lot size one. Additive manufacturing is an example of such a technology. Printing products according to specific customer wishes requires new skills of those creating and producing the goods, and calls for more interaction between all people on all levels involved in the production process.

The opportunities and challenges resulting from a comprehensive use of industry 4.0 appear to be far-reaching, but offer considerable potential for improvement. However, aspects, such as decisions based on insufficient process and product knowledge in respect with interdependencies of many inter-related decisions, maybe in a sense of non-cooperative use of information asymmetries, pose major challenges to the implementation of industry 4.0. The success of industry 4.0 is often a question of the system boundaries in which it is applied and operated, and one important part of it includes human aspects. Practical and scientific research is therefore confronted with major challenges that lie in the detail of how to successful use technologies such as additive manufacturing, in addition to the broad generalization of the advantages of industry 4.0 [12]. This paper addresses these issues and shows by means of examples that qualification is a major success factor and that companies need to focus on providing all possible options to appropriate skills.

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