The Use of Advanced Manufacturing Technology to Reduce Product Cost

Fatmir Azemi[1], Goran Šimunović[1], Roberto Lujić[1], Daniel Tokody[2], Zoltan Rajnai[3]

[1]Mechanical Engineering Faculty in Slavonski Brod, JJ Strossmayer University of Osijek, Trg Ivane Brlić Mažuranić 2, 35000, Slavonski Brod, Croatia; fazemi@sfsb.hr, gsimun@sfsb.hr, rlujic@sfsb.hr

[2]Doctoral School on Safety and Security Sciences, Óbuda University, Népszínház utca 8, 1081 Budapest, Hungary; tokody.daniel@dosz.hu

[3]Bánki Donát Faculty of Mechanical and Safety Engineering, Óbuda University, Népszínház utca 8, 1081 Budapest, Hungary; rajnai.zoltan@bgk.uni-obuda.hu

Abstract: The rapid development of new technologies has led to a change in the ways of manufacturing in industrial organizations. As a result of this development, many companies and factories started to look for new forms of organizational structure and the implementation of new technologies in their manufacturing process. In this context, the CAD/CAM/CAE systems play a crucial role in the process of manufacturing and generally in the transition to digital manufacturing, as the basis of a new industrial revolution. This paper presents the application of new technologies in a product life-cycle, namely the application of an advanced CAD/CAM/CAE system to support the organizational lean manufacturing initiative of SMMEs in Kosovo as a means to achieve world-class performance. Two case studies have been completed, one on the advantages of applying the CAD/CAM system in product development and the second by applying traditional manufacturing. A further aim of this present paper is to bring initiatives to the collaborative environment and to bridge the gap between industry and educational institutions.

Keywords: CAD/CAM/CAE system; Lean Manufacturing; Smart Factory; SMMEs of Kosovo

1 Introduction

The use of ICT (Information and Communication Technology) and other technological options are still at an early stage for enterprises in Kosovo [1]. Introducing computerized systems and other ICT facilities in the process of manufacturing still pose a problem for company managers and their staff and most of them are hesitating to take initiatives in the process of replacing traditional manufacturing with advanced manufacturing technology. The lack of knowledge and training programs, the high costs of purchasing/maintaining such technology, the inadequate education of unskilled workers, the lack of creative administrative leadership and poor research in this field at the enterprises in Kosovo are the main challenges in the process of transforming enterprises using traditional manufacturing into ones using advanced manufacturing technology [2].

However, a recent survey carried out in South-East Europe found that 71% of the enterprises reported a profit of more than 5% in the last financial year. This is a good opportunity to open the door for technological investments which are essential in the transition process [3].

Adopting ICT and other technological facilities at the enterprises in Kosovo is a great challenge, especially if we take into account that the Kosovar market has a limited size, and the possibilities to distribute products in external markets are also very limited. However, most enterprises in Kosovo show a positive tendency toward the growing use of Computer and other ICT facilities in the development process of manufacturing [1].

The term of Advance Manufacturing Technology - AMT refers to the usage of computer technologies in the process of design, process of manufacturing, testing, transportation and controlling, etc. AMT ensures an organization with a possibility to successfully market place and establish for itself a competitive advantage. Academics and manufacturers believe that Advance Manufacturing Technologies can decrease operating cost, provide high levels of output by reducing inconsistent human input, improve flexibility in manufacturing and lead time to market [4].

AMT represents a wide diversity of mainly systems based on computer, that providing firms to be more adopted with the potential to improve operations in manufacturing greatly. It is extensively expected that the consequent improvement in performance of operational will increase the firm’s ability to gather the underlying market, business and strategic benefits for whom the systems were adopted. Another definition of AMT may refer as a family of technologies which include engineering systems and computer-aided design (CAD), MRP systems (materials resource planning systems), computer controlled machines, automated materials handling systems, flexible manufacturing systems, electronic data interchange, robotics and computer-integrated manufacturing systems. AMT has been related as a system of programs machines or programmable machine that can produce a diversity of parts or products with almost no time lost for changes. The machines, linkages and computer control, as well as the human operator involvement, seems to be on a windy path from islands of technology towards some far wider grade of computer integration, noted to as computer integrated manufacturing (CIM) [5].

Successful AMT (Advanced Manufacturing Technology) implementations, such as the use of integrated CAD/CAM /CAE[1] systems and other new technologies are considered as the means to overcome the difficulties in manufacturing competitiveness. Among other tools which are important in the process of transforming traditional manufacturing into modern manufacturing, the CAD/CAM/CAE systems can have a special role.

Integrated CAD/CAM/CAE systems provide support for companies through reducing costs, improving product quality, saving time and fulfilling new customer requirements. Lean product development in this context [6] constitutes of several engineering methods and techniques. Therefore, the application of advanced CAD/CAM/CAE systems in product development can support organizational Lean Manufacturing initiatives in SMEs. Until now, relatively little quantitative research has been carried out on lean product development with the application of integrated CAD/CAM/CAE systems, especially at the enterprises in Kosovo.

Advanced industrial organizations have profoundly changed their manufacturing processes through the adoption of computerized technologies [7] [8]. This development is frequently viewed as the basis for a new industrial revolution—the advent of the "factory of the future"- and a new form of organizational structure [9]. Manufacturing in today’s world has developed and changed due to new technologies and worldwide competition. As a consequence, a need for faster product development has arisen. Other design and manufacturing technologies such as concurrent engineering, design for manufacture, just-in-time production, and computer aided design (CAD) have pushed the design envelope further [10].

The transformations happen through digital manufacturing and design from paper-based processes to digital processes in the manufacturing industry. The CAD/CAM/CAE system applies to all phases of activities from the product design to customer support in an integrated way (Figure 3), using different methods, means and techniques in order to increase production improvement, quality improvement, cost reduction, fulfilment of scheduled delivery dates, and total flexibility in the manufacturing system [11] [12].

[1] CAD – Computer Aided Design, CAM – Computer Aided Manufacturing, CAE – Computer Aided Engineering

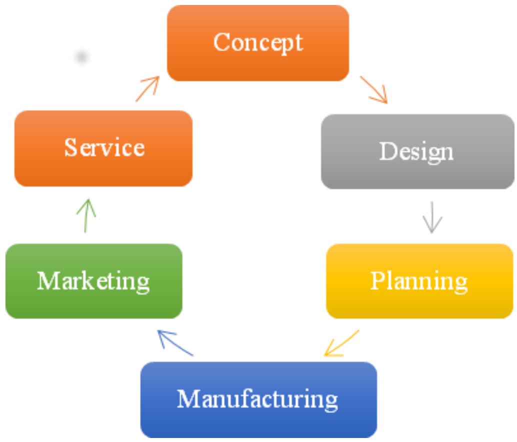

Figure 1
Product development cycle [10]

This paper presents the advantages of using ATM instead of traditional manufacturing technologies in order to encourage managers and other decision-makers to take initiatives in their start-ups to achieve advanced manufacturing through the implementation of integrated CAD/CAM/CAE systems in Small and Medium Manufacturing Enterprises (SMME). Through the examples of the following case studies, our paper also aims to bring initiatives for the collaborative environment to bridge the gap between industry and educational institutions.

2 Case Studies

The first case study has been done at the Laboratory of Faculty of Mechanical and Computer Engineering – University of Mitrovica "Isa Boletini" in Mitrovica. At the Faculty of Mechanical and Computer Engineering, currently there are five different programs: BSc Industrial Machinery, BSc Economic Engineering, BSc Engineering Informatics, MSc Engineering Informatics and MSc Production Technology. Among other equipment and machines, the laboratory provides the students of Mechanical Engineering with state-of-the-art engineering workstations and CAD/CAM/CAE software for a variety of applications in solid modelling, kinematics, dynamics, finite element modelling and analysis, numerical control machining simulation and others [13] [14].

The second case study has been done in a factory of mechanical production parts. This factory, established in 1974, was one of the biggest manufacturers of automotive parts in the region. Since the end of the war, however, this company has failed to apply any advanced technologies which could have increased efficiency and quality in production, and it is still using traditional manufacturing.

From these case studies we are tried to focus on the transformation of traditional manufacturing into digitalized manufacturing as well as on bridging the gaps between industry and education [15].

2.1 Methodology of the Case Studies

This part of the paper explains which method has been used to reach the objectives of the present study. The final objective was to present the advantages of the application of advanced manufacturing in the process of product development, which can help companies to reduce production time and costs and improve quality. To achieve this goal, two different types of inputs have been used; literature review and case studies. At the beginning our research focused on literature review, which was followed by the case studies. Two case studies were carried out to gather data from a factory and from an educational institution and finally the comparison of both data analyses were done.

2.2 Literature Review

To maintain or to be competitive and profitable, a manufacturing company or enterprise must have the ability to respond to a number of challenges, including rapid improvements in technology, workforce and in strategy in all aspects of product manufacturing due to globalization. Additionally, substantial changes in government policies have had significant impacts in many countries, as well as the increasing level of global trade. Manufacturing companies need to be clearer understanding of what their customers want and why customers purchasing their products instead of their competitors. Therefore, they need to fully understand the objectives of their business in terms of its customers, market segments, product attributes and geographical markets. The adoption of management technologies by SMEs may be the result of the pressure from the government, associated companies or customers.

In product development, wastes are inevitable, but they should be minimized as much as possible to have sound profit and sustain product development performance. Most of these wastes are time and process dependent and can be expressed in terms of costs, lead time, rework, defect rate, etc. To be successful in a competitive business environment, products and managers need a know-how of organizing as well as product development and manufacturing. Lean product development is a way to organize product development according to a set of principles [16] [17].

Lean product development in this context, constitutes of several engineering methods and techniques. The application of advanced CAD/CAM/CAE systems in product development supports organizational Lean Manufacturing initiatives in SMEs. However, relatively limited quantitative research has been carried out on lean product development with the application of integrated CAD/CAM/CAE systems, especially in Kosovo.

Recently, there have been an improvement in computer performance and manufacturing technologies, companies have integrated computer aided design [18] (CAD) into their design strategy, as well as CAD/CAM/CAE systems to increase efficiency. Lean production can be supported and facilitated by these tools.

Other deployment methods include training, supplier integration, machine configuration, the provision of greater understanding of the internal processes within the case company by illustrating ways in which ideas are generated, the approach taken and how the CAD/CAM system changed the organization's work methods [19] [20].

Liu and Barrar suggested that a firm with a higher level of strategy-technology integration has achieved a degree of "fit" between strategy and technology, and thus would make the firm compete more effectively in the marketplace and attain a better operational as well as financial performance [21]. They also stress on the need for consistency between manufacturing strategy and business objectives. Apparently, many organizations lack this consistency [22] [23].

Studies of different AMTs suggests that they can be successfully introduced into SMEs, but that they will be implemented in ways that differ from large businesses. For example, in implementing TQM[2], small companies put more emphasis on leadership, employee involvement and quality information whereas larger firms emphasize training, feedback, quality assurance, and supplier cooperation [24].

The advantage of dealing with the issue of creating an NC code in the CAD/CAM system's CATIA model for machining on a vertical milling machine tool system is that the creation of the NC program takes relatively short time regarding the complexity of the shape components utilized in milling. These systems are facilitated by the sufficiently rapid generation of NC codes and their easy adaptation to a suitable form for the CNC machining center. Using the systems with a CNC machining center in practice reduces the risk of errors arising during operation [25].

2.3 Case Study 1: The Use of an Integrated CAE/CAD/CAM System during the Parts Design

Computer Aided Design (CAD) systems are involved most of the activities in the design cycle, they are recording all data of the product, and they are used as a platform for collaboration between remotely placed design teams. CAD systems can shorten the design time of a product, enable the application of concurrent engineering and can have a significant effect on final product cost, functionality and quality [26].

[2] TQM – Total Quality Management is a management approach that originated in the 1950s and has steadily become more popular since the early 1980s

The objective of the two case studies presented in this paper is to elaborate the main advantages of using an integrated CAE/CAD/CAM system in product development instead of traditional methods. The first case study was carried out with the participation of nine students with an average knowledge of the CAD techniques in the process of design. The time spent for designing three parts with CAD software was measured. Results are presented in Table 1.

Computer Aided Manufacturing (CAM) creates physical models, generally refers to the use of numerical control (NC) computer software applications to generate detailed instructions (G-code) that drive computer numerical control (CNC) machine tools for the manufacturing of parts. In order to create the actual model, CAM works alongside CAD data designs, CAM uses numerical coding to run the machine that makes the product. A CAD/CAM package software allows companies to develop and save their own product designs, and program machines to make the actual component [27].

Table 1

The time for product design by students using CAD software

	Time for design product 1	**Time for design product 2**	**Time for design product 3**
	Unit [h:mm:ss]	Unit [h:mm:ss]	Unit [h:mm:ss]
Average	0:18:41	0:20:27	0:19:02

To measure the time of processing products, procedures were separated in two phases: the time for code generations with CAM software and the time for machining parts in CNC machines. Three products were produced with the involvement of nine students who produced the parts, and the time for the generation of G-Code and the time for machining was measured. Table 2 shows the measured time in the phase of product processing-manufacturing with the application of CAM software and a CNC machine.

Table 2

Average time of three products, measured during product processing with the aid of CAM software and a CNC machine

	Time for G-code generation CAPP[3] and CAM software [h:mm:ss]	**Time for machining in CNC machines [h:mm:ss]**	**Total time [h:mm:ss]**
Average	0:12:06	0:03:15	0:15:21

After the pieces had been manufactured in the CNC machines, they were measured with the help of various measuring tools and equipment. Results are presented in Figure 2.

[3] CAPP – Computer Aided Process Planning

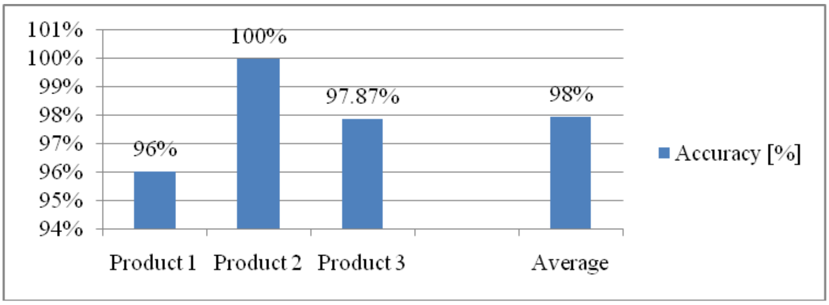

Figure 2
Accuracy of the pieces produced with advanced manufacturing

2.3.1 Cost of Product with the Application of Advanced Manufacturing

Cost of product refers to the costs used to make a product. Cost of manufacturing is the amount of the costs of all resources used in the process of making a product. The manufacturing cost is assorted into three categories: direct labor cost, direct materials cost and manufacturing overhead. To calculate the cost of the product we will focus only on the parameters which directly affect the ways of processing, and on the time which was spent on the process of design, on code generation and on product processing. The time which is required to produce one unit of Product 1 with the application of a CAD/CAM system is based on the above time results.

Participants: a design engineer, a production engineer and an operator.

Time for product manufacturing (case study 1):

$$T_m = t_d + t_m + t_s + t_{add} \quad \textbf{(1)}$$

Where are:

t_d[min] – design time, t_m[min] – machining time, t_s[min] – setup time, t_{add}[min] – additional time.

Where are:

Average design time (table 1)

$$t_d = 18.683\ min = 0.31\ h$$

Average machining time (table 2):

$$t_m = 15.35\ min = 0.26\ h$$

Setup time is supposed to be the same for both methods of manufacturing:

$$t_s = 0.083\ h$$

Additional time is:

$$t_{add} = 0.030\ h$$

Now, time for the manufacturing of one piece of the product is:

$T_m = 0.31+0.2558+0.083+0.030=0.703\ h$

The price of the product in function of time, according to the time spent per workforce:

$C_w = DE \cdot t_d + PE \cdot t_m + 2 \cdot O \cdot (t_s + t_{add}) = 2.66$ €

Where:

DE = 4 €/h – payment per hour of Design Engineer.

PE = 3.8 €/h – payment per hour of Production Engineer.

O = 2 €/h – payment per hour of Operator.

Price of stocks is the same for both methods, therefore it will not be calculated.

Then, the cost of product in function of consumed time per workforce is:

$C_p = C_w = 2.66$ €

It should be noted that in the calculation of the cost of the product some factors which do not depend on the method of manufacturing were not taken into consideration.

2.4 Case Study 2

Case study 2 served to collect data about the time spent on product design and product processing, about the accuracy and the cost of product when using conventional methods.

To obtain the results of the product design time in case of using conventional methods, the time spent on designing three products with the involvement of nine Design Engineers was measured. Results of the time spent on the process of design are presented in Table 3.

To measure the time of processing products, procedures were separated in two phases: the time for code generations by hand and the time for manufacturing parts. Three pieces have been produced with the involvement of nine students. Table 4 shows the measured time results in the phase of product processing-manufacturing with the application of conventional methods.

Table 3
The time of products design by Engineers using conventional methods

	Time for design product 1	**Time for design product 2**	**Time for design product 3**
	Unit [h:mm:ss]	Unit [h:mm:ss]	Unit [h:mm:ss]
Average	0:37:16	0:42:39	0:40:46

Table 4
Average time of three products measured during the processing of products using conventional methods

	Time for machine operation calculations - process planning [h:mm:ss]	Time for machining [h:mm:ss]	Total time [h:mm:ss]
Average	0:19:47	0:05:37	0:25:24

After the pieces had been manufactured in the machines, they were measured with the help of various measuring tools and equipment. Results are shown in Figure 3.

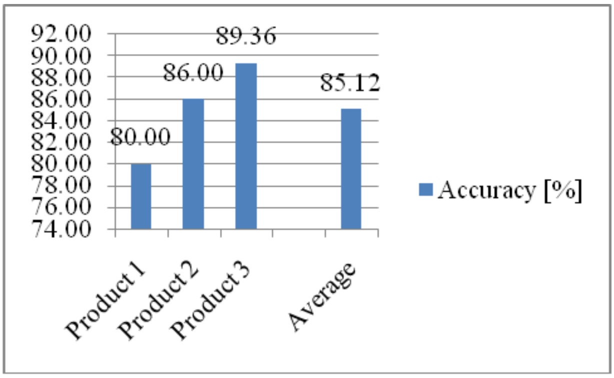

Figure 3
Accuracy of pieces produced by traditional manufacturing

2.4.1 Cost of Product Produced by Conventional Manufacturing

The required time for the production of one piece of product 1 with conventional methods based on the results from Table 3 and Table 4.

Participants: a design engineer, a production engineer and two operators.

Time for product manufacturing (case study 2):

$$T_m = t_d + t_m + t_s + t_{add} \quad (2)$$

Where are:

t_d[min] – design time, t_m[min] – machining time, t_s[min] – setup time, t_{add}[min] – additional time.

Average design time (Table 3):

$t_d = 37.266\ min = 0.621\ h$

Average machining time (table 4):

$t_m = 25.04\ min = 0.4233\ h$

Setup time is supposed to be the same for both methods of manufacturing:

$t_s = 0.083\ h$

Additional time is:

$t_{add} = 0.054\ h$

Now, the time for manufacturing one piece of the product with traditional manufacturing is:

$T_m = 0.6211+0.4233+0.083+0.054 = 1.044\ h$

The price of the product in function of time, according to the time spent per workforce:

$C_w = DE \cdot t_d + PE \cdot t_m + 2 \cdot O \cdot (t_s + t_{add}) = 4.54\ €$

Where are:

DE = 4 €/h – payment per hour of Design Engineer.

PE = 3.8 €/h – payment per hour of Production Engineer.

O = 2 €/h – payment per hour of Operator.

Price of stocks is the same for both methods, therefore it will not be calculated.

Then, the cost of product in function of consumed time per workforce is:

$C_p = C_w = 4.54\ €$

2.7 Comparison of Methods

This part of the thesis presents the issues of the measurement and the comparison of advanced manufacturing technology (AMT) and traditional manufacturing in the process of product development. Comparison is made between the product development using an integrated CAD/CAM/CAE system at the Laboratory of Faculty of Mechanical and Computer Engineering – University of Mitrovica "Isa Boletini" in Mitrovica and in a factory producing mechanical parts through traditional manufacturing.

Figure 4 presents the comparison of the average time of designing three products by nine students with the application of CAD software, and by nine engineers using traditional methods.

As it can be seen from Figure 4, the average time of designing products with Advanced Manufacturing Technology is less than the average time of designing products through Traditional Manufacturing. Figure 5 presents the comparison of the average time of processing products with advanced manufacturing technology and by using traditional manufacturing.

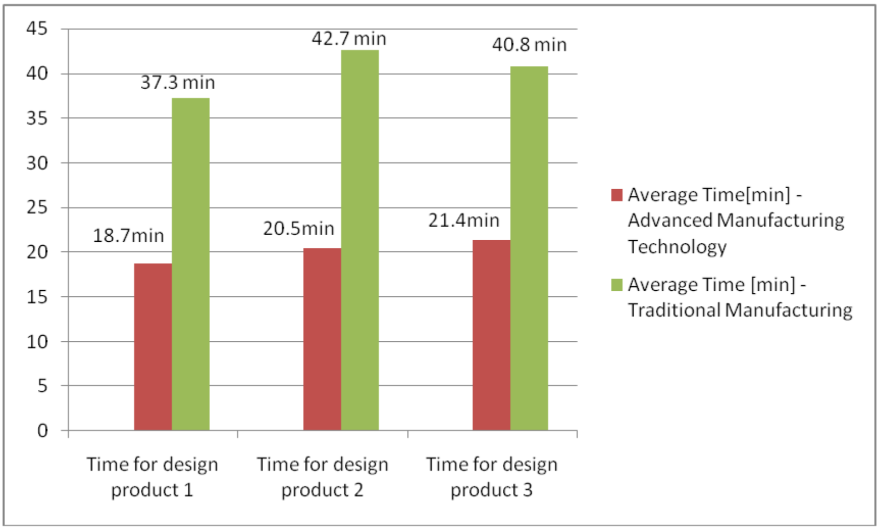

Figure 4
Comparison of average time of product design by AMT and TM

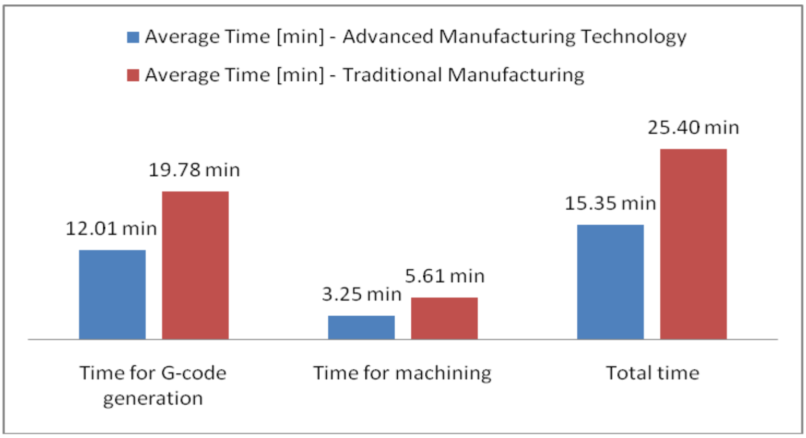

Figure 5
Comparison of the average time of processing

Figure 6 shows that the time of processing products with advanced manufacturing technology is also less than the time of processing products through traditional manufacturing.

Figure 6 shows the comparison of the accuracy of the production of three parts using AMT and TM. The accuracy rate is 98% with the application of advanced manufacturing technology, whereas it is 83% in the case of traditional manufacturing.

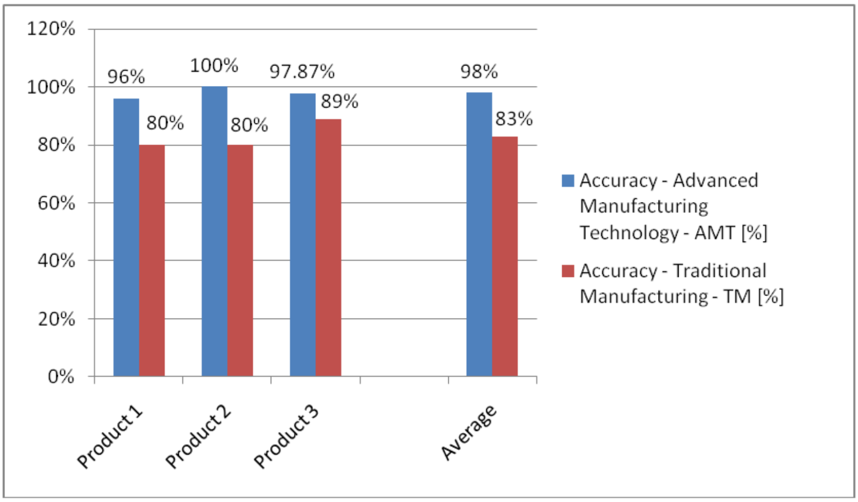

Figure 6
Comparison of the accuracy of the pieces produced with AMT and TM

Except for the above mentioned features, AMT has also been shown to reduce the amount of rework and wastes, which assign into improved quality and confidence to the customer. This reduction has been connected to the elimination of the manipulator (ATM has been automated the process of production), as well as the elimination of operator upset and fatigue.

Use of CAD/CAE also helps to create the better innovations in the product. By integrating analysis and process of design in development of product at the earlier stages the productivity can be enhanced and could be obtained superior designs (Authors Study) [28] [29].

3 Conclusions and Recommendations

The implications for educational institutions, for manufacturing firms and for the Kosovo government are substantial. Some businesses have already started to implement some of the new advanced technology in their production (questionnaire, interview), but many of them are not positioned to succeed in the implementation of any new advanced manufacturing technology. Enterprises in Kosovo need to radically change their approach to providing a constant and consistent framework within which all firms aspire to prosper.

The findings of this research conclude some phenomena based on case study analyses and literature review, as below:

- Traditional manufacturing processes face more difficulties than advanced manufacturing technology (Integrated CAD/CAM/CAE system).
- Advanced manufacturing technology processes save more time in production than traditional manufacturing. With AMT the time of production is 32.66 % less than in case of traditional manufacturing (case studies).
- CAD/CAM system processes can produce more accurate products in terms of the dimensions of parts than traditional manufacturing.
- The application of AMT can save material of stocks, increase productivity and improve communication.
- The cost of product with the application of advanced manufacturing technology is about 40% less than in case of traditional manufacturing (case studies).

The implementation of integrated CAD/CAM/CAE systems at the enterprises in Kosovo is essential to achieve Lean Manufacturing, to reduce overproduction, over-processing, defects, costs and workforce, and to improve quality.

4 Future Prospects and Challenges

At present, the main direction of development, within European industry, is defined by digitalization. Similar to the way the Industrial Revolution changed manufacturing, digitalization is having a profound impact on the transformation of today's industrial processes. Among other things, it provides basis for the creation of smart manufacturing systems and smart factories. Furthermore, this new technology enables manufacturing companies to move from mass production to customized production at a rapid pace. The future, therefore, is digital and digitalization is affecting all industries and all aspects of life.

This transformation, however, also presents some challenges. Computer Integrated Manufacturing (Industrial Automation Systems), for example, can be rather rigid in view of the frequent changes of demand. This means that existing systems may prove to be difficult to transform or expand, and performance can significantly decrease in anomalous circumstances. Strongly hierarchical and centralized systems are usually characterized by rigid interconnection, which results in non-flexible communication systems, where the flow of information implies the realization of a top-down autocratic hierarchy.

Manufacturing companies have been considered to be rather slow to take the opportunities presented by digital technologies, such as the use of intelligent robots, sensor technology, drones, artificial intelligence, nanotechnology and 3D printing. The digital transformation of manufacturing is also affected by such trends as IoT, Industry 4.0, data and analytics, artificial intelligence and machine learning. IoT can have an especially important role in the manufacturing industry, as it can significantly streamline and simplify various manufacturing processes by providing real-time feedback and alerting companies in case of errors or defective products.

Currently, these algorithms change the methods of data collection, performing skilled work or predicting costumer behavior. Smart factories using integrated IT systems can provide sufficient data for both sides of the supply chain in a much more convenient way, which can significantly increase production capacity. Big data analyses, however, can be a rather complex and time-consuming process, therefore digitalized factories may struggle with the management, update and analysis of product and customer information. Despite all these difficulties, the above changes seem to be inevitable. It is certain that Smart Factories, Smart Manufacturing and Smart Products will soon become integral parts of our lives.

Acknowledgement

We would like to thank the staff of the Faculty of Mechanical and Computer Engineering – University of Mitrovica "Isa Boletini" in Mitrovica that they have given us the opportunity to do research work at the Laboratory, as well as the staff of the factory (who wished to remain anonymous) for their support in the experimental research in the department of manufacturing.

References

[1] Azemi, F., Lujic, R., Simunovic, G., Maloku, B.: Utilization and impact of ICT on SMEs: The case study of the Kosovo private sector at furniture and metalworking industry. 17th International Multidisciplinary Scientific GeoConference SGEM 2017, 29 June – 5 July 2017, Albena – Bulgaria, 751-758

[2] Azemi, F., Hajrizi, E., Maloku, B.: Maturity Level of Kosovo Manufacturing Industry with regard to Industry 4.0. 6th International Conference on Business, Technology and Innovation 2017, October 27-29, 2017, Durrës, Albania

[3] K. D. Gunawardana, "Introduction of Advanced Manufacturing Technology: a literature review," *Sabaragamuwa Univ. J.*, 2010

[4] P. Milgrom and J. Roberts, "The Economics of Modern Manufacturing: Technology, Strategy, and Organization," *Am. Econ. Rev.*, 2008

[5] OECD; How South East European Countries' Statistics Measure Foreign Direct Investment. Paris: Organisation for Economic Co-operation and Development. 2007

[6] Bencsik, A. L., Lendvay, M., Trimmel A. K., Némethy, K., "Integration of new equipment by advanced process optimization," 2016 IEEE 11th International Symposium on Applied Computational Intelligence and Informatics (SACI 2016) Timisoara, 2016, pp. 305-310, doi: 10.1109/SACI.2016.7507391

[7] Horvath, L., Rudas, I. J., Generic modeling of manufacturing processes using Petri net representations (1997) IEEE International Conference on Intelligent Engineering Systems, Proceedings (INES 1997) pp. 539-544

[8] Lojka, T., Bundzel, M., Zolotová, I., Service oriented Architecture and Cloud Manufacturing, Acta Polytechnica Hungarica Vol. 13, No. 6, 2016, pp. 25-44

[9] Belassi, W., Fadlalla, A., "An integrative framework for FMS diffusion". Omega. 26: pp. 699-713, 1998

[10] Roy U., Bharadwaj B., Kodkani SS., Cargian M. (1997) Product development in a collaborative design environment. Concurr Eng Res Appl 5:347-365

[11] Rudas, I. J., Horvath, L., Modeling man-machine processes in CAD/CAM and flexible manufacturing system (1996) IECON Proceedings (Industrial Electronics Conference) 3, pp. 1484-1489

[12] Radhakrishnan, P., Subramanyan, S., Raju, V., CAD/CAM/CIM, New Delhi 2008

[13] Pokorádi, L., Uncertainties of vehicle system modelling and simulation (2010) Proceedings of the Mini Conference on Vehicle System Dynamics, Identification and Anomalies, pp. 511-519

[14] Horvath, L., Rudas, I. J., Tenreiro Machado, J. A., Hancke, G. P. Application of part manufacturing process model in virtual manufacturing (1999) IEEE International Symposium on Industrial Electronics, 3, pp. 1367-1372

[15] Tokody D., Digitising the European Industry - holonic systems approach, 11th International Conference Interdisciplinarity in Engineering, INTER-ENG 2017, manuscript

[16] Szakál, A., "Application of Product Model for Engineering Process Definition," 2011 Fourth International Conference on Emerging Trends in Engineering & Technology, Port Louis, 2011, pp. 66-71, doi: 10.1109/ICETET.2011.36

[17] Morgan, J. M. & Liker, J. K. (2006) The Toyota product development system: Integrating people, processes, and technology. NY: Productivity Press

[18] Horváth, L., Rudas, I. J. Integrating expert knowledge in behavioral feature based product models (2002) IECON Proceedings (Industrial Electronics Conference) 3, pp. 2479-2484

[19] Horvath, L., Rudas, I. J., Bencze, J., Petri net modeling of manufacturing processes for CAD/CAM and FMS applications (1997) IECON Proceedings (Industrial Electronics Conference) 3, pp. 1216-1221

[20] Esan A. O., Khan M. K., Qi H. S., Naylor C., (2013) Integrated manufacturing strategy for deployment of CAD/CAM methodology in a SMME. Journal of Manufacturing Technology Management, 24 (2): 257-273

[21] Liu H., Barrar P., “Performance implications of strategy-technology connections: an empirical examination”, Journal of Manufacturing Technology Management, Vol. 20, No. 1, pp. 52-73, 2009

[22] Dangayach, G. S., Deshmukh, S. G., “Advanced manufacturing technology implementation: evidence from Indian small and medium enterprises (SMEs)”, Journal of Manufacturing Technology Management, Vol. 16, No. 5, pp. 483-96, 2005

[23] Sonntag, V., “The role of manufacturing strategy in adapting to technological change”, Integrated Manufacturing Systems, Vol. 14, No. 4, pp. 312-323, 2003

[24] Sun, H., Cheng, T.-K., "Comparing reasons, practices and effects of ISO9000 certification and TQM implementation in Norwegian SMEs and large firms" International Small Business Journal 20(4): 421-442

[25] Jambor, J., Quality of production process with CAD/CAM system support, in: DAAAM International Scientific Book 2012, Vol. 11, Austria, pp. 277-286

[26] Bilalis, N., Computer Aided Design CAD; Report produced for the EC funded project, Technical University of Crete, January 2000

[27] Leondes, C.; Systems Techniques And Computational Methods, London, 2001

[28] F. Azemi, X. Mehmeti, and B. Maloku, “The Importance of CAD/CAE systems in development of Product Design and Process of Optimization,” 2019

[29] F. Azemi, G. Šimunović, R. Lujić, and D. Tokody, “Intelligent Computer-Aided resource planning and scheduling of machining operation,” Procedia Manuf., Vol. 32, pp. 331-338, 2019