Lecture Notes in Mechanical Engineering

Adam Hamrol
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Advances in Manufacturing

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Adam Hamrol · Olaf Ciszak
Stanisław Legutko · Mieczysław Jurczyk
Editors

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Editors
Adam Hamrol
Poznan University of Technology
Poznań
Poland

Stanisław Legutko
Poznan University of Technology
Poznań
Poland

Olaf Ciszak
Poznan University of Technology
Poznań
Poland

Mieczysław Jurczyk
Poznan University of Technology
Poznań
Poland

ISSN 2195-4356 ISSN 2195-4364 (electronic)
Lecture Notes in Mechanical Engineering
ISBN 978-3-319-68618-9 ISBN 978-3-319-68619-6 (eBook)
https://doi.org/10.1007/978-3-319-68619-6

Library of Congress Control Number: 2017955280

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This volume of Lecture Notes in Mechanical Engineering contains accepted papers presented at the 5th International Scientific-Technical Conference (MANUFACTURING 2017), held in Poznan, Poland, on October 24–26, 2017. The conference was organized by the Faculty of Mechanical Engineering and Management, Poznan University of Technology, under the scientific auspices of the Committee on Machine Building of the Polish Academy of Sciences, and the Committee on Production Engineering of the Polish Academy of Sciences.

The aim of the conference was to present the latest achievements in mechanical engineering and to provide an occasion for discussion and exchange of views and opinions. The scope of the conference comprised of issues relating to:

- design, building, and research of machines and devices
- technological and assembly processes planning
- cutting machining, founding, plastic forming, devices, and tool-systems
- metrology and measurement systems
- materials engineering
- quality engineering
- production engineering and management

The book is organized into five chapters, according to the main conference topics: (1) production engineering (2) design, building, and research of machines and devices (3) cutting machining and technological and assembly processes (4) measurement systems and quality engineering (5) materials engineering.

Members of the Conference Scientific Committee were experts from various areas of manufacturing systems. They were engaged in evaluating papers submitted to the conference.

The organizers received 142 manuscripts from 18 countries. After a thorough peer review process, the committee accepted 92 papers prepared by 240 authors from 18 different countries (acceptance rate of about 65%). All of these papers have been published in conference proceedings. Chosen for their excellent quality, extended versions of selected papers will be published in the scientific journals

Management and Production Engineering Review (published by De Gruyter and indexed by ISI/SCI) and *Archives of Mechanical Technology and Materials* (published by De Gruyter).

We would like to especially thank the members of the International Program Committee for their hard work during the review process.

We acknowledge all that contributed to the staging of MANUFACTURING 2017: authors, committees, and sponsors. Their involvement and hard work were crucial to the success of the MANUFACTURING 2017 conference.

Poznań, Poland
October 2017

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Part I
Production Engineering

Analysis of the Conditions for Effective Use of Numerically Controlled Machine Tools

Adam Hamrol, Slawomir Zerbst, Mariusz Bozek, Marta Grabowska and Markus Weber

Abstract The paper demonstrates that the effective replacement of conventional machine tools with numerically controlled machinery (CNC) requires the simultaneous conducting of actions related to organization and control of production, management of human resources, and tool economy. The direct costs of machining for a selected group of surgical tools, performed with the use of conventional, as well as CNC machinery, were analyzed. The assumptions adopted for the analysis of profitability of machinery park restructuring were compared with the actual costs generated after a year from implementing the project.

Keywords Efficiency · Production costs · Tool economy

1 Introduction

A process-oriented approach to managing a manufacturing company means perceiving all actions, equipment, and machinery, such as machine tools, for instance, as links in the chain of delivery of parts or assemblies. The internal and external clients within this chain pose mutual requirements concerning the quality, costs, and timeliness of deliveries. The level of their fulfillment is the result of technological, organizational, human, material and other factors [1–3].

The technological factors (technologies and machine tools, including their accessories) play special importance here, especially in regard to the quality of the parts, subassemblies, and products manufactured, since they have a large impact on the dimensional and geometric accuracy, and the mechanical properties of the

A. Hamrol · M. Grabowska (✉)
Poznan University of Technology, Poznan, Poland
e-mail: marta.grabowska@put.poznan.pl

S. Zerbst · M. Bozek
AesculapChifa sp. z o.o., Nowy Tomysl, Poland

M. Weber
Aesculap AG, Tuttlingen, Germany

A. Hamrol et al. (eds.), *Advances in Manufacturing*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-319-68619-6_1

machined tools. The better the technology, and the better the machine tools, the better the qualitative requirements can be fulfilled.

The significance of technological factors in terms of costs and timeliness is more complex, however. On one hand, e.g., in case of numerically controlled machine tools being the subject of this paper, a number of potential benefits of using them, compared to conventional machine tools, may be pointed out [4, 5], e.g.,:

- increased flexibility, owing to the possibility of performing various operations on a single machine, and limiting the number and duration of retooling procedures,
- reduced demand for different accessories,
- limitation of the possibility of the operator's intervention in the technological process (higher repeatability of the machining conditions, limitation of human errors),
- possibility of several machines being operated by the single operator.

CNC machinery features a number of advantages compared to the conventional machines also in personnel terms [6, 7], such as:

- lower requirements for general qualifications (high qualifications are required, but in a relatively narrow scope),
- improved work conditions,
- increased workplace safety.

On the other hand, the implementation of CNC machines is related to higher costs of purchase and maintenance (service, part replacements), but also provides higher efficiency compared to conventional machines. The higher efficiency of individual work stands requires proper organization and control of production flow. If these two aspects: the stand's efficiency and production flow organization are not coordinated, then the efficiency of the entire production system is reduced (e.g., the machined or processed tools must wait in queue for subsequent operations, or large batches of parts produced too early are stored) [8, 9].

The factor that negatively impacts the effectiveness of the use of CNC machines may be the high cost of tools. Therefore, the implementation of CNC technologies must be assessed from the point of view of different criteria, including economic ones.

2 Assessment of Effectiveness of Implementation of New Manufacturing Methods

Investments consisting of the replacement of machine tools and the use of modern production technologies should be profitable in economic terms, since the basic goals of any enterprise are: generating profits, gaining positive operating cash flow, and increasing value. For technological investments to achieve these goals, they should be preceded by proper financial analyses.

The process of introduction of a new technology in the enterprise is understood, from the economic point of view, as an investment action, i.e., the engagement of funds in different objects aiming at the maintaining and development of the enterprise's potential [10]. The economic assessment of the implemented investments may be measured by a number of indicators, e.g., accounting rate of return, net present value, internal rate return [10–12]. They may be measured before the commencement of investment (ex ante), or after its completion (ex post). The choice of the proper measurement should be made based on the information needs of the decision maker or investor. For the calculated indicators to reliably verify the obtained benefits (or losses), the quality of input data is very important. They should take into account the business assumptions and the further plans of the enterprise. The range and scope of parameters to be taken into account in the analysis should be agreed mutually between the department performing the investment, the financial department, and the management body. The analysis may be of direct nature—verifying the effects only in the area of implementation of the new technology, as well as direct and indirect, i.e., also taking into account the impact of the new technology on other areas. Additionally, factors must be eliminated that may impact the results of analysis, even if they are not related to the given investment (e.g., change in the method of cost allocation, budgeting, etc.).

Direct analysis, referring to effects in the area of implementation of the new technology, will be used in this article. The analysis will use data on the costs generated in the selected production division, responsible for the introduction of specific group of products.

3 Analysis of Profitability of Selected Investment at AesculapChifa sp. z o.o.

AesculapChifa sp. z o.o. company (ACP) is a manufacturer of surgical tools. The assortment of the produced tools is very wide, which results from the requirements of the clients who use them to carry out different surgical procedures. At present, ACP manufactures about 3 thousand of models of surgical tools, with the annual demand for different models ranging from 10 pcs up to as much as 5 thousand pieces.

The case study concerns an investment consisting of the replacement of conventional machines with CNC machinery in machining processes of a selected group of surgical tools. The performance of investment included the following phases:

- decision-making and replacement of conventional machines with CNC ones,
- operating and economic analysis after 1 year from introducing CNC machines,
- preparation to the improvement of organizational and technological CNC processes.

3.1 Premises for Replacing Conventional Machines with CNC Machinery at ACP

ACP company continuously strives for improving the quality of the offered products and fulfilling the clients' requirements, e.g., concerning shorter order processing times. The high significance is also attached to improving the organization of internal processes, and optimizing production flow, e.g., through reducing inventories, both in current production as well as ready products. One of the preconditions for fulfilling the above goals is modernization of production resources, including the machinery park. One of the examples of actions in this field is the replacement of conventional machinery used for machining tools such as scissors or pliers with numerically controlled machines. The tools from the mentioned group may be generally characterized as: comprising of two arms joined with a single rivet joint (Fig. 1).

The process of production of tools from the scissors and pliers group includes six basic technological operations: plastic processing, machining, initial assembly, thermal treatment, grinding, and final assembly.

On conventional machines, each machining operation was performed on a different machine, and the quality of making was dependent on the operator's experience. Due to the necessity of transferring semi-products from one machine to another, inter-operational interruptions occurred.

With a CNC machine, all operations are performed on a single machine, in a single clamping, and the operator's work is reduced to clamping the semi-product, and then removing the ready tool arm from the machine.

The decision on modernizing the tool machines stock was preceded by carrying out an economic analysis that was based on the following goals and principles:

– the company aims at improving the production capacity of the entire mechanical processing division, but the analysis is performed for the production volume corresponding to the maximum efficiency of machinery park comprising of conventional machines

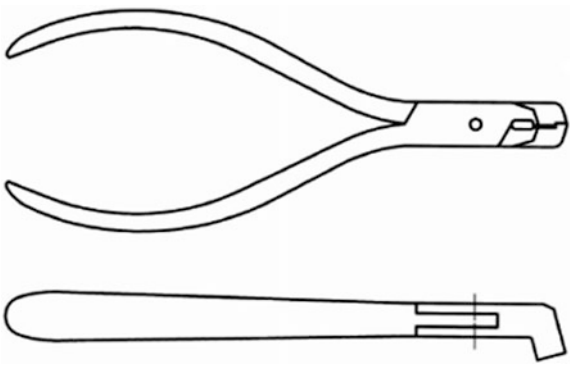

Fig. 1 Structural drawing of an example tool from the: scissors and pliers group

– the cost of machining will be reduced, since the increase in the costs of tools used with CNC machines is compensated by the decrease in personnel costs and production area of the plant,
– the increase in quality (repeatability) of the obtained semi-products from machining will translate into shortening the preliminary assembly time and grinding work, which in turn will result in lowered costs of producing the end product.

According to the performed technological and operational analyses, it was assumed that the use of individual resources to producing the same production volume should lead to savings in terms of man-hours, number of machines, and the occupied space, as well as increased demand for tools (Fig. 2) [13–15].

Based on tool specifications and the performed research, it was calculated that the life of a single set of tools for a conventional machine, in consideration of the possibility of regeneration, is equivalent to 12 sets of tooling for a CNC lathe. Taking into account the fact that the cost of tools for conventional machinery is two times higher than for CNC machinery, it was assumed that the cost of consumption of the latter is six times higher (Table 1).

In order to compare the costs of machining in the conventional and CNC technologies, data concerning the direct costs were gathered, including:

– labor costs: personnel remunerations;
– machinery: amortization, service and repairs, supply and occupied space;
– tools: purchase, production, regeneration, and storage.

It was assumed that the direct costs borne with the use of conventional machines is 100%; they were compared to the projected costs of producing the same production batch with the use of CNC machines (Table 2).

Based on the actual and predicted costs analysis, and based on the assumptions made, it was concluded that the cost of machining on CNC machines will be 11% lower.

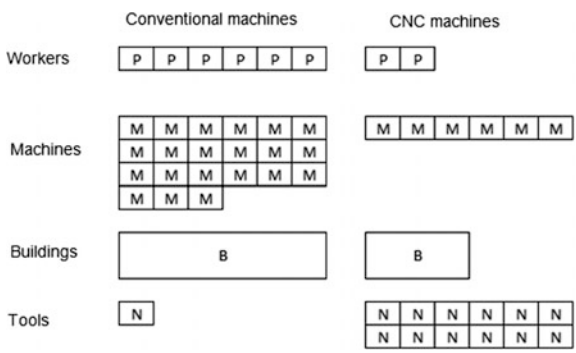

Fig. 2 Comparison of projected engagement of resources for achieving the same production volume of semi-products within 1 h time

Table 1 Comparison of selected parameters of CNC tools and conventional tools necessary for processing the same batch of products

Comparative criterion	Conventional machine tools	CNC machine tools
Life [time/pieces]	1	12
Purchase cost [PLN/set]	2	1
Consumption cost [PLN/pieces]	1	6

Table 2 Comparison of projected cost of production of the same production volume on conventional machines and CNC machines

Cost group	Conventional machine tools (%)	CNC machine tools (%)	Shift (%)
Workers	78	22	−56
Machines	12	9	−4
Tools	10	58	+49
Total	100	89	−11

Explanation: 100% is the total direct costs when using a conventional machine

3.2 *Operating and Economic Analysis After 1 Year from Introducing CNC Machines*

After a year of use of CNC machines, operating analysis was performed aiming at verifying the assumptions preceding the decision on modernizing the machinery park (Fig. 3).

The achieved results confirmed the positive effect in terms of the time and demand for surface area. The workers and machinery engagement was reduced three times, and the space necessary for producing the assumed volume was reduced by half. As an effect, the enterprise also increased its production capacity. However, a problem was observed with achieving the planned level of tools

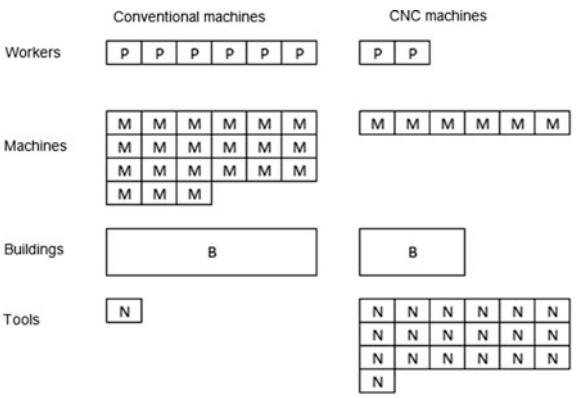

Fig. 3 Comparison of actual engagement of resources for achieving the same production volume of tool arms at the same time

Table 3 Structure of direct costs for the same production volume for conventional and CNC machines

Cost group	Conventional machine tools (%)	CNC machine tools (%)	Shift (%)
Workers	78	18	−60
Machines	12	7	−5
Tools	10	75	+65
Total	100	100	0

Explanation: 100% is the total direct costs when using the given technology

Table 4 Comparison of manufacturing cost of the same production volume on conventional machines and CNC machines

Cost group	Conventional machine tools (%)	CNC machine tools (%)	Shift (%)
Workers	78	22	−56
Machines	12	9	−4
Tools	10	92	82
Total	100	123	+23

Explanation: 100% is the total direct costs when using a conventional machine

consumption, which was twice higher than it was assumed based on the analysis of specifications and technological trials.

The values of costs were determined based on historical data and additional operating analyses (Table 3).

The change in the cost structure after using CNC machines is confirmed by the character of the given technology: the CNC one is automated, e.g., with high capital demand, and the conventional one has high labor demand. The largest share of CNC costs belongs to the tools consumption (75%), and then workers and machinery. With conventional machinery, the key cost is worker remunerations (78%). Then, the values of actual costs of using conventional and CNC machinery for the same production volume were compared (Table 4).

The individual percentage shares of costs for CNC machines are compared to the value of the given item for direct costs when using conventional machinery. It may be noticed that:

- personnel costs after introducing CNC machines was reduced from 78 to 22%;
- machinery costs after introducing CNC machines was reduced from 12 to 9%;
- tools cost in case of CNC increased from 10 to 92%;
- as an effect, the total cost of producing the same volume on CNC is 23% higher than on conventional machines.

According to the results of operating and economic analysis, the cost of machining increased by 23%, due to the 60% higher tool wear than assumed in the business plan.

3.3 Preparation to Organizational and Technological Improvement of Production Processes

In order to explain the reasons for increased costs of tools, a team was appointed that comprised of: machine operators and personnel managing the machinery park, process engineers, and programmers, tool regeneration department, as well as controlling department. The first stage of the works of that team was to point out to the potential reasons for increased wear of tools compared to the assumed one. These were then grouped and presented on the Ishikawa diagram (Fig. 4).

The team agreed that the reasons from the "human" and "management" group must be eliminated in the first place, and then trials and analyses concerning the technology and tools must be carried out (Fig. 4).

It was additionally noted that, when carrying out the trials being the subject of this article, the tools consumption cost was conformant with the assumptions preceding the purchase of CNC machinery (Table 1). The explanation of that is the conclusion that both the "human" as well as "management" were directly shifted from the conventional technology that was characterized by significantly lower focus on the issue of tool costs. During the performed observations and experiments concerning tool consumption, the operators operated them with greater care, and the processes of their collection and replacement were specially supervised. It was, therefore, concluded that the most urgent improvement actions should include trainings for increasing the workers' awareness on the losses resulting from improper fixture of tooling. Also, new principles of the tool supervision system were proposed.

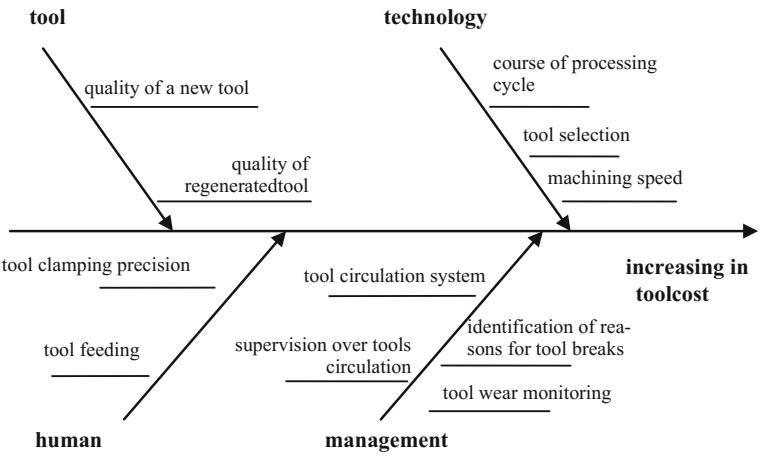

Fig. 4 Ishikawa diagram for the problem of high costs of tools for CNC machines