Production Engineering - Personnel Education for the Needs of Market Economy

Gawlik, Józef and Gawlik, Remigiusz

Cracow University of Technology, Cracow University of Economics

2011

Prof. dr hab. inż. Józef Gawlik, Ph.D.
Chair of Manufacturing Processes, Machining and Production Automation Institute, Faculty of Mechanical Engineering, Cracow University of Technology

Remigiusz Gawlik, Ph.D.
Department of International Economic Relations, Faculty of Economics and International Relations, Cracow University of Economics

PRODUCTION ENGINEERING – PERSONNEL EDUCATION FOR THE NEEDS OF MARKET ECONOMY

Summary

Production Engineering is the youngest, but fast developing scientific discipline in Poland. Its field of interests fully corresponds to the formerly created "Management and Production Engineering" study dominant. Production Engineering covers issues such as planning, designing, implementing and management of production and logistic systems and maintenance of their functioning. These systems are understood as socio – technical constructs that aim to integrate the employees, information, energy, materials, tools and processes during the whole product life cycle. Production Engineering bases on technical, economic, human and social sciences. It uses the know – how of telecommunication, informatics, management, public communication and human resources management. Therefore it has all the qualities necessary for educating engineers accordingly to the needs of modern market economy. The paper presents briefly chosen aspects of engineering activity in the field of production engineering.

***

1. Introduction

Notions of Production Management and Production Engineering are related with Work Study, namely Methods – Time Measurement (MTM) appropriate for particular production conditions (Fig. 1).

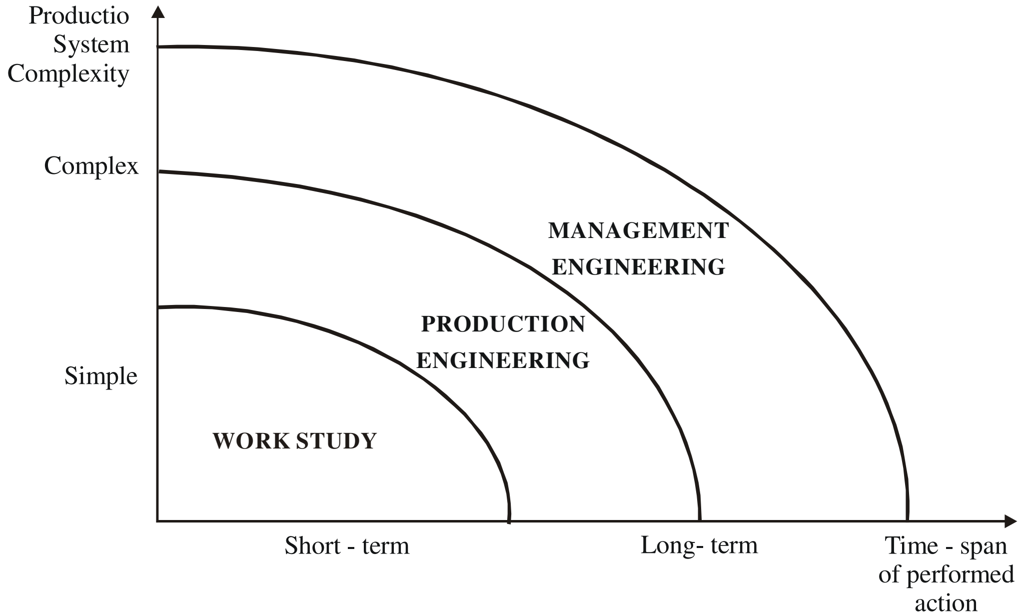
In broader approach, the Work Study focuses on optimizing the division of performed operations into smaller components and rationality analysis – range, sense and sequence of actions. The development of information technology allowed the incorporation into production engineering processes of following factors:

- designing of environment – friendly products in accordance with the product life cycle;
- process and technological operations structure;
- choice and planning of working space – lean production;
- flow of objects, employees, information, energy – both inside and outside production sphere;
- personnel qualifications [1, 2, 3].

---

[1] Durlik I., *Reengineering i technologia informatyczna w restrukturyzacji procesów gospodarczych,* WNT, Warszawa 2002.

Fig. 1. Application areas of Work Study, Methods – Time Measurement and Management Engineering



Source: *Stan i perspektywy badań naukowych w obszarze inżynierii produkcji w Polsce.* R. Knosala (ed.), Komitet Inżynierii Produkcji PAN, Warszawa 2010, p. 6.

Production Engineering covers issues such as planning, designing, implementing and management of production and logistic systems and maintenance of their functioning. These systems are understood as socio – technical constructs that aim to integrate the employees, information, energy, materials, tools and processes during the whole product life cycle. Production Engineering bases on technical, economic, human and social sciences. It uses the know – how of telecommunication, informatics, innovativeness, management, public communication and human resources management. Its crucial components are: human – factor orientation and optimization of working environment. Human factor (labour) is the most important factor influencing working efficiency, costs and quality.

Management Engineering is a broader term in comparison to Production Engineering. It covers issues related with closer and further environment of production systems. Besides production systems management, Management Engineering deals with problems from the fields of industrial marketing, production costs management, corporate staff, safety engineering, competition study, R&D intelligence, technological innovativeness, cooperative production management, supply logistics and distribution, environmental analysis, legal issues.

[2] *Komputerowo zintegrowane zarządzanie. Tom 1.* R. Knosala (Ed.), Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2011.
[3] *Metody i techniki zarządzania w inżynierii produkcji.* J. Matuszek (Ed.), Wyd. Akademii Techniczno-Humanistycznej, Bielsko-Biała 2008.

An important number of international institutions deals with Production Engineering problems, i.e. The Association for Operations Management (APICS), Production and Operations Management Society (POMS), American Society for Management Engineering, The European Industrial Research Management Association, The International Foundation for Production Research, The International Academy for Production Engineering (CIRP), German Academic Society for Production Engineering (WGP), Japanese Operations Management an Strategy Association, Chinese Institute of Industrial Engineers, Asia Pacific Industrial Engineering and Management Society, The Philippine Institute of Industrial Engineers, Brazilian Association of Production Engineering. Poland has been represented since 1997 by an NGO named **Polish Association for Production Management** composed of 21 sections located at main research institutions all over the country.

Management and Production Engineering is actually the fastest developing study dominant on graduate and postgraduate studies. Declaring Production Engineering as an official science opened broad opportunities for personnel education also on third level, which are doctoral studies. This stands in conformity with modern challenges faced by enterprises. Transformation of economical processes that brings new problems in different areas and levels of decision making needs appropriate goals, functions, tasks and proper organization of production processes, as well as their management[4]. Modern attributes of economic activity based on knowledge and development of innovative technologies and growing dynamics of environmental changes raise the meaning of intellectualization of economic processes[5]. Production Engineering meets these expectations. Industry branches strongly bound with this dominant and scientific discipline are mainly machining (engineering of production of machines and tools), food (engineering of food production), construction (construction engineering) and chemistry (engineering of chemical production).

2. Chosen areas of research

Process Engineering covers management of production processes issues, i.e. production of parts for machines and tools through shaping, resizing, modification of surfaces crucial for product's utility and bonding of elements (welding, adhesive bonding, mounting). This group of processes consists of chipless machining: powder metallurgy, foundry work, plastic forming, processing of plastics, plastic forming of surface properties, application of

---

[4] *Doskonalenie procesu zarządzania przedsiębiorstwem w obliczu globalizacji.* R. Borowiecki, A. Jaki (eds.), Wyd. katedra Ekonomiki i Organizacji Przedsiębiorstw Uniwersytetu Ekonomicznego w Krakowie, Kraków 2008.

[5] *Zarządzanie restrukturyzacją w procesach integracji i rozwoju nowej gospodarki.* R. Borowiecki, A. Jaki (eds.), Wyd. katedra Ekonomiki i Organizacji Przedsiębiorstw Uniwersytetu Ekonomicznego w Krakowie, Kraków 2008.

layers and covers, as well as processes of material removal processing: machining (abrasive, erosion, electrical discharge, laser, photon, ion). This field answers also questions from employees' time management, production sources and flow of information and materials.

An example of Process Engineering applied research is the use of abrasive machining in production of thin – walled elements (microelements)[6]. Machining of thin – walled microproducts is very problematic. Plastic and resilient deformation of processed material can occur. In case of resilient deformation the machined surface bends causing i.e. vibrations. Plastic deformation can cause faults of shape of machined objects and own – tensions, very difficult to remove from object's surface. Own – tensions and deformations of fragments of machined parts very often cause expenses in many microproduct processing operations, especially due to production faults and prolongation of production time. In example, during machining of complex mechanical units, deformations of their components can make their assembly difficult or even impossible. Own – tensions of machined elements can be caused by former machining operations of sub – product (plastic, thermo-, abrasive, coarse, etc.), but also by plastic deformation and thermo- gradients that occur during machining.

Little machining trace dimensions in precise cutting force us to take into account at different modelling stages 'scale effects" and dislocation influence. In some cases the thickness of machined surface is comparable to round – off radius of cutting edge. In such a case the influence of the stagnant zone and "microflashes" on values of components of cutting force and on deformation of machined object can be significant. Some factors that differentiate micromachining from traditional macroscale machining can be distinguished. Machining effects and product quality will be mainly dependent on:

- machined material microstructure (size and shape of grain, phase types, inclusions), cutting tool material and its characteristics (microtoughness, fine – grained, surface type);
- cutting blade geometry (round – off radius, advance angle);
- cutting parameters (mainly cutting speed).

Appropriate elaboration of microproduct or thin – walled object should take into account the correction of potential machining faults through:

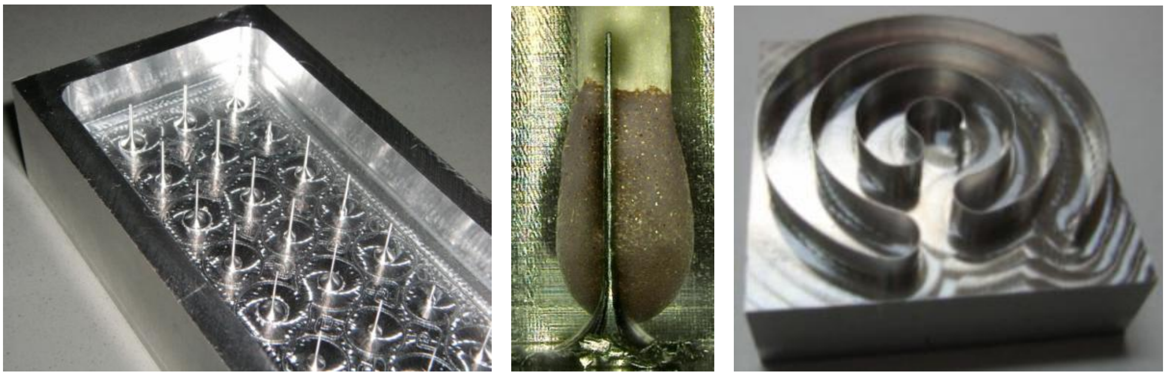
- optimization of machining strategy;
- upgrade of cutting speed (High Speed Cutting);
- optimization of cutting parameters (feed and cutting depth) in accordance with minimization of cutting force component, perpendicular to machined surface.

---

[6] Gawlik J., Zębala W., Matras *A., Kształtowanie i nadzorowanie jakości mikrowyrobów w precyzyjnej obróbce skrawaniem,* referat na Szkołę Obróbki Skrawaniem, wrzesień Opole 2011

Machined microelements have 7 mm height and 0,06 mm wall thickness (Fig. 2 in the middle shows it compared to the size of a head of a match). The proposed example from one technology field only proves the complexity of the research area that stays in frames of process engineering. Similarly, Production Engineering solves many complex optimization issues in machining, food, chemical, construction and other industries through use of informatics (application of genetic algorithms, artificial neuron networks, fuzzy sets theory, dynamic programming and others).

Fig. 2. Examples of elaborated microproducts and thin – walled elements



Source: own research - literature [4]

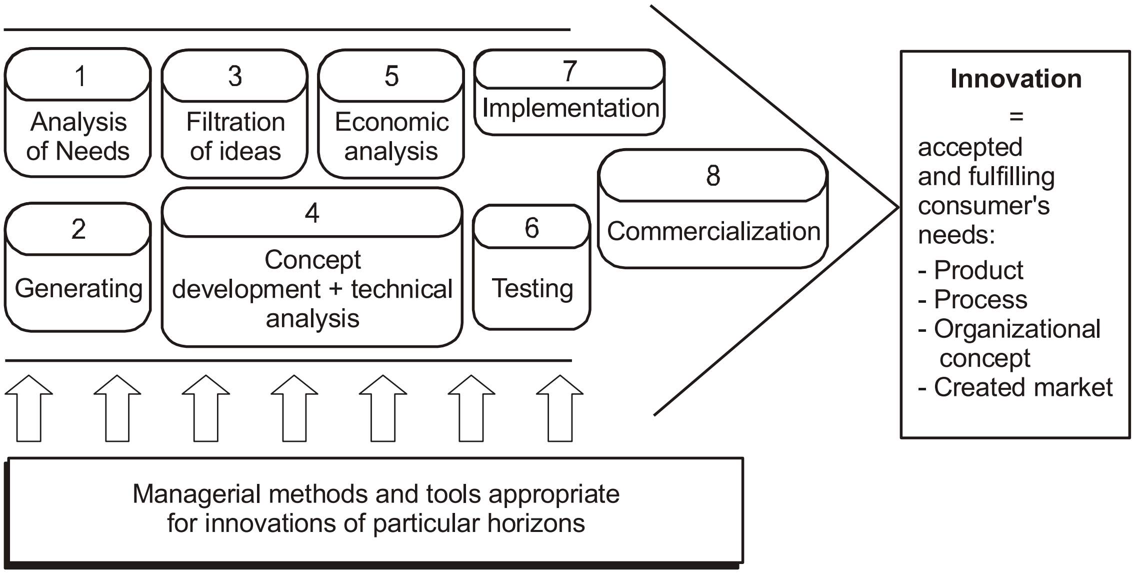
Innovation Management brings the need for adapting companies to changes caused by globalization and resulting high level of competition on global markets. Seeing innovation at its functional range and time – span[7]. Effectively implemented innovation is a sequence of activities that need effective management (Fig. 3).

Adopted classification of innovations coming from statistics or marketing does not offer any methodological base for creation of constant and effective management systems. Therefore a division presented on Fig. 4 has been proposed. As rooted in various managerial functions, it creates the possibility for finding the innovations that have strategic, tactical or operational dimension.

Operational innovations (usually rationalization ideas and solutions, i.e. application of new material, little construction changes, face – lifting) result from direct entrepreneurial activity. They are characterized by short implementation time and relatively low costs. They are caused by actual demand changes, need for upgrading working conditions or higher product quality. Financed by existing budgets.

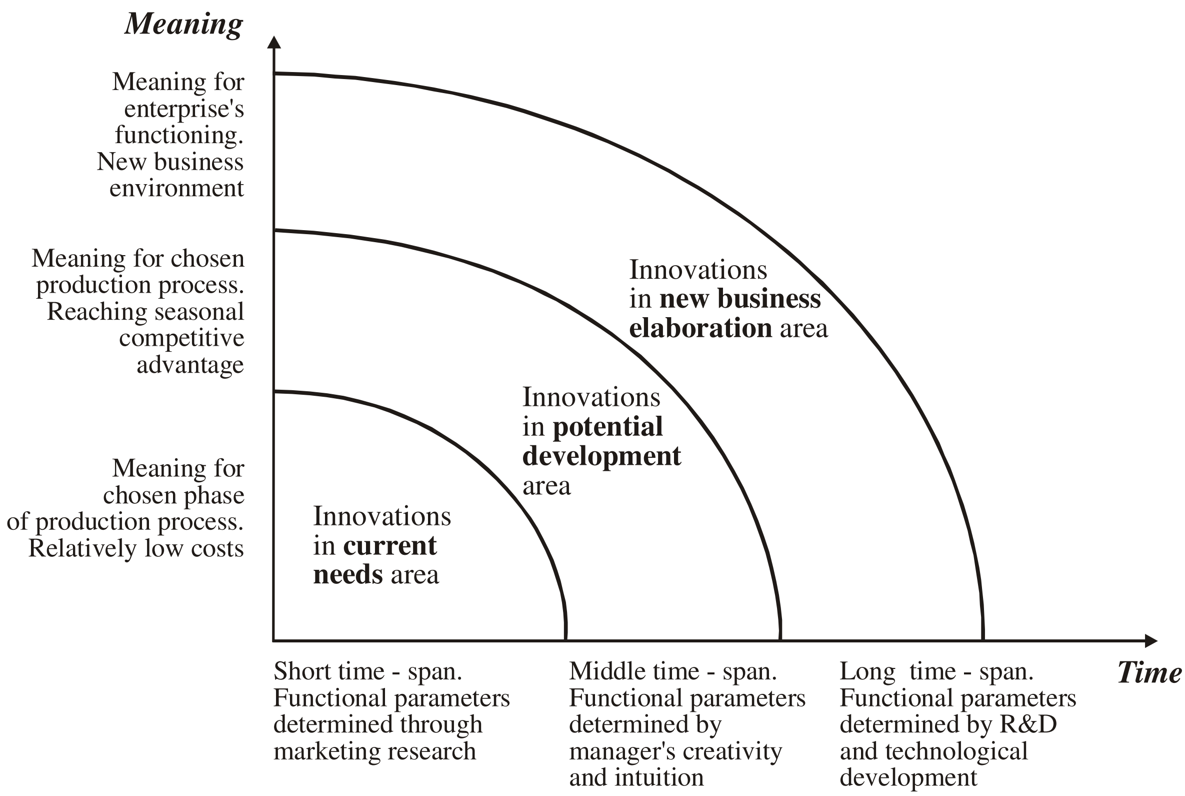
[7] *Komputerowo zintegrowane zarządzanie. Tom 1.* R. Knosala (Ed.), Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2011, p. 433 - 443.

Fig. 3. Innovation Process Management



Source: *Komputerowo zintegrowane zarządzanie. Tom 1.* R. Knosala (ed.), Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2011, p. 434

Fig. 4. Innovations classification in relation to their functional range and time – span



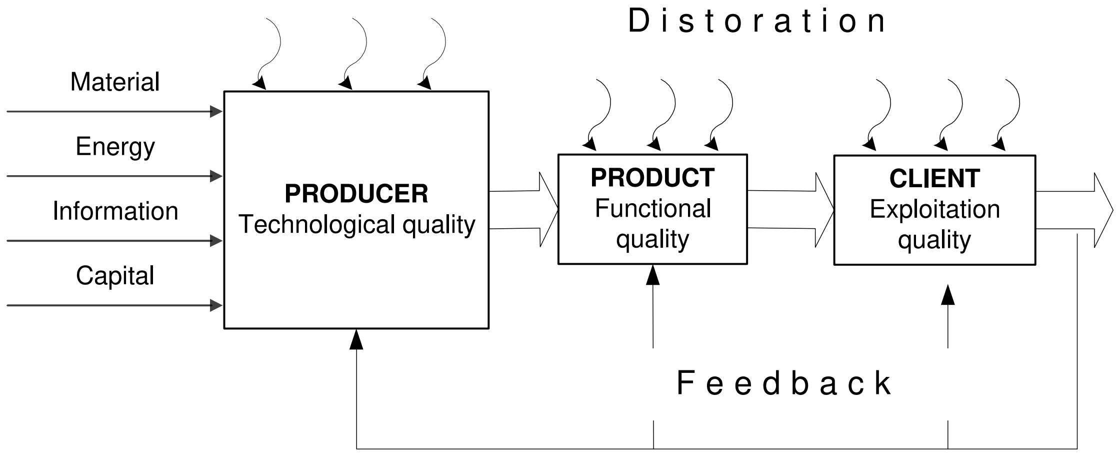
Source: *Komputerowo zintegrowane zarządzanie. Tom 1.* R. Knosala (ed.), Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2011, p. 435

Tactical innovations cover medium – range time – span, their implementation allows to profit from competitive advantage under given market conditions. Implementation of this type of innovation is more complex than in case of operational innovations. An important role is attributed to such factors as analysis of market needs and creativity of managers. Their implementation needs cooperation of different departments of the enterprise and usually exceeds available budgets. Examples of such innovations are: application of new production technologies, implementation of integrated management systems.

Strategic innovations are the effect of R&D programs, they are based on long – term analysis of technical and technological development and demand trends. They are characterized by a high level of innovativeness, long elaboration time and complex implementation process. Very often they would need new systemic solutions in the organization of production processes and management of industrial corporation. Usually they also need high level of investment and bear much a higher risk than operational innovations.

Quality management is currently an integral element of realization of production processes and services. Production systems are composed of technological processes resulting in expected product **technological quality** acquired through successive technological operations. Assembly processes play an important role in case of high – complexity products. Their elaboration leads towards forming of a complex product (machine, technological tool) with given **utility**. Clients exploit their products in different conditions, only then its **exploitation quality** is being revealed. Feedback from clients and servicemen should be used to implement expected product improvements in order to raise its technological quality and utility and therefore their exploitation quality (Fig. 5).

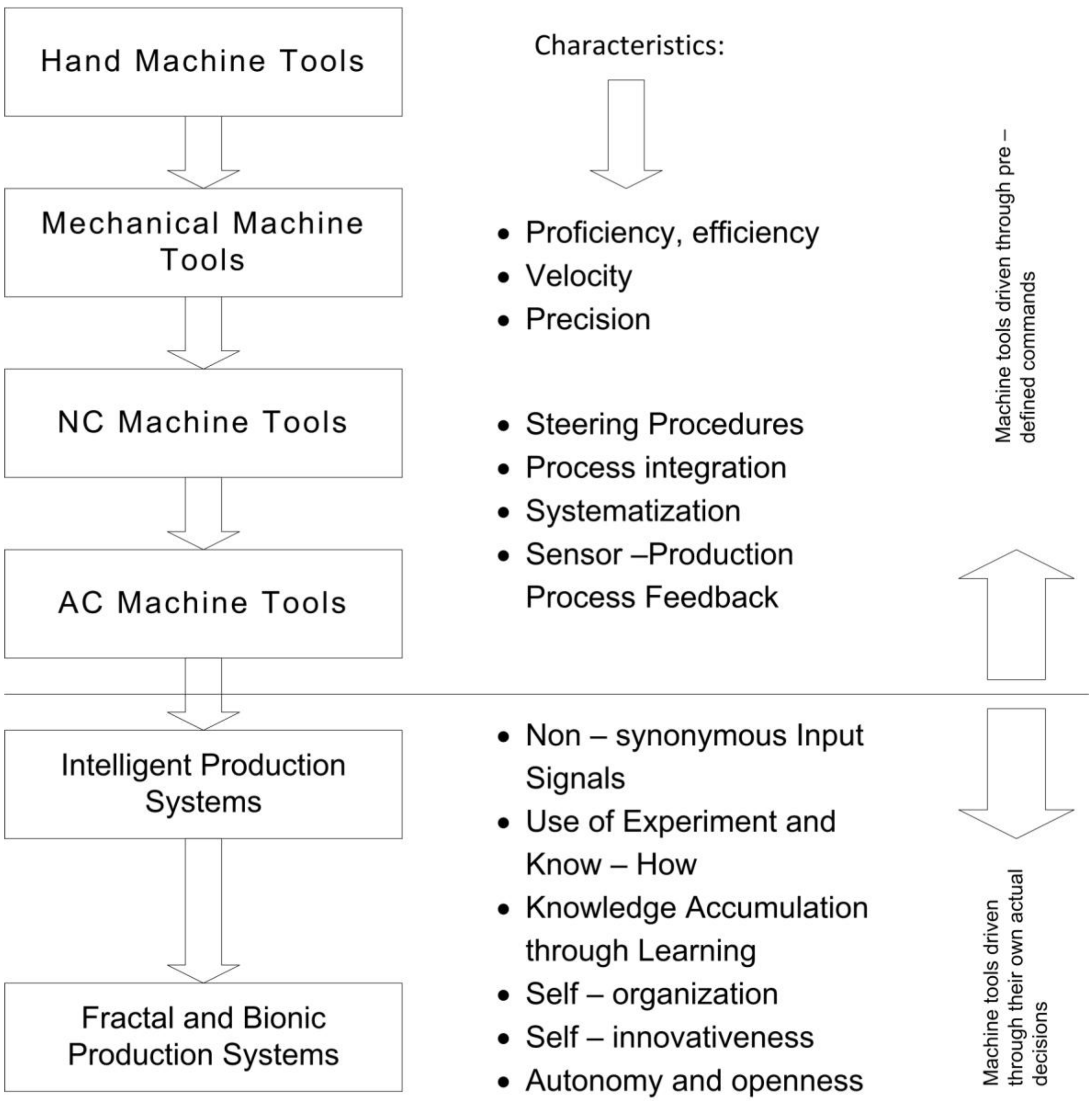
Fig. 5. Forming of product quality during production and exploitation processes



Source: own elaboration

Production systems expectations evolved with changes in consciousness of clients and their awareness for possibilities of raising their demands. Important and dynamic development of production systems starts with raising options for application of automation and information technology[8] (Fig. 6). For this reason single product or short series can be produced on individual demand without resigning from product quality (i.e. producing cars with equipment adapted to client's needs).

Fig. 6. Example of development of machining systems coming from automation and information technology development

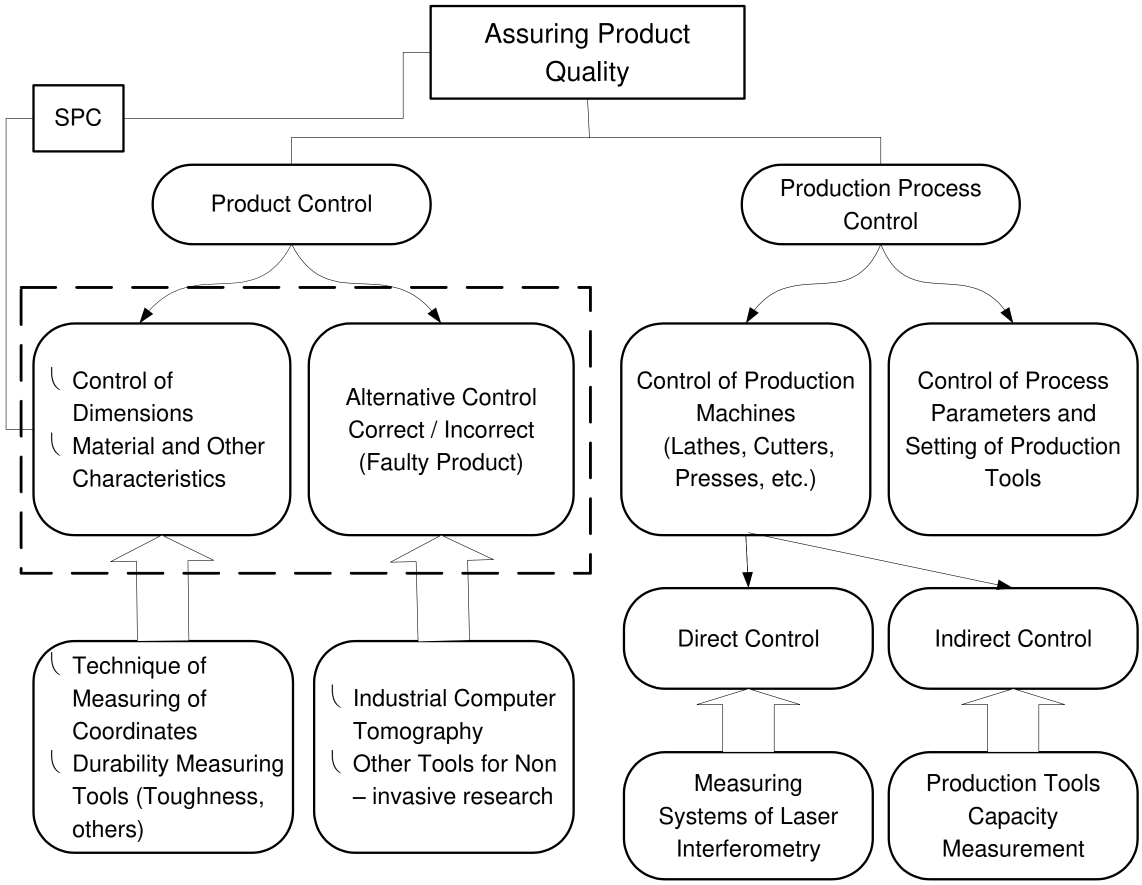


Source: own elaboration

[8] *Virtual Design and Automation.* Z. Weiss (ed.), Publishing Mouse of Poznań University of Technology, Poznań 2005.

Technological quality of the product is highly dependent on characteristics and state of technological tools and a proper realization of production process. Securing technological quality is impossible without **supervision** understood as a process that measures actual values of chosen parameters characterizing the state of technological tool or process advancement. Next step is composed of identification of conformity of measured parameter values with accepted values and of constant monitoring. Monitoring results allows to state whether process realization occurred without disturbance or deregulation. Sometimes monitoring procedure is being accompanied by a **prognostics module** supervising the state of machines and technological tools and realized production processes. It allows predicting future changes in parameter values, basing on actual trends. An enlarged version of such a module, including possible production options can be built on basis of **Analytic Hierarchy Process** (AHP) method. This tool would allow choosing measurement criteria accordingly to the specification of given production process. As a result, a choice of decision alternative fulfilling both customer and producer's needs at possibly maximal level would occur. Quality Management systems should also be adapted to expectations towards production systems (example – Fig. 7).

Fig. 7. An example of Quality Management system in machining industry



Source: own work – literature [12].

Examples of decision alternatives that could occur in such production task could possibly be the following:

a. assuring possibly highest final product quality, but at higher cost per unit;
b. minimization of production costs, even with higher PPM values (Parts Per Million) – more products rejected at quality control;
c. operating at quality minimum edge – finding possibly lowest quality and therefore cost level, but still satisfactory for the client and economically rational;
d. finding a quality / cost optimum (possibly highest product quality at possibly lowest cost per unit).

Each of the alternatives above is an attempt to find the answer to the problem of negative relation between product quality and cost of production of 1 unit of the good. In seems obvious that concentrating on highest quality of final product brings faster machine and cutting tool wear. Another component of constant costs is the time issue, or more precisely the lost opportunities cost generated by devoting too much time for producing exquisite quality products. In such a situation production machines and personnel are not able to perform other, more economically rational, production tasks.

As we deal with a production process that has to take into account cost – effectiveness issues, the decision criteria set could be the following:

a. income from production activities – general level of money acquired through realized production process;
b. final product quality – a set of characteristics describing the final product in relation to possibly maximal client satisfaction;
c. cost per unit – cost of producing one unit of final good;
d. marginal cost – cost of producing additional one unit of final good;
e. level of technological advancement of the product – characteristics of level of advancement of technologies used in production process, as well as those used during product exploitation;
f. level of organizational advancement of production process – factor showing the level of complexity of organizational issues related with management of analyzed production process.

After defining criteria and alternative decisions expert evaluations of weights of particular decision criteria should take place. The expected outcome is the choice of one decision alternative, accordingly to the weights attributed by the experts to each criterion.

This provides space for the application of AHP method that offers the possibility of pairwise comparisons of particular criteria between each other in order to evaluate which factor in each pair is more important for realized production task and by how much. It is important to underline that the application of AHP method for Production Engineering forces the manager to create separate sets of criteria, separately for each specific production problem. Examples of practical application of this approach can be seen in other publications of the authors [5].

3. Summary

University Alumni face expectations the realisation of which will contribute to the development of innovative economy. This can be achieved by trained engineers that will be able to undertake various tasks that change continuously and dynamically in market economy. Interdisciplinary study dominant Management and Production Engineering and Production Engineering scientific discipline provide opportunities for preparing engineering staff with appropriate level of knowledge, competences and skills both in engineering and managerial area.

Literature:

1. *Doskonalenie procesu zarządzania przedsiębiorstwem w obliczu globalizacji*, Borowiecki R., Jaki A. (eds.), Wyd. katedra Ekonomiki i Organizacji Przedsiębiorstw Uniwersytetu Ekonomicznego w Krakowie, Kraków 2008.
2. *Doskonalenie systemów jakości*, Szymonik J., Z. Szymonik (eds.), Inżynieria Maszyn, Zeszyt 3-4, Wrocław 2000.
3. Durlik I., *Reengineering i technologia informatyczna w restrukturyzacji procesów gospodarczych,* WNT, Warszawa 2002.
4. Gawlik J., Zębala W., Matras A*., Kształtowanie i nadzorowanie jakości mikrowyrobów w precyzyjnej obróbce skrawaniem,* referat na Szkołę Obróbki Skrawaniem, wrzesień Opole 2011.
5. Gawlik R., *Managerial Decision Making in Geopolitically Turbulent Environments*, w: *Generating Innovative Solutions to Recurring Problems in the Global Business Environment: A Multi-, Inter-, and Trans Disciplinary Approach to Formulating and Maintaining a Competitive Organizational Edge*, Delener, N. & others (eds.), GBATA, New York 2011, s. 214 – 221.
6. *Komputerowo zintegrowane zarządzanie. Tom 1*, Knosala R. (ed.), Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2011.
7. *Metody i techniki zarządzania w inżynierii produkcji*, Matuszek J. (ed.), Wyd. Akademii Techniczno-Humanistycznej, Bielsko-Biała 2008.
8. *Stan i perspektywy badań naukowych w obszarze inżynierii produkcji w Polsce*, R. Knosala (ed.), Komitet Inżynierii Produkcji PAN, Warszawa 2010.
9. *Virtual Design and Automation*, Weiss Z. (ed.), Publishing Mouse of Poznań University of Technology, Poznań 2005.
10. *Zarządzanie przedsiębiorstwem w turbulentnym otoczeniu*, Krupski R. (ed.), PWE, Warszawa 2005.

11. *Zarządzanie restrukturyzacją w procesach integracji i rozwoju nowej gospodarki*, Borowiecki R., Jaki A. (eds.), Wyd. katedra Ekonomiki i Organizacji Przedsiębiorstw Uniwersytetu Ekonomicznego w Krakowie, Kraków 2008.
12. *Zwiększanie dokładności wytwarzania. Nadzorowanie jakości wyrobów,* Gawlik J. (ed.), Inżynieria Maszyn, Zeszyt 3, Wrocław 2010.

INŻYNIERIA PRODUKCJI - KSZTAŁCENIE KADR NA POTRZEBY GOSPODARKI RYNKOWEJ

Streszczenie

Inżynieria produkcji jest obecnie najmłodszą bardzo dynamicznie rozwijającą się dyscypliną naukową w kraju. Jej merytoryczny zakres w pełni koresponduje z utworzonym wcześniej kierunkiem kształcenia „zarządzanie i inżynieria produkcji". Inżynieria produkcji obejmuje zagadnienia planowania, projektowania, implementowania i zarządzania systemami produkcyjnymi, systemami logistycznymi oraz zabezpieczania ich funkcjonowania. Systemy te są rozumiane jako układy socjotechniczne, integrujące pracowników, informacje, energię, materiały, narzędzia pracy i procesy w ramach całego cyklu życia wyrobów. Inżynieria produkcji bazuje na naukach technicznych, ekonomicznych, humanistycznych i społecznych. Wykorzystuje wiedzę teleinformatyczną, wiedzę o zarządzaniu, komunikacji społecznej i pobudzaniu kreatywności pracowników. Jest to więc obszar kształcenia dobrze przygotowujący kadrę inżynierską na potrzeby rozwoju współczesnej gospodarki rynkowej. W referacie krótko scharakteryzowano wybrane przykłady działalności inżynierskiej w obszarze inżynierii produkcji.