# DETERMINANT OF QUALITY IN METALWORKING ENTERPRISES

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**Abstract**

The publication presents the most important quality determinants in the metalworking industry. It discusses the structure of processes involved in the technology of metals. The purpose of the publication is to identify the quality determinants for this processes and to identify the main parameters defining quality in the discussed industry. On this basis, criteria for assessing the effectiveness of the quality management system that can be applied in the metalworking industry have been proposed. During the analysis of technological quality determinants, the following processes were analyzed: cutting, turning, planning and chiseling, pulling and pushing, drilling, countersinking, reaming, milling, machining of helical surfaces, machining of screw surfaces, abrasive machining, grinding, honing and oscillating superfinishing, lapping and abrasive polishing, rotational and vibratory smoothing of containers, treatment of loose abrasive grains, erosion treatment, electroerosion treatment, electrochemical treatment, blasting, protective and decorative coatings, metal protective coatings, inorganic protective coatings, organic protective coatings.

**Keywords:** Quality determinants, metalworking industry, process quality, product quality, quality management system

## 1. INTRODUCTION

Manufacturers operating in the metalworking industry are constantly facing numerous challenges related to the quality of the product. This challenges are a direct consequence of constantly growing customer's requirements and associated pressure to continuously improve business efficiency. In this context, metalworking industry is a very important sector from the point of view of quality management, because it applies the methods and tools of quality management aimed at improving the quality of its products. Thereby it is interesting to identify the determinants of quality in this industry which can be further used to formulate measuring criteria of the quality management system effectiveness.

The purpose of the publication is to identify the determinants of quality for processes and to identify the main parameters defining quality in the discussed industry. On this basis, criteria for assessing the effectiveness of the quality management system have been proposed that can be applied in the metalworking industry. The added value of the paper is identification of quality determinants in metalworking industry. In the literature is only description of the main quality determinants for production processes not especially for metalworking industry. Also up till now didn't existed conception how to asset quality management system in metalworking industry.

## 2. TECHNOLOGICAL QUALITY DETERMINANTS IN METALWORKING ENTERPRISE

The structure of processes included in metalworking industry determines its interdisciplinary character. Despite many years of development of this science and technology discipline, still many phenomena determining the success of processes are not fully explored. An interesting research concept is the use of the plastic consolidation process for the production of new composite materials and recycling of small metallic forms [1]. Authors in the researches try to determine various variables connected with material production processes as: temperature [2], structure characteristic [3], structure evolution [4], strength [5], recycling possibility [6], mechanical properties [7] or potential reuse of product [8] Research works aim to understand and explain the physical phenomena that accompany metalworking processes and formulate relations occurring between processed material and the process parameters [9]. To do this there is indispensable to use benchmarking methods [10] to analyze quality management systems between the companies [11]. In literature there are some examples [12] of this type of analysis in the metal industry [13].

These processes cannot be considered only in the context of the requirements of manufacturing technology and predefined parameters. This is due to a number of factors which do not relate to material treatment process itself, but refer to [14-16]:

- selection, storage, identification and quality of materials used,
- qualifications and experience of the staff,
- principles of cooperation with external entities involved especially in forming and improving processes,
- principles of validation of technological processes,
- selection and technical condition of used machines and tools,
- environments in which metalworking processes are carried out,
- organization of metalworking processes understood as a sequence of operations together with accompanying technical and process documentation as well as visual identification,
- monitoring the process status and preventing loss of control over its parameters and downtime costs,
- organization of control,
- the use of control and measurement equipment with a defined metrological status.

The above list indicates that the determinants of quality for these processes will be included in a wide spectrum, more appropriate for quality management than for quality assurance. Because of this taking into account knowledge in both management and engineering of industrial processes is a necessity. The historical development of quality management which have its genesis in the metalworking industry, teaches that the selective approach to metalworking processes deprived of management aspects usually resulted in the loss of economic profitability of production or inability to achieve the desired quality on a large scale of production.

**Table 1** presents the basic processes specific to individual technologies included in the discipline of Machine Technology together with the determinants of quality respectively in technical, technological and organizational terms. The table was prepared on the basis of literature analysis and interviews with employees from the metal processing industry. We conduct our survey in 2016 in the metalworking industry. We asked 60 engineers working in metalworking industry in Polish organizations. The all organization had quality management systems according to ISO 9001 requirements.

**Table 1** Quality Determinants of Technology in the metalworking industry

| Process | Quality Determinants of Technology in the metalworking industry | Main parameters defining quality |
|---|---|---|
| Machining | | |
| Machine cutting | Proper representation of cutting edge contour on object surface with deviations from the ideal contour - as a result of the progressive blade wear.<br>Trajectory correctness of the object and tool during mutual movement.<br>Vibrations of the machining system (e.g. vibrations transmitted by the machine tool foundations, disruptions in the hydraulic system operation, power disturbances, and many others) and affecting the surface waviness.<br>Inaccuracies of the machine - causing shape errors.<br>Heat dissipation from the machining system, the more effective the smaller the metallographic transformations in the workpiece and the longer life of the tools.<br>Tool feed speed - the larger the tool, the shorter the contact with the material and the smaller metallographic transformations of the workpiece surface. | Tolerance limits,<br>Shape compliance,<br>Surface roughness,<br>Undulation,<br>Thickness, Texture,<br>microhardness and hardness profile in near-surface layer |
| Turning | The blade shape function and feed speed largely defines the surface roughness an object while at the same time plasticity of the material and the machining system vibrations has only small influence on this parameter. | Roudness error,<br>Cylindricity Error,<br>Surface roughness. |
| Planing and chiselling | The number of strokes per unit of time determines the wear of the blade, which affects the dimension tolerance.<br>The motion speed, selection of the cutting fluid and cutting force determine the surface roughness. | Dimension Tolerance,<br>Surface roughness. |
| Pull broaching and push broaching | The dimensional deviation depends largely on the tool condition.<br>Roughness depends on the type of machined material, thickness of machined layer, cutting speed and the type of cutting fluid. | Dimension Tolerance,<br>Surface roughness. |
| Drilling, reboring, deepening, reaming | The use of tools positioning the drill in the initial drilling phase affects the position of the hole.<br>The choice of machining liquid has a significant impact on chip removal and cooling of the hole, which affects the dimensional deviation and condition of the surface. | Dimension Tolerance,<br>Hole shape,<br>Hole location,<br>Surface condition. |
| Milling | The surface roughness depends on the value of the blade feed function.<br>The radial run-out of the cutter blade affects shape and position errors.<br>Moving of milling cutter rotation axis in relation to the milling axis leads to a flatness error.<br>The lack of stability of the machining system affects the stereometry errors and the formation of marks on the blades.<br>The feed speed affects the dimensional deviation and surface roughness. | Dimension Tolerance,<br>Surface roughness,<br>Shape and position geometrical compliance,<br>Surface flatness,<br>Stereometric parameters. |
| Production of gearwheel | Selection of speed and cutting power,<br>Angle and mill pitch,<br>The value of feed per blade. | pressure angle compliance,<br>tooth shape compliance,<br>Dimension Tolerance. |
| Helical machining | Type of tool,<br>Selection of thread cutting speed,<br>Tool feed,<br>Tool outline - thread profile errors increase both with increasing lead angle of the thread and mill diameter increasing.<br>Selection of processing fluid. | Thread contour compliance,<br>Thread accuracy class<br>Direction of thread lead |
| Grinding | Changes in cross-feed value results in roughness alteration.<br>Increasing the peripheral speed of the workpiece causes a slight decrease in the roughness value, with a significant increase in the wear of the grinding wheel.<br>The use of grinding wheels with a smaller diamond particle size leads to a surface with lower roughness.<br>The use of opposite rotation direction of the grinding wheel and a table results in increase of surface roughness. | Surface roughness,<br>Abrasive material waste<br>Material plastic deformation |

**Table 1** Continue

| Process | Quality Determinants of Technology in the metalworking industry | Main parameters defining quality |
|---|---|---|
| Machining | | |
| Honing and Oscillating honing | Pressure,<br>Grain size,<br>Honing direction,<br>Selection of process kinematics and cooling liquid. | Surface roughness<br>Honing performance. |
| Lapping and abrasive polishing | Grain size,<br>Selection of the amplitude of oscillations,<br>Frequency of oscillation,<br>Filtration of the cooling liquid. | Surface roughness |
| Rotation and vibration adjusting | Angular speed of the container,<br>Selection of abrasive shapes,<br>Selection of chemicals.<br>Filtration of the cooling liquid. | Surface roughness . |
| Loose abrasive grain processing | Selection of abrasive material,<br>The selection of bearing materials<br>Air pressure in the sprinkler. | Surface roughness . |
| Erosion machining | | |
| Electrical discharge machining | Limit voltage,<br>Intensity of discharge,<br>Discharge time,<br>Selection of working fluid. | Material volume removed by single impulse<br>Surface representation error |
| Electrochemical machining | Electrolyte selection suitable to electrical current conductivity,<br>Overpressure and electrolyte flow rate through the gap,<br>Selection of resin for surface isolation,<br>Selection of the shape for the assumed geometry. | Stereometric structure<br>Microstructure,<br>Surface roughness . |
| Blasting work | Selection of feed speed and laser power appropriate to material physical parameters - surface reflexivity, heat of fusion, heat of evaporation. | Shape and size accuracy<br>Edges hardening,<br>Surface layer state. |
| Protective and decorative coating | | |
| Metal protective coating | Duration of electrolysis,<br>DC voltage,<br>Electrolyte temperature,<br>Thermostat efficiency,<br>Electrolyte composition. | Layer thickness. |
| Inorganic protective coating | Burnout temperature of the enamel coating,<br>The condition of the surface of the material before applying the coating,<br>Selection of the spray coating technique. | Enamel coating thickness |
| Organic protective coating | Surface cleanness of the material before applying the coating,<br>The choice of the surface cleaning method before applying the coating,<br>PH control of the solvent in a water bath or temperature in the case of thermal treatment. | Coating thickness,<br>Surface roughness,<br>Color compliance,<br>Surface uniformity |

On basis of: [17,18].

## 4. ASSESSING CRITERIA OF THE QUALITY MANAGEMENT SYSTEM EFFECTIVENESS IN METALWORK INDUSTRY

To assess the Quality Management Systems in metalwork industry it needs to determine proper criteria. To do this we conduct expert analysis. We send 50 surveys to specialist in the field of quality management (25 from scientific fields and 25 practices). They chose criteria from the list end on the basis of their chose we prepare the list of criteria useful to assets the quality management systems in metalworking industry.

If it is assumed that the main purpose of the company operating with the implemented Quality Management System should comply with the requirements of the ISO 9001 standard. To achieve this we should to continuously meet customer requirements as a factor determining survival on the market and generating profits in the medium and long term. Also organization needs to continually improve products and services. Therefore,

processes in the organization should achieve goals established on the basis of data analysis regarding current and future customer needs. Therefore, the following criteria are proposed for assessing the effectiveness of QMS in metalworking industry enterprises:

1) The organization's ability to understand the client's needs and their transformation into decisions expressed through:
   a) Measurement of customer satisfaction,
   b) Frequency and reliability of customer satisfaction measurement,
   c) Selection of a representative sample for measuring customer satisfaction,
   d) Application of customer satisfaction measurement results in the decision-making process,
   e) Determining the quality function in the case of product design, e.g. the QFD method,
   f) Applying benchmarking to competitive products,
   g) Applying benchmarking to competitors' processes,
   h) Review of technical documentation received from the Customer and records of any differences in interpretation,
   i) Analysis of contract / order in terms of equipment and qualifications before order acceptance,
   j) Offer calculation before committing to implementation,
   k) Using the defined communication path (procedure) in relation to the documentation provided by the Customer,
   l) Use of a defined communication path and procedures in relation to customer complaints,
   m) Monitoring the status of complaints by personnel independent of persons carrying out the complaint procedure.

2) Ability to manage processes and achieve goals expressed through:
   a) Use of indicator set by the organization for all processes. Indicators take into account the specificity of individual processes,
   b) Conducting by the organization quality cost account and calculating the unit cost of the product,
   c) Application by the organization different statistical tool sets, e.g. 7NT (Traditional Tools) or 7NN (New Tools),
   d) Applying systematic methods of cause-and-effect analysis using group work techniques and on the basis of them planning and implementing improvement and corrective actions (eg 5WHY, Ishikawa Chart, Pareto Chart),
   e) Communication of the results of employees quality analyzes which are the incentive system basis,
   f) The personnel responsible for quality control is independent and has the appropriate empower and authorization,
   g) Implementation of an effective traceability system for orders. Individual operations are retraceable.

3) Knowledge - the ability to obtain and maintain it in the organization expressed through:
   a) Defining the set of qualifications (including education, empowerment, training and experience) required to work on a given position,
   b) Defined training paths for each position, including mandatory periodic training,
   c) Implementation of qualification level gradation system,
   d) Determining the required qualifications for individual orders, which determine the appropriate staff to implement them,
   e) Regular checking of employees' knowledge and on the basis of them allowing to execute orders according to the level of difficulty,
   f) Implementation of the employee appraisal system,
   g) Defining the rules of internal training and principles of proper trainer selection (level of knowledge),

h) Running courses or company schools in order to acquire and educate future staff
i) Applying an incentive system for employees which train other employees,
j) Applying a system of social incentives,
k) Developing career paths for individual positions,
l) Planning in advance to acquire personnel with specific qualifications in accordance with the decisions of a strategic nature - for example, the development of a new production department.

4) Ability to change and achieve goals expressed through:

a) Management of projects related to improvement, application of risk management tools. Projects are subject to periodic reviews,
b) Budgeting individual projects,
c) Making decisions and writing them down in detail to the contractors together with deadlines, allocation of resources and criteria choice for accepting the result,
d) Selection of objectives using measurable and comparable indicators,
e) Developing bottom-up mechanisms of innovations supported by the incentive system,
f) Conducting activities aimed at the integration of staff within the department / organization,
g) Conducting reviews of management with the participation of manager of all organizational units at short intervals, e.g. weekly - arrangements are settled at subsequent meetings. Keeping records.

5) Ability to create and maintain mutually beneficial relationships with suppliers expressed through:

a) To have personnel with qualifications competent to assess the quality of materials and services from deliveries,
b) Having a laboratory to assess the quality of materials and services from external supplies,
c) Use of detailed specifications for materials and services purchased from suppliers,
d) Verification of declarations of potential and existing suppliers by means of audits by the supplier and external laboratories,
e) Having developed and implemented procedures for the verification of the quantity and quality of deliveries along with the mechanisms for handling non-compliant delivery,
f) Having developed and implemented procedures for moving the labeling of materials during all logistic and processing processes. Staff authorized to carry labels were designated,
g) Defining alternative suppliers for all critical materials and services,
h) Define assessment indicators for individual suppliers - e.g. PPM for non-compliant deliveries,
i) Defining the ordering system that does not generate unnecessary stocks.

## 4. CONCLUSION

On the carried out analyzes, the determinants of quality in the metal processing industry were identified. Determinants are divided into the following categories: chip machining, abrasive machining, erosive machining, as well as protective and decorative coatings. Then, for each of the categories, the main parameters defining quality were defined. In the next stage, the criteria for measuring the effectiveness of the quality management system for the metal processing industry were proposed. In the literature were only general quality management systems tools not customized to specific metalworking industry requirements. Identification of the criteria useful in metalworking industry company quality management system assessment is the added value of the paper. These criteria have been divided into five groups: the organization's ability to know the client's needs and their transformation into decisions, ability to manage processes and achieve goals, knowledge - the ability to obtain and maintain it in the organization, the ability to change and achieve goals, the ability to create and maintaining mutually beneficial relationships with suppliers.

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