IDENTIFICATION AND ANALYSIS OF NON-CONFORMITIES IN PRODUCTION OF CONSTRUCTION MATERIALS WITH THE EXAMPLE OF HOT- ROLLED SHEET METAL

CZAJKOWSKA Agnieszka

Kielce University of Technology, Kielce, Poland, EU, a_czajkowska@o2.pl

Abstract

In times of intensive competition for survival in the market, the enterprises are forced to improve their products in order to satisfy customers. The only method for improving the quality is continuous improvement of all the processes that are used in the enterprise, which is possible only through application of the methods and tools of Total Quality Management. The paper analyses non-conformities identified during the process of cutting hot-rolled sheet metal. The non-conformities were hierarchized using a Pareto chart. Analysis of the examinations shows that 43.5% of all the defects identified are overlooked during the initial inspection and hidden (which occurred in the steelworks). An interrelationship diagram was used to identify the relationships between the non-conformities and causes of occurrence of these non-conformities.

Keywords: TQM, Pareto diagram, interrelationship diagram, hot-rolled sheet metal

1. INTRODUCTION

Any enterprise which needs to survive in the market and to achieve competitive advantage has to ensure high quality of products. Market globalization forces enterprises to strive for continuous improvement of processes, products and services. The process of continuous improvement, also known as total quality management (TQM) means continuous striving for improvement of quality in order to satisfy customers [1].

The main areas of TQM are: [2]

- strategy of quality oriented at customers,
- collective approach to problem solving,
- quality management system,
- preventing defects and inconsistencies in all the phases of the industrial process through understanding processes and using methods and tools to ensure quality.

There are a number of methods and tools which, depending on the specific nature of activities, might be used to achieve measurable benefits [3]. These usually include simple tools which require regularity and commitment.

In the construction sector, quality depends on numerous factors, which, for example, are connected with condition of the ground, climate conditions or physicochemical properties of materials. It seems that the materials provided should be one of the most predictable components of the process of realization of the construction investment. However, the question is whether construction enterprises can expect high quality of these materials. Obviously, this depends on the type of materials used in construction since some of them might surprise with their response to e.g. temperature, which is connected with physicochemical properties. High quality of the materials used represents a prerequisite for high quality of final products.

In the case of construction services, quality of materials is of essential importance, and the construction enterprises have to utilize available means of inspection to avoid using materials with insufficient quality. There are a number of criteria for division of construction materials. The overall division of construction materials, which is enhanced by modern technological solutions [4] is presented in **Fig. 1**.

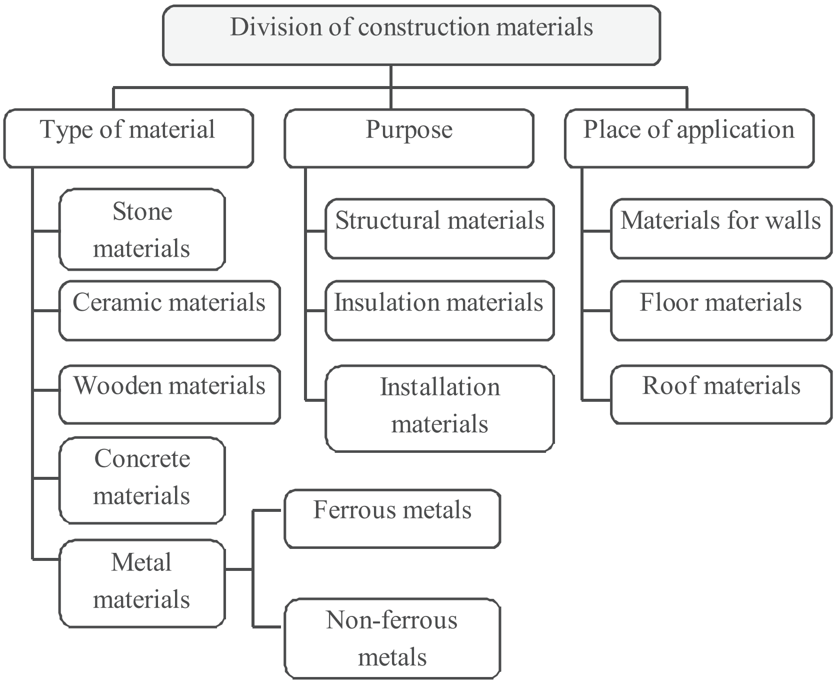


Fig. 1 Division of materials used in construction [own study]

The focus of the study is on metal materials which can be widely used in construction, starting from nails and rivets, through profiles, crates and bridge decks, door frames, pipes and sewage system fittings, heaters, products in the form of profiles for production of window and door woodwork, concrete reinforcement or roofs. Hot-rolled sheet metal, which is analysed in this study, are used in the sectors where thickness of sheet metal and easy processing are essential. It is used most frequently in the construction sector for buildings, gangboards, stairs, bridges [5, 6] and in the shipbuilding and machine industry. The paper analyses the technological process of manufacturing of sheet metal used in the construction in terms of inconsistencies. There are a number of techniques of cutting the sheet metal [7]: using a water stream, laser, gas, plasma or with guillotine cutters. The choice of the method is conditioned by the specific nature of the materials cut, their thickness and final application.

In the paper, analysis of the defects that occur in the process of sheet metal cutting was based on the Pareto chart. The tools of quality management such as Pareto chart belong to the means that are aimed at improving the level of quality and do not require high financial expenditures. Identification of defects using Pareto chart requires regularity and persistence in observation of the technological process in terms of detection of products which are inconsistent with specifications. This diagram is also termed the 20/80 rule, which means that 80% of the effects come from 20% of the causes [8, 9, 10] i.e. high number of events is attributable to small number of causes. Analysis of the diagram reveals a transparent standpoint for identification of defects which generate the highest loss and, using the principle of step-by-step, one can identify the sources of these defects, including machines, people and processes [11, 12].

An interrelationship diagram was used to identify the relationships between the defects and causes of occurrence of these defects. Interrelationship diagram is somehow similar to Ishikawa diagram, with one difference: apart from cause-and-effect correlations, it also demonstrates cause-and-cause relationships.

2. CHARACTERISTICS OF THE PRODUCT AND MANUFACTURING PROCESS

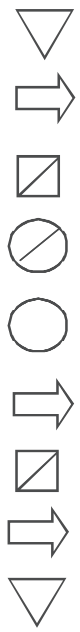
The focus of the examinations is on sheet metal prepared for the construction sector. Production of sheet metal is performed on three manufacturing lines that process hot-rolled sheet metal coils (one longitudinal cutting line and two transverse cutting lines). Geometrical characteristics of the lines used are presented in **Table 1**.

Table 1 Geometric characteristics of manufacturing lines

Line	Line 1 (for longitudinal cutting) [mm]	Line 2 (for transverse cutting) [mm]	Line 3 (for transverse cutting) [mm]
Thickness	1.5 - 5	1.5 - 6 mm	3-12 mm
Width	25 - 1500	300 - 2000mm	750 - 2050 mm
Length	-	14000 mm	14000 mm

Source: own study based on materials obtained from the enterprise analysed

In the enterprises studied, structural steels (e.g. S235JR, S355J2), high temperature steels, low alloy steels with higher strength, steels for cold forming and other types of steel are used for manufacturing of hot-rolled sheet metal. The manufacturing process of hot-rolled metal sheets is presented in **Fig. 2**.



Reception of hot-rolled sheet metal coil from the warehouse.

Transport to transverse cutting stand Centring and positioning of the hot-rolled sheet metal coil in the uncoiler.

Inspection.

Transition of the sheet metal through straightening rolls. Measurement of sheet metal thickness and inspection of the documentation for the coil cut.

Cutting of the metal sheet.

Transport of metal sheets on the rolls combined with spray marking.

Quality control.

Transport to the final product warehouse.

Final product warehouse.

Fig. 2 Technological process of cutting of hot-rolled sheet metal [own study]

3. IDENTIFICATION AND ANALYSIS OF INCONSISTENCIES IN SHEET METAL MANUFACTURING

The research period was 6 months of the year 2012. Twelve types of discrepancies were identified in this period. Their identification and hierarchization was based on a quality management tool (Pareto chart). The substantial effect on reduced level of quality of the final product is from material defects overlooked by the initial inspection which occurred in the steelworks. Some of them were revealed during cutting, with employees having no influence on this fact. The defects identified in the sheet metal manufacturing enterprise were divided into those which occurred in the steelworks and those which occurred in the enterprise studied during cutting operation. **Tables 2 and 3** present the most frequent defects in manufacturing of sheet metal with their percentage contribution and accumulated contribution. A Pareto chart was prepared based on the data contained in the table for the defects which occurred in the enterprise studied (N) (see **Fig. 3**) during cutting operation and the defects which occurred in the steelworks (Nm) (**Fig. 4**) revealed in the area of the enterprise studied.

Table 2 Defects of hot-rolled sheet metal identified during cutting [own study]

Symbol	Name of defect	Contribution [%]	Accumulated contribution [%]
N1	Sheet metal waviness	45.41	45.41
N2	Unequal sheet metal edges	34.28	79.69
N3	Mechanical defects	12.48	92.17
N4	Impressions on the surface	4.88	97.05
N5	Improper dimensions of metal sheets	1.99	99.04
N6	Other	0.96	100

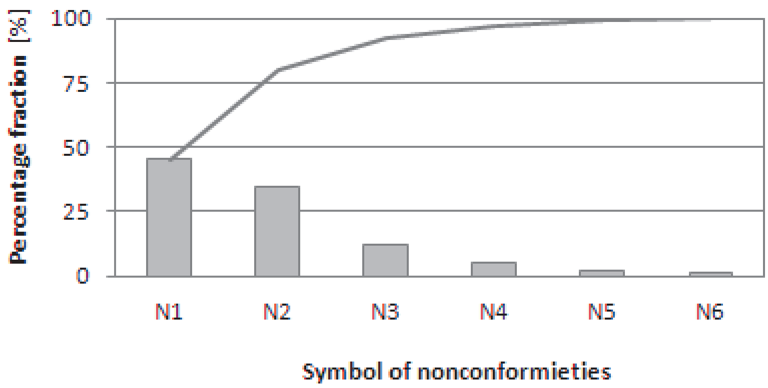


Fig. 3 Hierarchy of defects that occurred in the process of sheet metal cutting [own study]

Table 3 Defects in production of sheet metal manufacturing in the steelworks [own study]

Symbol	Name of defect	Contribution %	Accumulated contribution
Nm1	Delamination on the sheet metal surface	51.93	51.93
Nm2	Mechanical defects	12.81	64.74
Nm3	Transverse bend of sheet metal	10.83	75.57
Nm4	Falcate sheet metal	9.92	85.49
Nm5	Bends along sheet metal surface	7.37	92.86
Nm6	Lapping on the sheet metal surface	6.04	98.9
Nm7	Corrosion of the sheet metal surface	1.1	100

Analysis of Pareto chart prepared for the defects that occurred during the process of sheet metal cutting (**Fig. 3**) shows that two defects represent almost 80% of all the defects in sheet metal production. These include: N1 - Sheet metal waviness, N2 - Unequal sheet metal edges. Analysis of Pareto chart prepared for discrepancies that occurred in steelworks shows that two defects (Nm1- Delamination of the sheet metal surface and Nm2 - Lapping on the sheet metal surface account for 64.74% of all the defects in this area. The interrelationships diagram (**Fig. 5**) was used for attempting to indicate the relationships between defects in the process of cutting sheet metal and their causes.

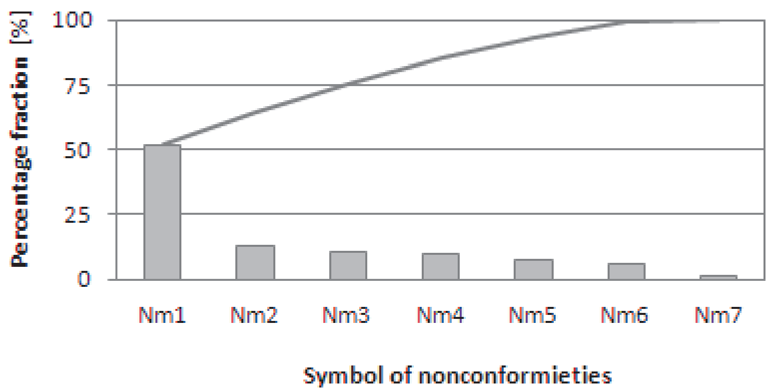


Fig. 4 Hierarchy of defects that occurred in steelworks [own study]

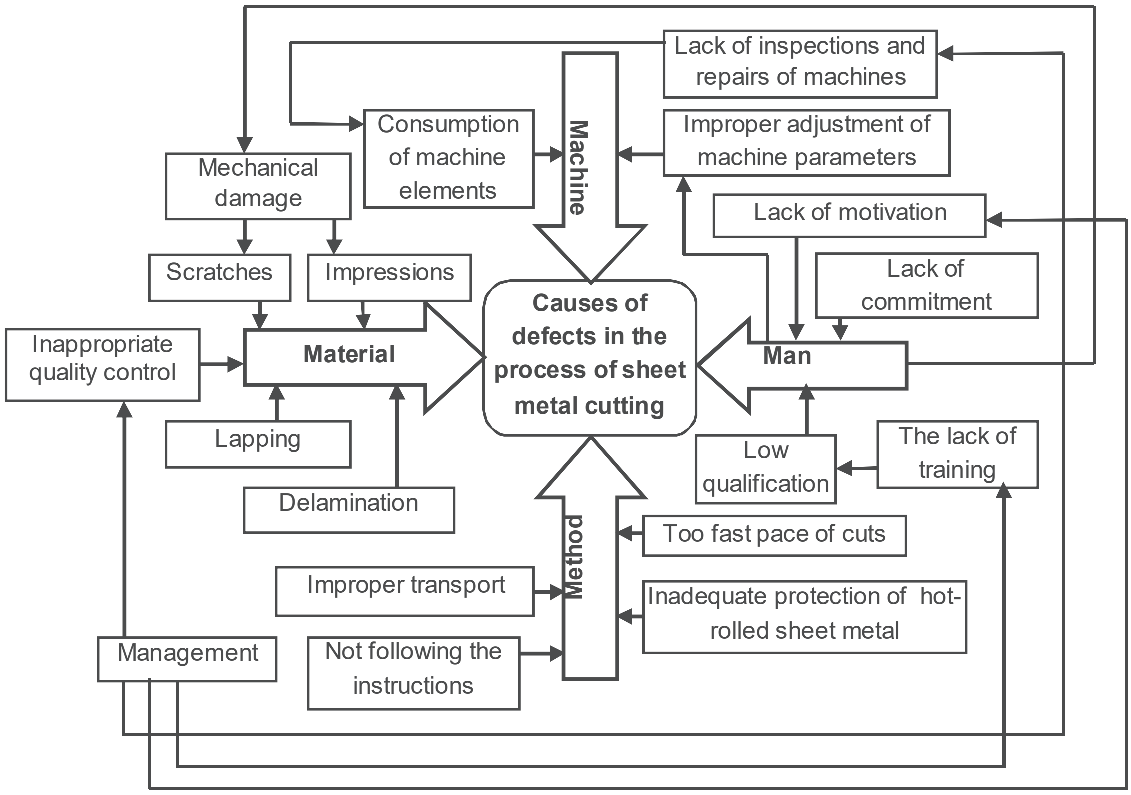


Fig. 5 Interrelation diagram for the causes of defects in sheet metal cutting process [own study]

The analysis revealed that the causes of defects in the process of sheet metal cutting can be organized in four areas: material, machine, method and human. Analysis of the diagram (**Fig. 5**) shows that the substantial effect on quality of hot-rolled sheet metal is improper organization of work in the enterprise studied. Lack of commitment of the managers influences low experience of employees, lack of qualifications, poor motivation of employees for manufacturing of products consistent with standards. The causes of defects include non-observance of the technological procedures by employees, which results from low skills, negligence and insufficient understanding the technology. These defects are caused by damaged machines and production equipment. The source of defects is lack of commitment of managers and employees to implement TQM principles.

4. CONCLUSION

Metal sheets used in the construction sector have to undergo several processes before they become the final structural product. The investigations presented in this study show that many defects result from insufficient final inspection in steelworks and initial inspection in the enterprise that cuts sheet metal. This means that the major part of the defects identified occur before transportation into the area of the enterprises and they are revealed only during cutting process. It was found after analysis of these defects that six of them result from negligence in steelworks, a part of them are caused by overlooking during inspection and another part is detected during cutting. The analysis also shows that the defects that occurred in the steelwork account for 43.5% of all the defects identified. The third most important defect that occurs during sheet metal cutting is mechanical defects, which account for 12.48% of all the defects. The cause of deformation and material damage is negligence during transportation and warehousing.

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