THE FMEA METHOD USED IN PROCESS APPROACH TO THE QUALITY MANAGEMENT OF SHEET METAL PROCESS

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Abstract
A process approach needs some substantial management changes, that means an orientation of activities of the company onto processes and not on the particular actions that are put into practice by particular company units. A productive system of the steel work, divided into some smaller processes such as: preparatory processes, supportive processes as well as the most important ones, has been presented in the work. The FMEA method has been used to analyze the process quality. The method has identified the risk of the discrepancy appearance. The main risk was related to a charge preparation as well as with the of the rolling process. Some correcting actions were applied and the FMEA method was applied again. The process quality was improved as well as a risk factor decreased in the mentioned areas.

1. Introduction
By „a process“ we understand the series of actions mutually connected and mutually interdependent, which change elements from inputs to outputs [5]. Such approach acquires that all the processes be measured and monitored. That means, that in the quality management we have to use measuring methods that exclude the forming of the discrepancies and faults, that means failing the process requirements. In the production process of metal plates a maintenance of the high quality depends on many factors related to the character of particular stages of production, that are grouped into preparatory processes, main processes and finishing processes. The quality control in those stages shows in what degree the material is fulfilling the quality requirements added to the quality of final products – the plate. The actions related to maintaining the high quality of plates do not only relate to the parameters of the finished products, but also to all part processes in which a plate is formed. It is advisable to work out a quality control plan, which (starting from the checking the supplies, through the production control, to the control of output) will define how, where, when and in what degree we should measure the process and how to predict the risk of discrepancy appearing [6]. Checks, inspections and additional examinations are performed in the production process according to the quality plans and procedures. The methods of the checking and inspections are described by testing-point procedures. Only the materials that fulfil the parameters are directed to the further process. The products faulting the outside parameters, discovered in testing, are marked, and then they can be classified, segregated and withdrawn from the production line as soon as it is possible. The plates are not released (passed onto distribution) until all the checks and measurements are finished [7].

2. Process approach in the work of the rolling-mill
Majority of thick plates is rolled from slabs – a product of continuous steel casting. Those rough entry materials are subjected to the preparation process [3], such as removal of scale, reduction of thickness and rolling to the required dimensions. The stages of the technological production process are: hot rolling, a coil etching, cold rolling, galvanizing, chroming, tin plating. A whole of the technological process is presented in figure 1.
Fig. 1. Thick steel plate production process regarded to: preparatory process, main process and finishing process connected with possibility of discrepancy appearance and process risk investigation
Source: own research
The process diagram (Fig.1) shows the risk of the quality failure involved in specific stages of production. The quality of materials used for the production of steel plates, cast in a continuous process, is controlled by the computer system. The continuous cast ingots, before being sent to the rolling-mill position, are checked by the steel-mill quality control unit controllers. The other materials, that directly influence the quality of plates, in particular rollers of the rolling machines, checked by the quality control supervisors at the entry to the steelworks. There are several factors influencing the quality range of products at the offer. These are: chemical composition of steel, time and the temperature of the slab heating, the range of the rolling temperatures, the range of plate deformation and the rate of cooling after rolling. The technological process involves hot rolling of plates and sheets with the finishing operations, which are shown on diagram 1, such as [1]:
- heat treatment (normalizing, hardening, heat improvement, annealing),
- finishing the edges, cutting into sheets,
- final examination including non-intrusive checking with ultrasounds.

Each of the mentioned production stages involves the risk developing the discrepancies. It can happen that many stages of production of plates are responsible for discrepancies (it would involve the difficulty of identifying the area responsible); it may also happen that a rolling-mill developed a series of discrepancies that adds on each other in different production processes. Identifying of those processes together with index assessment will be helpful in deciding on the connectional processes.

3. Discrepancies in rolling processes

On each stage of a plate production certain problem may occur, with which the steelworks have to cope. The most common problems are related to the surface of plates. The most common discrepancy between the surface of the material and the shape of the plate can serve as an example:
- deprecions or convexity of the rollers,
- scratches,
- gas blasters,
- cracks, thin hairline marks on the surface,
- sand patches, internal non-metallic impurities,
- scale lapping - marks on the rolled surface of a different shape, thickness and pattern.

The discrepancies are also observed in the internal structure of the material [2]. The discrepancy list related to rolling up to the year 2002 is shown in table 1.

Table 1. The discrepancy structure in the rolling-mill unit in 2002

<table>
<thead>
<tr>
<th>No.</th>
<th>Discrepancy</th>
<th>Discrepancy structure</th>
<th>No. cont.</th>
<th>Discrepancy structure cont.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Laboratory change of classification</td>
<td>22,6%</td>
<td>7</td>
<td>Waved on both sides and awry</td>
</tr>
<tr>
<td>2</td>
<td>Dishes, scratches</td>
<td>21,9%</td>
<td>8</td>
<td>Cut</td>
</tr>
<tr>
<td>3</td>
<td>Short and long</td>
<td>15,3%</td>
<td>9</td>
<td>Waved on one side and falciform</td>
</tr>
<tr>
<td>4</td>
<td>Wrong thickness</td>
<td>6,9%</td>
<td>10</td>
<td>Narrow and wide</td>
</tr>
<tr>
<td>5</td>
<td>Other</td>
<td>6,5%</td>
<td>11</td>
<td>Mechanical damages</td>
</tr>
<tr>
<td>6</td>
<td>Scrap metal</td>
<td>5,5%</td>
<td>12</td>
<td>Extractions on the edges</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td></td>
<td>TOTAL</td>
</tr>
</tbody>
</table>

Source: own research
The discrepancies can affect lowering the final mechanical and quality properties of the product. The discrepancies shown in table 1 may be classified according to the qualities mentioned before, such as: surface, shape, internal structure, material and discontinuous character of the material. (discontinuity) Such a classification is presented in table 2.

Table 2. Types of plates discrepancy and their classification

<table>
<thead>
<tr>
<th>Discrepancy number</th>
<th>A group of discrepancy</th>
<th>A discrepancy name</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Surface</td>
<td>spils (from the bottom and form the top), blasters, cuts, dishes, deprecions, scratches, non-polished, knobs, extractions on the edges.</td>
</tr>
<tr>
<td>II.</td>
<td>Shape</td>
<td>short, narrow, dispatched, awry, waved (on one and on both sides), thin, thick, unrolled, long, wide, short after the discrepancy cutting.</td>
</tr>
<tr>
<td>III.</td>
<td>Internal</td>
<td>delamination, inclusions of the other material.</td>
</tr>
<tr>
<td>IV.</td>
<td>Material</td>
<td>Improper melting analysis, wrong control analysis, improper batch, improper chemical composition, improper metalographical structure.</td>
</tr>
<tr>
<td>V.</td>
<td>Discontinuities</td>
<td>cracks, discontinuities of material after the ultrasound treatment.</td>
</tr>
</tbody>
</table>

Source: Own research

It has been proven that deciding factors in the discrepancies occurring mainly in the year 2002 were the discrepancies related to the shape and the surface of the plate (fig. 2).

![Fig.2. Groups of the rolling discrepancies observed in the year 2002](source)

Source: Own research based on table 1 & 2

As far as discrepancies of steel plates are concerned, they can also be classified according to the areas where they were initiated. In this case steelworks classify them as: “Change of classification – Rolling-mill”, “Change of classification – Steel-mill”, “Scrap metal – Rolling-mill”, “Scrap metal – Steel-mill”, “Change of classification – laboratory”

4. Characteristics of the FMEA method and the need for its application

The applied technologies, utilizing modern equipment, are leading to significant reduction of discrepancies on all stages of the production process of metal products. Although to perform correcting procedures, or anticipate occurrence of discrepancies, having the same technological means, one have to perform checks and controls and use them proactively [1]. If we identify possible weaker areas we can undertake some correctional actions, in aim to counter the most frequently occurring faults and factors increasing costs of production [6]. To obtain high quality of a process we need to identify the weak points. The FMEA analysis can serve such an identification (Figure3).
Fig.3. The FMEA sheet for a rolling process
Source: Own research
The FMEA method means a complex “analysis of causes and results of defects”. It estimates the risk of the discrepancy appearance as well as it defines possible results of their existence. It is, somehow, a prognostic method which allows to foresee mistakes and to prevent their forming. The FMEA method can relate to either a product or a productive process. Methodology of estimation and the FMEA sheet is presented in figure 3. As far as a product is concerned, its particular parts are estimated and their sensibility for the incompatibility appearance, however in case of a process – particular actions that lead to the product are defined [4, p.113]. In a previous chapter incompatibilities and their structure was mentioned. A rolling process was divided into three parts, according to the general diagram of a process. The three parts were related to preparatory actions, main processing and final treatment. A possibility of the discrepancy (of a chosen type, grouped into particular categories presented in table 2) appearance was examined for each of them. In case of each discrepancy the sources of mistakes, results of their appearance – its meaning for a customer, frequency of occurrence were estimated. Each of the mentioned factors has its own estimation note (1 – 10). A ratio of the factors allows to estimate Risk Priority Number. The greatest value of the number appearing in a main rolling process, some part of discrepancies resulted from the improper batch, improper batch preparation, temperature of rolling and from a cooling process. The discrepancies can be also related to the waste of machines and productive devices. Later in the FMEA method one have to distinguish the greatest values of the RPN and to undertake proper correcting actions. The fact if preventive actions are necessary depends on a risk level, in case of the investigated company it equals 100. The figure 4 presents how the estimated values of the discrepancy risk in the company are placed in the range of the appointed limit.

![Fig. 4. RPN value related to the production of thick sheet metals.](source)

The risk was overcome only in one case. Such high risk note was related mainly to an important meaning of the mistake for a final customer as well as impossibility of the discrepancy improvement and with an easy detection. Together such high notes gave a large risk of the N7 discrepancy formation – cracks. The batch control and a change of the cooling parameters is a recommended treatment.
5. Recapitulation

A product and a process improvement to fulfill the customer needs is the aim of the company. It helps the company to exist and it delivers profits to its owners. The newer technology enables production of cheaper and more and more ideal products and a quick fitting of a production section to the customer needs. Technology itself is not a constant category, it is being developed. It is related to materials, tools and instrumentation, used installation, methods of transport, methods of product measurement and product testing as well as methods of servicing. A continuous production updating takes place as a result of such changes. Steelworks, that want to fulfill the quality requirements to their customers, are enable to invest in new tools and technological changes, however they have to improve the level of the offered products. Usability of the techniques that allow to improve the process reliability was showed. The directions of the plate production as well as the parameters that influence the optimum properties of products were presented in the paper. It was pointed out that discrepancies, that should be identified and eliminated, are formed on each stage of the production process. Controls and trainings are applied to make particular parts of the technological process run efficiently. It was showed that a discrepancy state evaluation is not useful without any correcting actions. A company, which wants to „survive“ on the market, should concentrate on a preventive treatment, that is to predict forming of problems, not to react on problems after their appearance. The presented FMEA method, connected with the discrepancies that were monitored in the year 2002, proves that the prediction usability is lower than the current state evaluation.

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