THE MEANING OF “TOYOTARYZM” IN IMPROVING OF THE HOT-ROLLED PLATES PRODUCTION PROCESS

Abstract: Steel mill and metal plants in Poland are struggling with a crisis in the global market. Option for metal plants in Poland may be methods of organizing production using methods of the Japanese production companies. This chapter presents the concepts of “Toyotaryzm” and suggestions improvement of the mill hot-rolled plates by using asymmetric rolling process.

Keywords: Toyotaryzm, asymmetric rolling, hot-rolled plates, slab rolling, organization development

9.1. Toyotaryzm characteristic

In 2012, steel production (in steel mills in Poland) was about 8 million tons. In the same year, the share of hot-rolled steel amounted to approximately 90% (Tab. 9.1).

Increasing the share of hot-rolled products has the need to seek new ways of organizing production. These methods should ensure optimization of the manufacturing process and meet customer needs.

The solution to the problem may be the principle organization by Toyota.

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Table 1. Production of steel and hot-rolled steel in Poland in the years 2004-2012

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Steel production [10^6 tons]</th>
<th>Hot-rolled products [10^6 tons]</th>
<th>The share of hot-rolled steel compared to the production of steel [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>10.59</td>
<td>7.48</td>
<td>70.62</td>
</tr>
<tr>
<td>2005</td>
<td>8.44</td>
<td>6.19</td>
<td>73.28</td>
</tr>
<tr>
<td>2006</td>
<td>10.01</td>
<td>7.67</td>
<td>76.60</td>
</tr>
<tr>
<td>2007</td>
<td>10.63</td>
<td>7.91</td>
<td>74.41</td>
</tr>
<tr>
<td>2008</td>
<td>9.73</td>
<td>7.60</td>
<td>78.15</td>
</tr>
<tr>
<td>2009</td>
<td>7.10</td>
<td>6.18</td>
<td>87.05</td>
</tr>
<tr>
<td>2010</td>
<td>8.00</td>
<td>6.88</td>
<td>86.08</td>
</tr>
<tr>
<td>2011</td>
<td>8.78</td>
<td>7.47</td>
<td>85.07</td>
</tr>
<tr>
<td>2012</td>
<td>8.34</td>
<td>7.56</td>
<td>90.70</td>
</tr>
</tbody>
</table>

Source: GUS

After World War II, "Toyota" has developed a new production system based on 14 principles. These Principles are a set of guidelines that allowed Toyota to achieve high competitiveness of products in a very short time in the world market. This methodology has found application in the Japanese automotive industry.

It should be added that, according to Toyota one of the most important elements in the production process is man (employee, supervisor, leader, manager, director), the knowledge and skills you have one and use that knowledge.

Is it possible to use the Japanese method of organization production in steel mills and metal plants in Poland?

Yes. Why not?
An attempt to transform Japanese methods of organizing production on the Polish market is Toyotaryzm.

"TOYOTARYZM" is a term invented by: Prof. n. tech. and n. ekonom. dr hab. inż. Stanisław Borkowski from the Czestochowa University of Technology (Poland).

The term is legally protected by the confirmation date (BORKOWSKI S. 2012c).

In This document defines the term "TOYOTARYZM":

*Toyotaryzm is a scientific discipline examining the relationship between man and machine, and man and man. Taking into account the process approach, Japanese culture, especially Toyota, aimed at organization development with the use of knowledge.*

In Figure 9.1 is shown model “Toyotaryzm”. This model contains four elements and the connection between these elements:

- **Man** (Circle) - founder, initiators, investors, senior management, leadership.
- **Man** (Hexagon) - executives, leaders, managers.
- **Man** (Ellipse) – executor process.
- **Machine** (Rectangle) – material resources.

![Toyotaryzm Diagram](image_url)

*Fig. 9.1. „TOYOTARYZM” – basic model.*

*Source: BORKOWSKI S. 2012a*
In the basic model "Toyotaryzm", "Man" occurs three times. This underlines the importance of the "human" in the functioning of the production system and the organization. “Toyotaryzm” use of knowledge from the Japanese culture and Toyota’s management principles.

The 14th principle of the Toyota management is as follows (BORKOWSKI S. 2012b):

**Principle 14. Become a learning organization through relentless reflection (HANSEI) and continuous improvement (KAIZEN).**

KAIZEN is also part of "Toyotaryzm" providing process improvement. KAIZEN is made up of two Japanese words. The first of them, "KAI" means to change something, spread, and the second "ZEN" - to improve (TAPPING D., T. SHUKER 2010).

Kaizen is to improve individual processes.

### 9.2. Production process of hot-rolled plates

The production process relates to the production of the product, or processing of materials into finished products. These activities are associated with the planning of operations, operative scheduling, control of quantity and quality of production (DURLIK I. 2007, BORKOWSKI S., ULEWICZ R. 2008).

The technological process is called the main part of the basic manufacturing process in which a change of shape, physicochemical properties, the external appearance of the processed material or permanent change of mutual position of the various parts included in the manufactured product, or assembly of components and products (DURLIK I. 2007, BORKOWSKI S., ULEWICZ R. 2008).

In terms of technology can be distinguished: the phase, processes and operations carried out throughout the manufacturing plant or a cell (BORKOWSKI S., ULEWICZ R. 2008).

The production process of the hot-rolled plates is presented in the Figure 9.2.
The operations specified in this process are following:

1. Storage of ingot.
2. Transport of ingot.
3. Heating of ingot in the furnace pusher 1150-1250°C.
4. Transportation heated ingots.
5. Transportation ingot from passing through the scale-removing rolls.
6. Transportation ingot four-high reversing mill.
7. Plate rolling.
8. Transport plate.
10. Transport plate.
11. Straightening plate for hot leveling machine.
12. Transport plate.
13. Cool to cold laminar band.
15. Implementation of non-destructive testing-Ultrasonic testing.
16. Cutting of plate and collection of samples for testing mechanical properties.
17. Storage of finished product.

Fig. 9.2. Production process of the hot-rolled plates in a technological aspect.

Source: own study
9.3. Improvement of the hot-rolled plates production process

Production process of the hot-rolled plates consists of 17 operations. The most important part of the process that affects the quality of the product is the plastic deformation of the material in the mill. All theories of the rolling plates are normally based on the symmetric rolling process. Which in industrial practice is rare. (DYJA H., WILK K. 1998, HADASIK E., SOBAŃSKI A. 1984). Symmetrical rolling process envisages that the plate coming out of the roll gap is straight. In practice, it's different. Due to the difference in peripheral speed and uneven deformation of sheet metal, sheet metal coming out of the roll gap is directed toward the lower or upper roller of.

The phenomenon of bending plate finished eleventh operation requires a production process with a view to its straightening. The use of asymmetric rolling process can eliminate the eleventh technological operations.

![Fig. 9.3. The deflection plate in the lower cylinder coming out of the roll gap. Source: own study from Forge 2008](image-url)
9.4. Experiment

Research focused on the impact of asymmetric rolling on the curvature of the plates coming out the roll gap. For this purpose, computer simulations carried out in the "Forge 2008". In the "Forge 2008" carried out simulations of rolling plates. The study carried out for plates with a height $h_0 = 50$ mm. Rolling temperature corresponds to the temperature normalizing rolling $t = 950$ °C. The value of the indirect draft in successive penetrations lies in the range 8 to 40%. Asymmetries rolling process implemented by changing the peripheral speed of the upper roller in the range of 1-15%. Assumed a constant circumferential speed of the lower cylinder $n = 50$ rpm. / min. Theoretical studies carried out for three values of the coefficient of friction $\mu_1 = 0.27$, $\mu_2 = 0.30$, $\mu_3 = 0.36$.

9.4.1. Material used to research

Steel used in the research belongs to a group of low-alloy steel of high strength materials.

The research was carried out on S355J2G3 steel specimens. Chemical composition of the steel investigated is given in Table 9.2.

<table>
<thead>
<tr>
<th>STEEL GRADE</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td>S355J2G3</td>
<td>0.15</td>
<td>1.36</td>
<td>0.33</td>
<td>0.017</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>Ni</td>
<td>0.089</td>
<td>0.03</td>
<td>0.23</td>
<td>0.03</td>
<td>0.0092</td>
<td>0.001</td>
</tr>
<tr>
<td>Mo</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>Cu</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>Al</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>N2</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>V</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>Nb</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>B</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>Ti</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>Sn</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>Ca</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
<tr>
<td>Zn</td>
<td>0.002</td>
<td>0.0003</td>
<td>0.002</td>
<td>0.018</td>
<td>0.0007</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Source: Polish norm PN-86/H-84018:1986
9.4.2. Results of research

Figure 9.4 presents the results of research the impact of asymmetric rolling process on the curvature of the plate coming out of the roll gap. Based on the obtained results, it was found that there are conditions for which it is possible to leave straight band from the roll gap.

This process is dependent on peripheral speed of the upper roller, and passes reduction and friction conditions. Based on the research, it was found that the relative indirect draft in the range of $0.3 \div 0.35$ and a coefficient of friction of 0.27 is possible to obtain straight band coming out of the roll gap. Changing the friction at the contact surface roller-band has a significant impact on the amount of curvature of the band. When the friction coefficient is 0.30, and $\varepsilon = 1 \div 8\%$. It is possible to output straight band from the roll gap for small values of reduction rates in the range $0.2 \div 0.3$. When the friction coefficient is 0.36, it is possible to output straight band from the roll gap for small values of reduction rates in the range $0.3 \div 0.35$ for $\varepsilon = 1\text{-}15\%$. 

![Graph showing the impact of friction and indirect draft on band curvature](image-url)
Fig. 9.4. Effect of asymmetric rolling process on the curvature of the plate "ρ".

For a) $h_0/D=0.05$, $\mu=0.27$, $\varepsilon = 8 + 40\%$,

b) $h_0/D=0.05$, $\mu=0.30$, $\varepsilon = 8 + 40\%$,

c) $h_0/D=0.05$, $\mu=0.36$, $\varepsilon = 8 + 40\%$.

Source: own study
9.5. Summary

Toyotaryzm is a scientific discipline that draws on the knowledge of the Japanese management methods. "KAIZEN" is one of the elements "Toyotaryzm". In order to improve the production of heavy plates proposes the use of asymmetric rolling. Asymmetric rolling process was to influence the curvature of the sheet coming out of the roll gap. Results of tests carried out in the computer program "Forge 2008" showed that the use of suitable rolling conditions allows to obtain a simple sheet metal. Applying these conditions allows for the elimination or reduction of the use of straightening plates.

Bibliography