DEVICE DISTRIBUTION SYSTEM PRODUCTIVITY MONITORING - MANUFACTURING EXECUTION SYSTEM ON THE ROLLING MILL EXAMPLE

MONITORING ZDOLNOŚCI PRODUKCYJNEJ ROZPROSZONYCH URZĄDZEŃ Z WYKORZYSTANIEM MES NA PRZYKŁADZIE WALCOWNI

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Abstract: The paper is focusing on device distribution system productivity monitoring - manufacturing execution system on the rolling mill example. The presented approach is helping both availability of manufacturing system shaping and safety keeping.

Keywords: availability, monitoring, MES

Streszczenie: W artykule przedstawiono rozwiązanie monitoringu zdolności produkcyjnej rozproszonych urządzeń z wykorzystaniem systemu przemysłowego MES na przykładzie walcowni. Prezentowane podejście umożliwia kształtowanie gotowości eksploatacji maszyn i urządzeń oraz zapewnienie wymaganego poziomu ich bezpieczeństwa.

Słowa kluczowe: gotowość, monitoring, MES
1. Introduction

In manufacture practice we have mostly device based distributed system, which availability calculation on-line is great practically cost-oriented important. Manufacturing execution system MES (Manufacturing Execution System) serves a very efficient communication solution between a business system such as Enterprise Resource Planning (ERP) and manufacture plant control devices [1, 2, 3, 4], e.g. rolling mill’s. The system is helping to manage production, scheduling, creating sequence, tracking rolling process, and delivering work instructions to operators. In addition, gives us full palette of reports showing very transparently every aspect of rolling mill activity. The productivity monitoring system will be discussed base on the rolling mill Manufacturing Execution System example.

2. Rolling Mill Manufacturing Execution System Description

Manufacturing Execution System (MES) on the Rolling Mill has two main tasks: collects information from production line and transfer reports to business area. To collects information in correct way system uses information technologies (IT). All information is placed in dedicated databases on the server. All applications installed on workstations are only clients of server’s databases. Feeding information to the system is both, automatic and manual. Of course as much automatic as better, but sometimes manual input is necessary. General configuration of the system’s network is presented on figure 1.

![Fig. 1 Manufacturing Execution System structure](image)
Chronologically, first operation is doing on the billet yard personal computer PC type. If MES is interfaced with ERP, then information about work orders and available heats are transferred in automation mode by special prepared interfaces. If not, operator has to put information about work orders and heats manually. After that, operator can prepare sequence of rolling, according information he has in the system and schedule form-planning department. Sequence is appearing on tracking computer.

To track rolling process, system is using signals from dedicated PLCs (Programmable Logic Controller) and HMDs (Head-Mounted Display). Platform to share these signals between level 1 automation systems and MES (Manufacturing Execution System) can be OPC (Open Process Control) Server (the application of the OPC standard interface makes possible interoperability between automation/control applications, field systems/devices etc.). Tracking application, tracks rolling process billet-by-billet and second by second. This philosophy is very useful to observe performance of the mill. Thanks that, there is possible to measure every important KPI (Key Performance Indicator). Also thanks to that, system “knows” where on the mill material is in every moment of process. Additional there is possible to grab gas and electricity consumption and rolls and guides usage. Next step is a scale, where information about weight of production is grabbed and loaded to the database. This is a second place on the mill where is possible connection with ERP system. Another interface can send to Enterprise Resource Planning necessary information about amount and time of production particular heats and work orders.

Now MES has enough information to generate reports. To read reports, we need especially dedicated application, which can be installed on any Work Station in MES Network or any other PC working in business network connected with MES Network. Using MES we can measure following parameters: productive time, speed losses, gas and electricity consumption, rolls and guides usage, metallic yield, quality yield, delays. All these factors got influence for fixed and variable costs of production. Now we can see the real value of MES. This can be a tool very helpful to calculate real costs on the mill. Tracking process of rolling, billet-by-billet and second by second gives us possibility to ascribe costs to particular billet, heat or campaign. Another advantage from MES is possibility to make some simulations, to see how our decisions can impact to particular Key Performance Indicators (KPIs) and costs. Functionality of Manufacturing Execution System on the Rolling Mill contains: billet yard area, tracking, delays, scales, rolls and guide shop, reports.

Billet yard area is the place, where operator has to manage all semi products dedicated to roll. Main task is to match work orders with available heats.
Result of his job is a sequence of rolling, which is the basic information for process engineer. According this sequence, process engineer knows detailed schedule of rolling and has to choose correct rolling recipe and set all rolling parameters on every device on the mill. Next step is tracking of the process. Thanks to that we can see performance of the mill, we can measure rolling time, and gap time and we can catch and classify all delays. Special module is responsible for catching all delays. First we have to establish the difference, between gap and delay. For example every period of time between billets bigger than 3 minutes we mark as delay. Every period of time between billets less than 3 minutes is a gap and is reported automatically. Shift leader or process engineer has to classify each delay. All delays reports we can find in our database, using historical data is very useful. Thanks to that very easy we can select bottlenecks and other danger areas on the mill. Next step is a scale machine. Here system is grabbing information about weight of production, bundle-by-bundle or coil-by-coil. This is also the place where tags for products can be printed. From scale, all needed information about production can be transferred to ERP system. To do this, is necessary to prepare special interface. Very important think, is possibility to measure rolls and guides usage. These tools are very expensive and calculation of costs in this area is crucial. To do this, MES uses module able to grab information about part of production divide on particular rolls and even grooves. Also this module is responsible for managing database dedicated to turning shop, where are collected all information about rolls as: diameters, sets, ID, hardness, manufacturer, etc. To use all information in correct way, we need module to read reports. This module is additional tool dedicated for supervisors, management of the mill and management of the plant. It gives to the user the full, complete and detailed information about production process. We can find there information about volume of production divided on work orders, heats and bundles or coils, with complete info about time, shift, crew etc. Of course we can find there productive time with all the delay details billet by billet with responsible, crew, profile, size, grade, equipment, part, failures. So everybody from their position can put all their efforts to avoid the mill stops in the further campaigns. MES is not only collecting data, is also can handle and supply any kind of information that the customer needs for different purposes as the following:
- increase productive time,
- increase metallic yield,
- increase quality yield,
- decrease speed losses.

Report module is focused on operational factors and is dedicated to people understand rolling process. To show better financial aspect of process, system is enhanced in costing module.

3. Rolling Mill Manufacturing Execution System Description

3.1. Module Description

Costing module of the rolling mill MES is dedicated straight to highest management of the plant, controlling department and of course sales and scheduling. It shows very transparently real costs of chosen part of production. This is the best way to see, full costs of production.

System is taking into consideration all aspects of rolling process. Productivity, time of rolling, time of changeovers, yield, delays, gas and electricity consumption, costs of rolls, rings and rolling guides, labor costs, billets costs, maintenance. All these values are very important. But most important is to attach right costs to right part of production. Rolling process is very complex and this kind of calculation are very difficult, but using good tool to make correct balance is priceless and gives us big advantage over competition.

Some calculations are made by comparison, to do that there is necessary to define product by product the real standard speed in tons/hour with a defined billet as a raw material. This table should be loaded to database. Also is necessary to prepare another table for the size changes and changeovers. This is important to have a base to compare real values with standard values.

MES is able to calculate in a very precise way the fix and variable cost of every billet rolled. Having the process cost of each billet is easy to calculate the cost per ton of every bundle or coil by heat, by work order, or by campaign.

This module can present in very transparent way, most profitable products. This functionality is very valuable for scheduling department and for sales department.

Very important from costing point of view is Overall Effectiveness Equipment (OEE).

3.2. Overall Effectiveness Equipment

The biggest advantage from implementation MES on the Rolling Mill is to calculate in correct way Overall Effectiveness Equipment (OEE). In
addition MES helps us to know what components of OEE are and what to do to increase OEE.
OEE stands for Overall Effectiveness Equipment. It comes from automotive industry. For a Rolling Mill the OEE should be calculated as following:

$$ \text{OEE} = \% \text{PT} \times \% \text{SL} \times \% \text{YM} \quad (1) $$

where:
- $\% \text{PT}$ = % of Productive Time,
- $\% \text{SL}$ = % of Speed Losses,
- $\% \text{YM}$ = % of Metallic yield* % of Quality Yield.

Let explain in details what is all about these Key Performance Indicators. First factor is Productive Time, which is a part of Available Time that material is present on the Rolling Mill:

$\text{Available Time}$ - to achieve the available time we have to go step by step taking out all the time that is beyond the control of the General Mill Manager:

$$ \text{Available Time} = \text{Avt} = \text{Nat} - \text{Schedule Maintenance} - \text{size changes} \quad (2) $$

where:
- Total Time = Tt = Chosen Period of Time (Year, Month, Day),
- Total operation Time = Topt = Tt - schedule not Production days. For example: market issues,
- Net Available Time = Nat = Topt - tests - calamities.

Productive Time = the time that material is rolling in the mill included a defined and limited gap:

$$ \% \text{Productive time} = (\text{Available Time} - \text{all Failures}) / \text{Available Time} \times 100\% \quad (3) $$

The second factor that builds the OEE indicator is % of Speed Losses and the origin of this KPI is the time comparison billet by billet between the real rolling time plus gap time with the previously defined standard rolling time and gap time for each product. The Standard Rolling Time and Gap Time should be previously defined for each product in the Product Catalogue. If the standard rolling time and gap time are correctly established in the product catalogue and the real speed (MTS (multimedia telecommunications services)/ SEC (simple event correlator)) and gap time (SECs) in the mill are set correctly the speed losses should be zero:

$$ \% \text{Speed Losses} = ((\text{Real Productive Time} - \text{Standard Productive Time}) / \text{Standard Productive Time}) \times 100\% \quad (4) $$
The third component that builds the OEE is the product of the following KPI’s, the % of the Metallic Yield & % of the Quality Yield. The % of Metallic Yield calculation is as follows:

\[
\text{% of Metallic Yield} = \frac{\text{Weight of the final goods}}{\text{Weight of the charged Billets}} \times 100\%
\]

(5)

The % of Quality Yield calculation is as follows:

\[
\text{% of Quality Yield} = \frac{\text{Weight of the Prime final goods}}{\text{Weight of all final goods}} \times 100\%
\]

(6)

Other way to calculate the % of Quality Yield is as follows:

\[
\text{% of Quality Yield} = \frac{(\text{Weight of all final goods-weight of all rejections})}{\text{Weight of all final goods}} \times 100\%
\]

(7)

All above presented factors can be measured by MES. To appreciate importance of these factors, we need a good tool to make right calculations. Now use described formulas, we can very easy check for example how one second less gap can influence for our annual financial result.

Another very important thing is to know all trouble areas or aspects on the mill. Thanks to delays database we can focus on most annoying problems and put our all effort to solve the problem. Doing this, we can increase reliability not only considered area but in fact of whole process.

Very similar situation we got with safety. We can focus on example on the stand where there is most possible to catch a cobble and do everything what is possible to avoid or minimize that undesirable situation. Increasing safety is most important, because safety should be first on every production line. Life and health of employees is priceless.

4. Conclusions

Presented system is not so popular today, but after some consideration it looks, as tomorrow it will be a fashion. Rolling mills are very complex installations and there is no better way to manage them as know exactly what is going on in every area and every moment of activity. If we add full information about costs, we got base to do good scheduling and take only right decisions. Another advantage of MES is that this is a tool useful not only for operational but also for financial people and for highest management of companies.

Crucial thing, necessary to prepare reliable MES dedicated for rolling mills is to understand the process of rolling. So operational people should prepare
the most valuable system with many years experience on the mill. Every MES for rolling mill should be tailors made product. There are no two identical mills all over the world. Concept is the same, but specific of each mill must be taken for consideration, every time MES is creating. Good MES dedicated for rolling mill is a real gift from rolling mill operators to rolling mill operators. The presented approach is possible to apply to others device distribution systems.

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**References**


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