Facilitating the Technological Line Renewing System in the Aspect of Quality Improvement

Key words
Servicing system, technological line, quality, information system, assessment.

Abstract
In this paper, the problem of facilitating the servicing system of metallurgical processing technological lines was presented. The project of the information system, supporting the maintenance within the plant, allows one to reduce the number of breakdowns, rationalise spare parts management, increase safety levels, and reduce manufacturing costs, which leads to improving the quality of products and extending the useful life of machines and devices.

Introduction
Technological lines used in metallurgical processing are characterised by a high level of mechanisation and automation of manufacturing processes, ensuring the required quality of the final products. The continuity of execution of this process depends on various factors; however, it largely depends on the reliability of the technical objects. Breakdown of any of the devices comprising the manufacturing line means that the line has to be stopped, which generates financial losses [3].

Maintaining the functional and task oriented fitness of the objects is guaranteed by the rationally organised servicing systems. By preventing and eliminating breakdowns, modern servicing systems guarantee high quality of the
final product [4]. They also take into consideration the maintenance costs, safety and natural environment protection, while simultaneously maintaining close links with the planning sectors, so the technological maintenance schedules do not collide with the manufacturing schedules.

The analysed example involves the improvement of the technological line servicing system used in the bent profile segment of the metallurgical processing plant.

The topicality of the presented problem stems from the great market demand for high quality products manufactured from metal sheeting, where each line stoppage generates financial losses to the company.

Numerous plants implemented quality management systems based on the ISO series 9000 standards, imposing requirements regarding providing and maintaining infrastructure necessary to achieve conformity with the requirements determined for the products. However, more and more often, the companies look for new solutions, the implementation of which could influence the improvement of the maintenance management. One of those solutions is information supporting systems, managing maintenance works, which are systems of the CMMS class (Computerized Maintenance Management System). The purpose of which is to support the maintenance management of the manufacturing plant. These systems allow one to keep a register of manufacturing tools, fixed assets, technical data for the subsystems, costs, purchase dates, continuity of service within the plant, technical documentation management, control of the completed maintenance works, and human resource management [6].

For the analysed case, the development of the project of the information system supporting the work maintenance management shall streamline the management of the machine park, mainly with regard to maintenance management, which is one of the most important factors for the plant in which the technological devices are utilised.

The assumed assessment models in the form of indicators allow one to conduct day to day, reliable assessments, while taking into consideration the possible modernisations and innovations.

The basis for the development of the computer application was formed by the data regarding the technical infrastructure of the analysed manufacturing line and information derived from the maintenance activities diagrams, consistent with the requirements of the ISO 9001:2000 standards. The application takes into consideration the tasks imposed by the standard, based on the function of the CMMS class system. In addition, this paper also presents the potential business and technical benefits possible to achieve thanks to the implementation of this type of software applications.
1. Identification of the investigation object

The investigation object is the technological line, exploited in the bent profile segment of metallurgical processing.

In this segment eleven technological lines operate. Nine of them are the lines used for manufacturing metal profiles. The last two are used for manufacturing roadside barriers. The plant is also equipped with two processes used for longitudinal cutting of metal for manufacturing the elements fed to the bending machines, a transverse cutting unit, for manufacturing metal sheeting and a coil packaging line as shown in Fig. 1.

![Diagram of technological lines]

Fig. 1. Arrangement of technological lines in the bent profile segment of the plant

- ACW (1,2) – Longitudinal cutting aggregates
- ACP – Transverse cutting aggregate
- K – Coils packaging line
Hot rolled metal sheeting in the form of coils are delivered to the transverse cutting unit and two longitudinal cutting units. The transverse cutting line allows one to obtain metal in form of sheets, which are then stored in the warehouses.

The longitudinal cutting units cut the metal coils into coils of a smaller width, which are then the feeding material for the profile bending devices.

The concept of improving the system servicing was presented using, as an example, the new technological line, working in the bent profile segment, which is the transverse cutting unit. This unit comprises of a number of devices of a serial reliability structure, comprised of shear sets, straightening units, conveyors, coils storage systems, trolleys, and stacking devices. Maintaining the appropriate reliability level of the unit, which will guarantee a high quality of the product, requires the completion of the ongoing and periodical maintenance procedures, conservation, and overhaul works, and all executed in accordance to the developed procedures and instructions.

The purpose of the servicing system is to ensure that the technological condition of the devices is maintained at the level that allows the manufacturing of products of the required quality, while at the same time, complying with the requirements specified for the natural environment protection. Those requirements were specified in the ISO 9001 Quality Assurance System and ISO 14001 Environmental Management System implemented by the plant.

2. Analysis of defects of the transverse cutting unit

By conducting a meticulous analysis of the technological process, realised using the transverse cutting unit, it is possible to identify damages that are a direct result of the manufacturing process (Table 1). Information contained in Table 1 allows developing servicing procedures, which in turn will lead to eliminating some of the defects.

Table 1. Analysis of the defects being a result of the technology of the manufacturing process

<table>
<thead>
<tr>
<th>Possible damages</th>
<th>Causes</th>
<th>Effects</th>
<th>Impact of the effects on the manufacturing process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage of the cross (star – piece) bearings</td>
<td>Weight of the metal coils is too high</td>
<td>There is no possibility of turning the cross</td>
<td>Loss of ability to store the coils, the manufacturing process slows down</td>
</tr>
<tr>
<td>Damage of the bending coils in straightening apparatuses</td>
<td>Material defects of the charge</td>
<td>A layer of the charge is stuck on the surface of the rollers or possibly the coils become chipped</td>
<td>Visible defects on the surface of the finished sheets, unit downtime</td>
</tr>
<tr>
<td>Damage of the slide bearings in straightening apparatuses</td>
<td>Misuse of straightening apparatuses 1 and 2</td>
<td>Rollers seizing in sockets</td>
<td>Damaged straightening apparatus cannot be used</td>
</tr>
<tr>
<td>Possible damages</td>
<td>Causes</td>
<td>Effects</td>
<td>Impact of the effects on the manufacturing process</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>-----------------------------------------------------</td>
<td>----------------------------------------------------</td>
</tr>
<tr>
<td>Damage of the blades cutting the charge at the beginning</td>
<td>Incorrect distance between the blades</td>
<td>Damage of the blades in the device cutting the charge at the beginning</td>
<td>Device out of operation, excluded from the technological process, possible unit downtime</td>
</tr>
<tr>
<td>Damage of the roller cutter or clippings breakers</td>
<td>The width of the clipping is too large</td>
<td>Clippings stuck in the breaker; damage of the breaker blades</td>
<td>No possibility to manufacture metal sheeting with trimmed side edges</td>
</tr>
<tr>
<td>Damage of the flying cutter</td>
<td>Manufacturing of short sheets made of thick metal sheeting at high speed</td>
<td>Damage of the flying cutter clutch</td>
<td>Unit downtime</td>
</tr>
<tr>
<td>Damage of conveyors</td>
<td>Incorrect flatness of the metal sheets; damage of the sheet edges</td>
<td>Stripping the conveyor material; cutting the conveyor</td>
<td>In a specific case of a large cut in the conveyor material – unit downtime</td>
</tr>
<tr>
<td>Damage of the feeders</td>
<td>Incorrect flatness of the metal sheets; wrong position of the feeder with regard to the current values for the manufactured sheets</td>
<td>Metal sheets stuck in the feeder arms; damage of the sheet pusher</td>
<td>If arms of the second feeder are damaged – the possibility of continuing the production using the first feeder; If arms of the first feeder are damaged – unit downtime</td>
</tr>
</tbody>
</table>

Apart from breakdowns stemming directly from the specificity of the technological process, the devices comprising the manufacturing line can also become damaged due to the wear and tear processes.

The complex analysis of the breakdowns allows one to foresee the future situations and to undertake preventative initiatives aimed at eliminating downtime due to the system breakdowns.

Repeatable defects, caused by the system’s wear and tear, for which their causes, effects, and consequences have been determined, are presented in Table 2.

The development of the damage register and utilisation of the CMMS class computer system allow to significantly streamline the system of servicing the analysed technological line.
<table>
<thead>
<tr>
<th>Damaged area</th>
<th>Causes</th>
<th>Effects</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coil star piece (x – bit)</td>
<td>Bearing worn out, transmission worn out</td>
<td>Turning the star piece is impossible</td>
<td>Warehousing of the metal coils is impossible, manufacturing process slowed down</td>
</tr>
<tr>
<td>Coil trolley</td>
<td>Coil trolley powering clutch worn out</td>
<td>Transporting the coils from the star piece to the coil winding device is impossible</td>
<td>Unit downtime</td>
</tr>
<tr>
<td>Double unreeeling device</td>
<td>Sliding strips of the unreeeling device worn out</td>
<td>Fluid alignment of the unreeeling device is impossible</td>
<td>Unit downtime</td>
</tr>
<tr>
<td>Double unreeeling device</td>
<td>Seals of the unreeeling device mandrel worn out</td>
<td>Oil leaks from the mandrel expansion mechanism</td>
<td>Unit downtime due to the necessity of sealing the oil leaking element</td>
</tr>
<tr>
<td>Pressing rolls</td>
<td>Rolls driving chain broken</td>
<td>Rolls driving mechanism out of order</td>
<td>Dressing the coil on the unreeeling device impossible – unit downtime</td>
</tr>
<tr>
<td>Straightening apparatuses</td>
<td>Element connecting the rolls driving shaft broken</td>
<td>Straightening roll driving mechanism out of order</td>
<td>Straightening apparatuses downtime – unit downtime</td>
</tr>
<tr>
<td>Straightening apparatuses</td>
<td>Work surface of the straightening roll worn out</td>
<td>Visible defects occurring on the surface of the finished metal sheets</td>
<td>Straightening apparatuses downtime – unit downtime</td>
</tr>
<tr>
<td>Metal sheeting cleaning device</td>
<td>Bearing nodes worn out</td>
<td>Brushes out of order</td>
<td>Manufacturing continued without the cleaning device</td>
</tr>
<tr>
<td>Flying cutter</td>
<td>Bearing nodes of the flying cutter driving mechanism worn out</td>
<td>Cutter driving mechanism out of order</td>
<td>Unit downtime</td>
</tr>
<tr>
<td>Flying cutter</td>
<td>Damage of the cutting mechanism</td>
<td>Cutting mechanism driving system out of order</td>
<td>Unit downtime</td>
</tr>
<tr>
<td>Flying cutter</td>
<td>Transmission belts of the flying cutter driving mechanism worn out</td>
<td>Cutting mechanism driving system out of order</td>
<td>Unit downtime</td>
</tr>
<tr>
<td>Stacking devices</td>
<td>Clutch of the arm opening mechanism worn out</td>
<td>Arm opening is impossible</td>
<td>If mechanisms of the second stacking device are damaged – the possibility of continuing the production using the first feeder; If mechanism of the first stacking device are damaged – unit downtime</td>
</tr>
<tr>
<td>Stacking devices</td>
<td>Transmission belts of the arm opening mechanism worn out</td>
<td>Arm opening is impossible</td>
<td></td>
</tr>
</tbody>
</table>
3. Project of the information system supporting the maintenance system

The designed system, through implementation of the IT solutions, in areas such as technical infrastructure management and maintenance (keeping a record of the manufacturing devices, fixed assets, technical data of the subsystems, costs, purchase dates, etc.), control of the work continuity within the plant, technical documentation management, control of the completed renovation and maintenance works or human resources management, allows one to improve and streamline the overhaul management.

The most important element, which will be included in the IT solutions, is planning the work of crews responsible for the maintenance of the manufacturing infrastructure. For this purpose, schedules were developed, containing all completed preventative maintenance works and data regarding the costs of the works, was introduced into the system. Implementation of the system of automatic ordering of spare parts and consumables allows determining the minimum level of spare parts and consumables stock stored in the warehouses, which lead to lowering the amount of the frozen capital. Coordination of the warehousing management with preventative maintenance is a key issue and will generate significant savings.

Requirements specified for the CMMS class system determine the following basic functions:

− Control of costs of the machine park and the associated technical infrastructure maintenance;
− Management of the overhaul crews, technical/maintenance department workers, and other persons responsible for the technical condition and servicing the machines and devices;
− Management of the contracts concluded with subcontractors;
− Controlling the exploitation of the devices;
− Fast access to the data regarding the maintenance and services;
− Control of the ordered maintenance works;
− Control of the spare parts warehouse stocks and automatic generation of orders for spare parts when the stock reserves fall below the specific levels;
− Management of the orders and contracts with suppliers;
− Management of the technical documentation, access to the documentation from the application level (e.g. CAD drawings, safety instructions);
− Readymade templates of standard reports and the possibility to generate unique individual reports; and,
− Keeping records of the completed maintenance and renovation works, including division into spare parts costs and workmanship costs.

The execution of the basic functions of the CMMS is influenced by its structure.
The architecture of the optimal CMMS system is presented in Fig. 2 [4]. It also illustrates the processes that will be affected by the implementation of the IT solutions being a part of the system.

![Fig. 2. Processes that will be included in the IT transformation within the scope of the CMMS system](image)

Data collected in this module can be used for calculating the costs of the maintenance of a particular object, analysing the failure frequency rate of the devices, and preparing the complex analyses. Within the scope of this module, the CMMS systems, as a standard, ensure the following: maintaining records and history of all defects, the possibility of maintaining records of the most often occurring breakdowns and breakdowns causing the longest downtime of the system, analysis of the actually incurred costs associated with the completion of orders, an analysis of the downtime periods, and the consistency with the requirements of the quality assurance system implemented within the plant. This includes keeping records regarding the completed orders, the possibility of calculating the failure frequency rate for particular objects and groups of objects, and collecting data for calculating the output of machines and devices (downtime periods, downtime periods caused by breakdowns, number of breakdowns).
Functions and abilities offered by the modules used for managing group work and work scheduling are very comprehensive. Not all functions must be required, thus the expectations towards the CMMS systems shall be thoroughly analysed. Since the implementation of those modules is a time consuming process, there is a necessity to prepare a detailed plan for the activation of the particular functions.

The developed application works as a relational database, containing numerous tables working as registers. Entering data into tables and table analysis can be done using the specially developed forms. The data analysing functions are realised with the use of search enquiries. The program contains data for appropriately classified machines and devices; this allows a simple use of the database and easy management of tasks associated with the particular elements of the manufacturing line. Appropriate entries placed next to the data make data sorting easier and allow classifying the data as planned, overhaul, or caused by a breakdown. Allocation of codes allowing the program to register the type of the breakdown also allows one to obtain the full scope of history data for machines and devices. The program was designed to primarily contain data for the machines, but it is possible to enter data pertaining to other elements of the infrastructure or transport machines. Within the tasks, it is possible to enter information regarding maintenance works comprising the particular task. The particular consumables can be assigned to the particular machines.

4. Assessment indicators

The basic criterion, which shall be taken into consideration when making the decision regarding the possible implementation of the maintenance support system, is not costs, but an analysis of problems occurring within the plant, which can be eliminated after the implementation of this type application [5]. Determinations of the critical problems influence the elimination of unnecessary work during the implementation process, thus lowering the cost of the implementation and improving the effectiveness of the program. Thus, it seems that an ongoing control, realised based on the collected exploitation data and the comparison of this data with the requirements specified by the indicators, is necessary. This data may include the following:

- Average time required for repair:

\[ \bar{t}_n = \frac{1}{N_n} \sum t_n, \]

where \( N_n \) – number of repairs during the analysed period of time,

\( \Sigma t_n \) – total repair time.
Downtime indicator:

\[ K_p = \frac{T_n}{\bar{T}_n + \bar{T}} \]

where

\( \bar{T}_n \) – average repair time,
\( \bar{T} \) – average time of device’s correct work between breakdowns.

Readiness for work indicator:

\[ K_g = \frac{\bar{T}}{\bar{T} + \bar{T}_n} \]

where

\( \bar{T} \), \( \bar{T}_n \) – as above.

Spare parts supplies indicator (for the device):

\[ K_o = \frac{\bar{T} + \bar{T}_n}{\bar{T} + \bar{T}_n + \bar{T}_o} \]

where

\( \bar{T} \), \( \bar{T}_n \) – as above.
\( \bar{T}_o \) – sum of average times of: defect removal time and downtime due to administrative procedures.

In the case of the analysed manufacturing line, the important assessment criteria shall also include the safety criterion and the environment protection criterion.

In addition, it seems reasonable to determine the following indicators:

- Parameter of the breakdowns stream,
- Parameter of replacement parts stream,
- Total number of breakdowns,
- Parameter of regulation stream, and
- Total cost of repairs.

In the analysed case, the attempt to determine the return on investment in implementation of the IT solutions for the maintenance processes is a reasonable request. This parameter can be calculated based on an equation comparing the financial profits from the implementation of the IT solutions to the total costs of the system’s implementation and maintenance.
\[ \text{ROI} = \left( \frac{\text{business benefits} + \text{technical benefits}}{\text{(purchase and implementation cost} + \text{risk)}} \right) \times 100\% \]

An important factor is the determination of the period for which the calculations will be completed. It is reasonable to determine after what time the system’s implementation and maintenance costs will be balanced with the achieved savings.

**Conclusions**

Supporting the system of the maintenance of the analysed technological line is possible through the implementation of the IT solutions in areas involving the technical infrastructure and maintenance of the plant. The project of the system based on the basic functions of the CMMS system will assure the following:
- Extension of the useful life of machines and devices;
- Reduction in the number of breakdowns resulting in line downtime and losses caused by those downtimes;
- Improvement of work safety thanks to appropriately executed maintenance and overhaul works;
- Reduction of the fixed asset maintenance costs;
- Constantly increasing knowledge database and fast access to the information regarding the fixed assets of the company, its technical condition, planned and currently conducted and completed overhaul works;
- Rational spare parts and consumables management; and,
- High brand valuation.

Implementation of this class of computer application will certainly lead to achieving the following benefits: better human resources management, a reduction in the number of breakdowns, quality improvement, and the extended useful life of machines and devices.

Ongoing control of the proposed indicators will allow one to make a reliable assessment with regard to the planned investments, and streamlining the management system.

**References**


Wspomaganie systemu odnawiania linii technologicznej w aspekcie poprawy jakości

Słowa kluczowe

System obsługiwania, linia technologiczna, jakość, system informatyczny, ocena.

Streszczenie

W artykule przedstawiono problematykę wspomagania systemu obsługiwania linii technologicznej przetwórstwa hutniczego. Projekt systemu informatycznego wspomagającego utrzymanie ruchu w przedsiębiorstwie pozwala na zmniejszenie liczby awarii, racjonalną gospodarkę częściami zamiennymi, wzrost bezpieczeństwa, zmniejszenie kosztów produkcyjnych, co w efekcie prowadzi do poprawy jakości produktów oraz wydłużenia okresu użytkowania maszyn i urządzeń.