AN ADVANCED INTERNET BASED DATA REPORTING SYSTEM FOR ON LINE MONITORING OF A HOT ROLLING MILL

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ABSTRACT

In industrial systems with high technological or operational complexity, the role of operators is more and more critical. They need deeper and deeper specialisation and a continuous monitoring of both process and plant to achieve high efficiency and correct working. On the other side, automation and process control systems make available a huge quantity of data, which, if correctly managed, provides useful information on both plant condition and production processes evolution.
Therefore, operator must be provided with information technology tools able to analyse plant/process/product information in a fast and "intelligent" way together with an easy access to such information.
In this paper the real application of an advanced graphic reporting system for on-line monitoring of a hot strip mill is described.
The system is based on Internet-Intranet technology, making simpler the results diffusion, even by remote platforms, once qualified through security criteria. This architecture determines further advantages: just think to the possibility for each user of gaining information, filtered on the basis of the interest level, at the most convenient location (eventually at home), and of communicating actions to be taken.
The system acquires data distributed on networks and analyses them following three main purposes:

- *On-line data reporting concerning plant/process/product.*
- *Data "intelligent elaboration" on all the data coming from the field.*
- *Plant and process data-base and statistical analysis*

Apart from the possibility to display graphics or tables, the "intelligent" elaboration provides final users with historical trends on plant/process/product parameters, diagnostic information about plant components and product quality, guidelines for managing production when some plant devices, sensors, or automation systems are out of service.
The results, made available on Intranet/Internet network, are open to any qualified terminal. This is a noteworthy increase of the advantages deriving from the adoption of the system.

KEYWORD: **intelligent monitoring, diagnosis, Internet, data elaboration, expert system, statistical analysis, object oriented**

1. INTRODUCTION

Software tools specifically studied for complex industrial system management can powerfully help for a correct production process management. Particularly, it has been observed that the availability for operators of tools for measurements analysis and interpretation is much more useful than having new plant and process data.
Furthermore, it has been demonstrated that a high number of sensors in complex plants does not determine a better analysis of the current process. Conversely, very often the overload of information results in lack of process management. When a great amount of data are acquired, the user may be no longer able to perceive those signals that indicate plant and process malfunction or degradation.

The use of software tools able to on-line analyse and elaborate data can help the operator to have a qualitative/quantitative synthesis of the current process. Such software tools should act as an expert of the process, able to understand whether the process itself is running in a *correct*, *acceptable* or *degraded* way. This is achieved through the synoptic reading of data, historical / statistical trends of the operating conditions and diagnostic information.

The tools measure and elaborate in an intelligent way the parameters thus providing: *trend of variables, anomalies diagnosis, statistic analysis of data.* Besides, it is evident that the plant user has more helpful information when the results are provided in a simply and immediate way.

The development of this kind of system, based on an Internet technology, gives further advantages by simplifying the diffusion of results. Just think to the possibility for each user of gaining information, already filtered on the basis of the level of interest, at the most convenient location (eventually at home!), and of communicating the necessary actions in broadcast or single mode.
In the following, an application of an advanced graphic reporting system for the on-line monitoring based on Internet technology is described. This system is applied to the hot strip mill production line at Acciai Speciali Terni, Terni – Italy.

2. THE PROPOSED SOLUTION

The proposed solution is based on ***Monitool***, an expert system for intelligent monitoring and fast diagnosis developed at CSM & SESM laboratories. Monitool has been developed using both innovative informatic tools like knowledge based system, fuzzy logic, neural network, web technology and traditional tools like relational database and mathematical models.
Monitool is a modular system, composed by several modules, the most important of which are:

- the database knowledge, a relational data base containing plant and process knowledge structured on FMEA basis,
- the acquisition module, for acquiring field data from whatever level 1 system
- the diagnosis system, which continuously elaborates plant/process/product data to detect possible degradation in the process management or in product quality
- the statistical module dedicated to statistical analysis and preparation of control charts
- the preventive maintenance module to schedule all the maintenance operations providing also, through the operative procedures module, a guide to execution.

The user interface, designed in close collaboration with final users, provides the results of the various elaboration in a fast and easy way through tables and graphics, leaving also the possibility to further information on the diagnostic reasoning path followed by the system.
Monitool is also characterised by low cost since all the used technologies are commercial software making the final application very cheap compared to traditional Expert System tools.
The functional architecture and the processing data flow of an on-line monitoring system based on Monitool is described in fig. 1

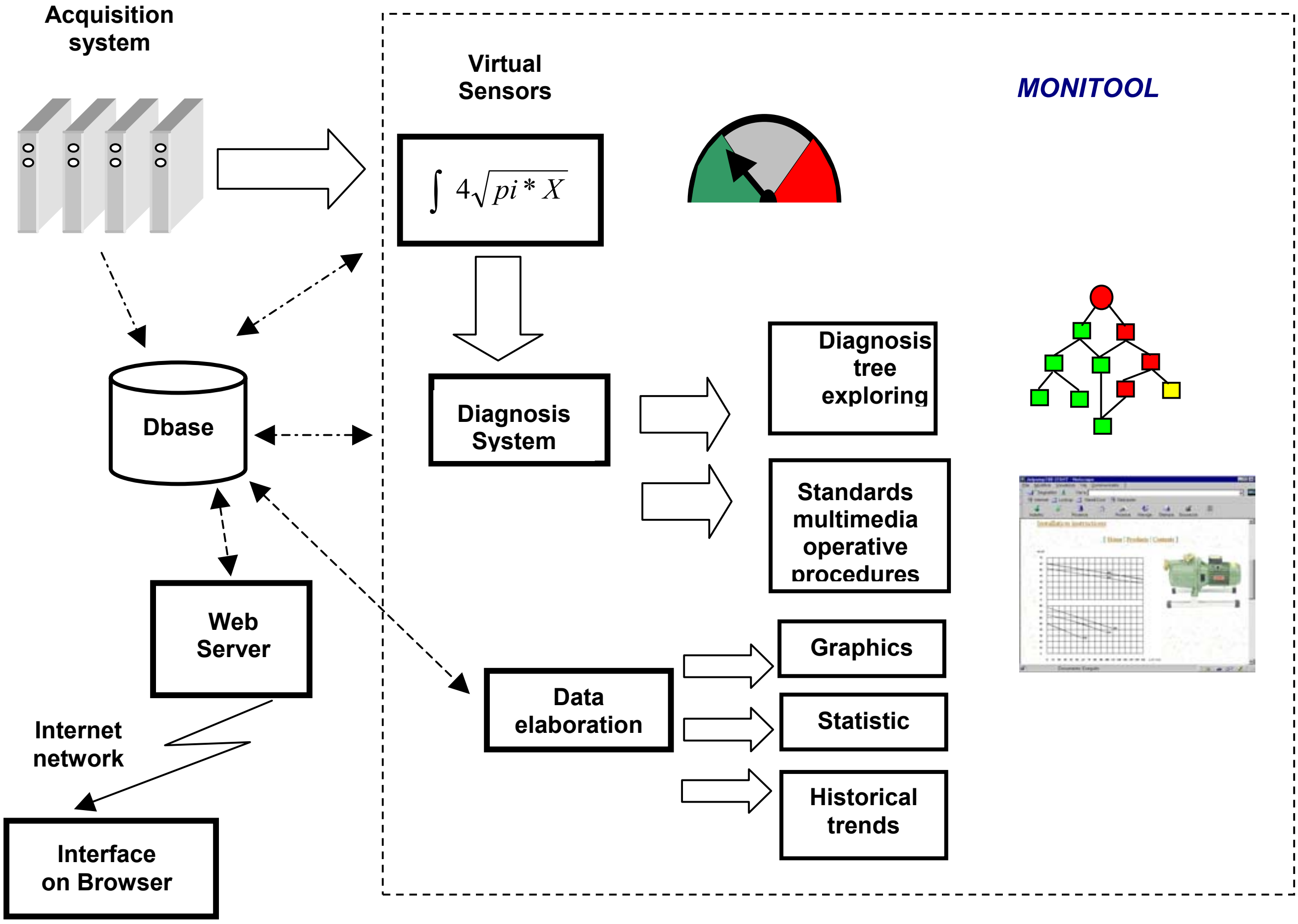

Fig. 1 Functional architecture and processing data flow of Monitool

3. REAL CASE DESCRIPTION

The Monitool application concerns the development of a system for advanced report, diagnosis and process control at the hot strip mill production line of Acciai Speciali Terni.
This plant, represented in fig. 2, can be divided the following areas:

a) Slab re-heating area
b) Finishing mill area
c) Coiler area

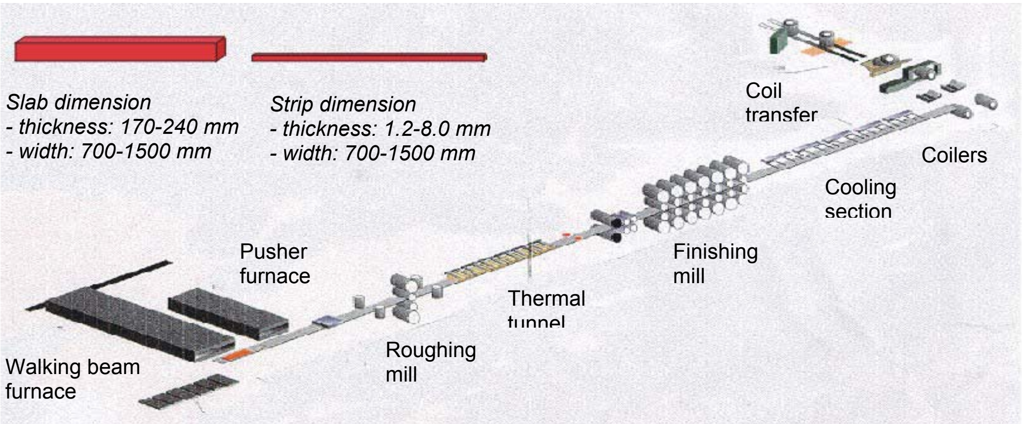

Fig. 2: AST hot strip mill production line (before installation of CSP)

Slab re-heating area
This area includes a walking beam furnace, with a productivity of about 220 ton/h processing stainless steel (AISI 300 and AISI 400), carbon and magnetic steel and a pusher furnace of 110 ton/h processing grain oriented magnetic steel. The reversing roughing mill has a total power of 7,5 Mw and it is fitted with entry and exit edgers for width control.
Finishing mill area
It is composed of a thermal tunnel furnace, with a passive zone and and active zone (fitted with burners, power 6,1 MW), a rotary crop shear for head and tail bar cutting and a finishing mill train. The finishing mill train has seven 4hi stands with a total power of 30 MW; it is also equipped with up-to-date systems to obtain the desired product quality (AGC, work roll bending, work roll shifting, etc.).
Coiler area
This area consist of: RX meter located at finishing mill exit for strip thickness, width and profile, a cooling section with 16 water blades to achieve the desired temperature at coiler entry. Each coiler has a power of 1.0 MW and can manage coils with diameter of 1900 mm maximum.

The whole plant is provided with automation and process control system for on-line calculation and actuation of the set-ups for the various devices.

A CSP (Compact Strip Production) line will be installed at short time at Acciai Speciali Terni: the hot strip mill will be consequently fed by traditional and thin slabs increasing production from 1.300.000 t/year to 1.900.000 t/year during the next three years.

AST plant technicians were interested to an on-line intelligent monitoring system which could guarantee benefits in terms of:

- product quality;
- productivity;
- operating safety;
- availability of specialised personnel;
- diffusion of plant data/information to the subsequent processing lines
- know-how capitalisation;
- portability,
- low cost.

By analysing the above requirements, the plant/process/product knowledge was engineered: the chosen method in this phase was the FMEA (Failure Mode and Effect Analysis).

The analysis started from the basic structure of the system and particularly from those elements of the system for which accurate information about failure mode and its causes were available. By analysing the functional relationships among these elements, it was possible to identify the possibility of propagation of each type of failure and predict its effects on the production performance of the whole plant.

The result of FMEA analysis was a collection of tables which contains, for each element, the failure modes, the causes, the effects and the necessary countermeasures. Moreover, since the developed system uses object oriented programming technologies, failure mode tables are the better tool to define the classes of maintenance. In fact, the generic class for the maintenance will be characterised by failure modes, by causes and by effects on other objects. Once finished the phase of knowledge acquisition and formalisation, the system was implemented on the basis of the users requirements. Particularly the FMEA knowledge was used to fill the database tables.

3.1 Main functionalities

Some of the main functionalities are described hereafter:

- ***Plant global indicator***

It is very important for the operator to know how the plant is working; for this reason a global index (a virtual sensor) has been defined for each plant area. This global index "I" is a sort of weighted mean of partial indexes "i" relevant to main parameters of a given section of the line. They consider the distance between the actual operating point and the optimum operating point. The weights are corrective coefficients which evaluate the importance of the correspondent variable on the global process.
The partial index i and the global index are calculated through the fuzzy logic.
The global index *I* and the partial index *i* range between 0 and 1. When *I* is equal to 1 the relevant variable has a value equal to its optimum value. It is clear that the global index *I* tends to its maximum value when all partial indexes *i*, which contribute to the calculation, have a high value and, consequently, all single variables are near to their optimum value.

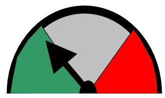

Fig. 3 Plant global indicator

The global index *I* is displayed through a graphic indicator (fig. 3) which allows an easy and rapid identification of the plant area condition.

- ***Online component/process diagnosis***

By analysing plant and process data the system is able to detect anomalies and provide guides for re-establish correct operating conditions. The component diagnosis is related to the main electro-mechanical devices (main drives, converter, transformer,..) while the process diagnosis is dedicated to out tolerances strips in terms of temperature, thickness and width. In this last case, for every produced strip, the related engineering log provided by process control is analysed on-line by the system and if an out of tolerances occurs, causes are highlighted to the final user.
Fig. 4 shows an example of the engineering log analysis concerning an austenitic stainless steel strip. The function is provided also with an "out of tolerances data base" , where, according to the steel grade and to the typology (temperature, thickness or width) is possible to have the list of out of tolerance coils with the relative causes.

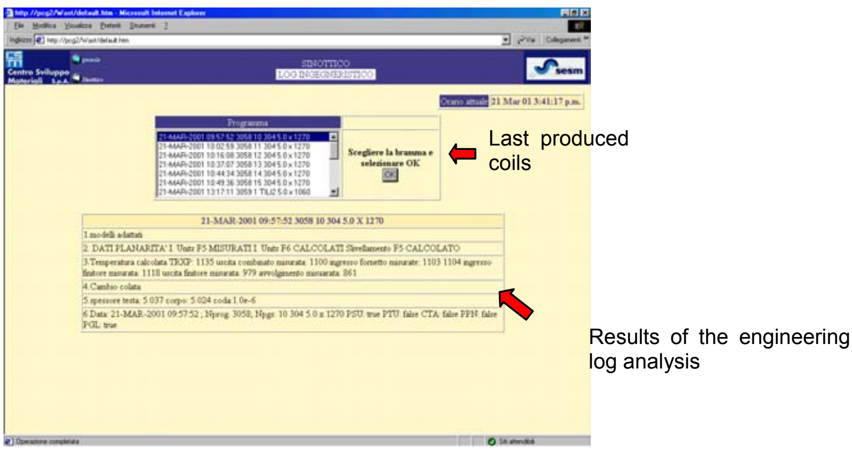

Fig. 4: Engineering log analysis

- **Graphical representation of plant and process data**

For almost all the plant and process variables is possible to recall a graph showing the selected variable (or a group of variables) behaviour versus rolling time (one second acquisition sample) for a selected coil.

As an example fig. 5 shows the graphical representation of the rolling loads for all the stands during the production of the coil. The user is supported by useful functionalities such as the modification of the scale of both the two axis and the enlargement of the area

covered by the graph. It is also possible to display the numerical values of the variables and data can be simply downloaded in Excel mode for special elaboration.

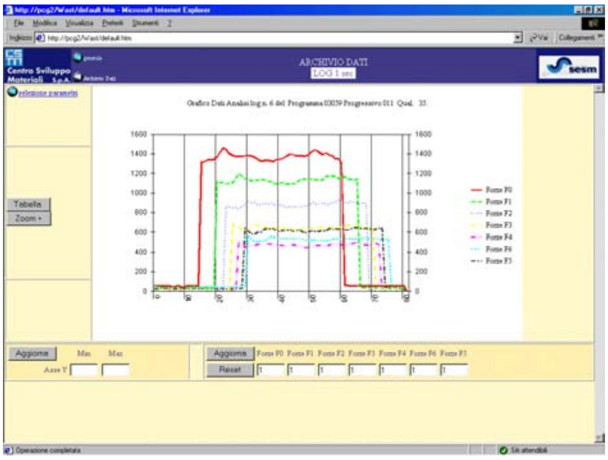

Fig. 5 Example of graphical representation of process data (rolling loads)

- ***Cobble Diagnosis:***

A special function is dedicated to the automatic identification of the causes of a cobble (sudden stoppage during rolling). In this case the system analyses plant and process data form a cobble log (150 ms acquisition time) immediately before and after the plant stoppage. The results of such a complex analysis is a list of causes that determined the cobble, together with guides to re-establish correct working conditions. This function provides also a graphical representation of the main plant and process variables acquired from the cobble log, useful to further detailed analysis by plant technicians.
Fig 6 presents an output of the cobble diagnosis function (a) with the detected causes and the graphical representation (b) of the relevant variables (in this case motor current)

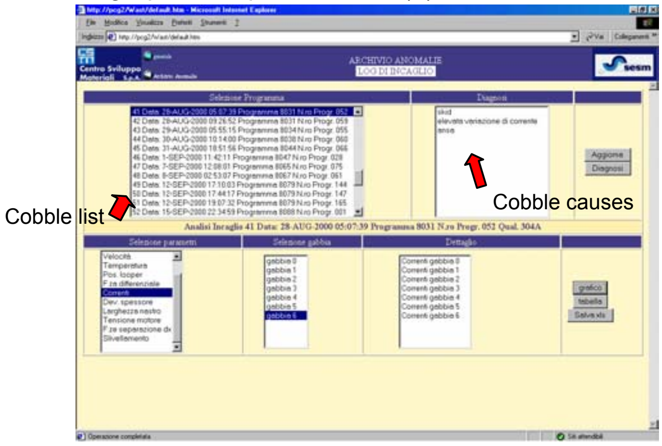

Fig. 6a. List of cobble causes

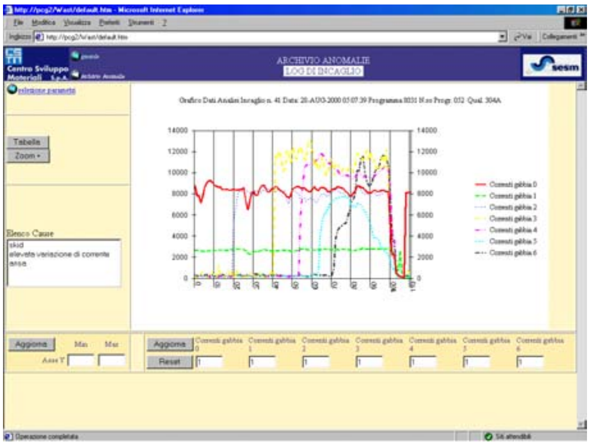

Fig. 6b. Graphical representation of the cobble

- ***Users guide***

The management of technical documentation inherent complex system now is becoming a rule for the industry. The users guide function permits the technical documentation fruition using the network. In case of anomaly, from the diagnostic causes tree it is possible to show to the operator the operative procedure to remove the anomaly causes. The operative procedures are shown through a normal browser and can be text files, sound files or movies.

- ***Control charts***

Crucial plant/process/product parameters are statistically analysed through control charts providing a continuous monitoring of the process capability to stay in the correct range of functioning. The trend analysis allow the operator to eventually perform suitable actions to restore the normal working conditions.
Fig. 7 presents an example of control chart concerning the entry finishing mill temperature of austenitic stainless steel strips.

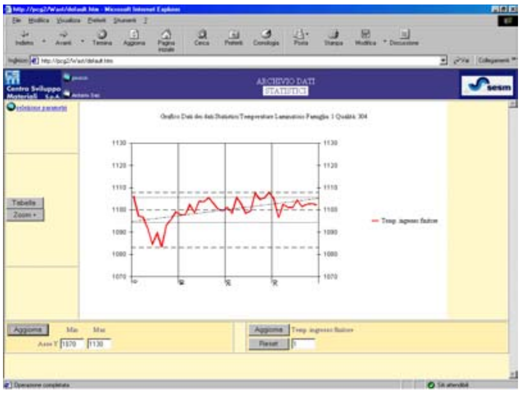

Fig. 7. Example of control chart (entry finishing mill temperature)

- ***Periodic maintenance management***

This function provides periodic maintenance indications. Tables present all the plant operation to be realised, ordered by data. The function is also designed for multimedia maintenance procedure visualisation.

- ***Operating practices database***

A dedicate data base concerns the operating procedures for the whole production of the hot strip mill. This function is particularly useful when process control systems are out of order or when the plant is not fully operative.

By selecting the steel grade, strip thickness and width, this function automatically provides the technicians with the various settings to be used along the process line.
Fig 8 shows as an example the settings of the finishing mill (a) and of the coiler (b) for an austenitic stainless strip.

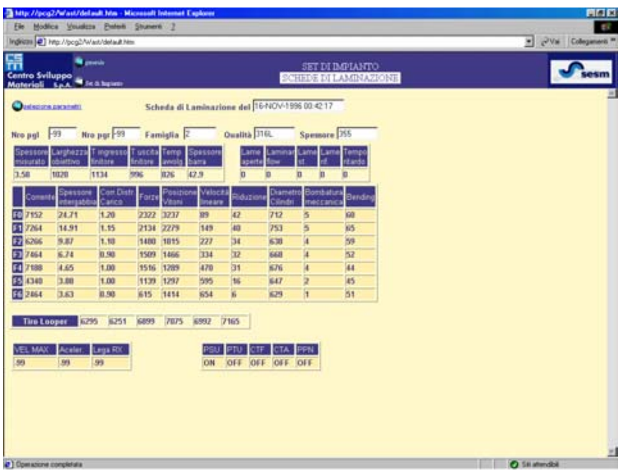

Fig. 8a. Finishing mill settings

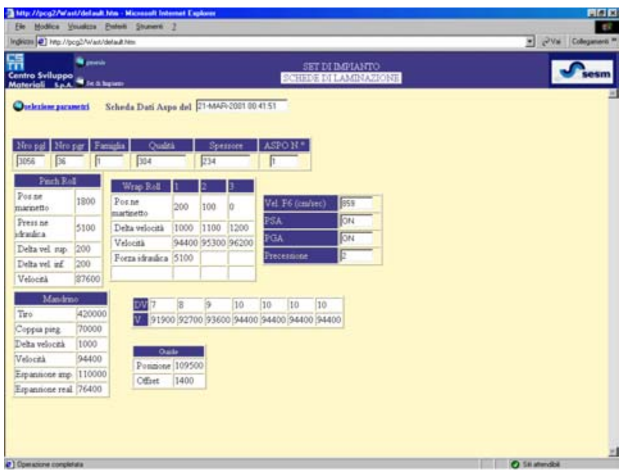

Fig. 8b. Coiler settings

- ***Easy knowledge modification***

The system is fitted for data entry in a very simple way, thus allowing plant experts, in every moment, to modify the plant/process knowledge. Using this data entry the operator can insert/delete/modify plant and process data, anomalies, instance and cause-effect relations. Without any compilation, a lot of updates are performed directly on-line.

4. CONCLUSIONS

The design of a complex modular system for diagnosis, monitoring and data elaboration / visualisation, based on virtual sensors and Internet technology, has brought to a realisation judged very positively by end-users.
In particular, the supply of synthetic and simply accessible information about plant/process/product has been well appreciated and permits a fast and easy identification of malfunction and anomalies, thus permitting to increase hot strip mill productivity
The system is already viewed as a tool for information interchange at different hierarchic and managerial company levels: for this reason the application to other Acciai Speciali Terni plants is foreseen.

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