CONCEPT OF INFORMATIZATION ON THE RAW MATERIALS PROCESSING

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Abstract

In raw materials EU sector a new vision is emerging, founded on leveraging informatization, digitalization, and visualization to utilize process data inside corporate management. The digital factory concept on the raw materials heat treatment offers an integrated approach to enhance products and production processes. The focus and key factor is the integration of the various planning and simulation processes. It's a kind of visual manufacturing that removes the barriers to effective collaboration and efficiency by delivering visual and real process data to all involved throughout the value chain. Business processes are naturally streamlined, and islands of automation are integrated into efficient drivers of customer value. Digital Factory efficiently drives bottom line business growth in areas like material flow management, material request orders, training, marketing, maintenance, logistics and all with measurable economical impact.

Keywords: Virtual factory, digital factory (DF), intelligent production (SMART Factory), Material Flow Management, Information and Communication Technology (ICT)

Introduction

Current European trends supported by globalization, a slight revived economy after recession and technical innovation are changing the way companies produce, distribute and support their products and processes. Globalization has opened up markets and sourcing opportunities for producers everywhere. It has brought new customers and increased sales, along with new competitors, unfamiliar customer expectations, relentless margin pressure, and the complexities of global supply and distribution. In adapting to this borderless market environment, producers have adopted

Lean principles, continuous improvement and other process disciplines aimed at increasing efficiency, improving quality, reducing waste, lowering costs and abbreviating development cycles. To implement these disciplines consistently across distributed operations, manufacturers are aggressively pushing information technologies into non-traditional areas, adding intelligence to every area of their operations and even into the products themselves. By distributing sensors, processors and communication capabilities throughout the enterprise and linking them to an integrated infrastructure, they are creating end-to-end visibility across previously discrete processes. The result is something that it is called the digital factory. These systems are currently widely used in aeronautics and automobile industry. There is an increasing trend of interest in these systems, which is reflected in the amount of successful applications. This tendency is not just a partial alternative; it is a strategic direction, i.e. production informatization. There is an increasing amount of information used during the whole product life cycle that is closely related to product automation. But in the area of raw material processing there is a lack of such solutions (if they exist) and the authors has not come across any Digital Factory conception globally yet. The original idea of a Digital factory on the raw materials heat treatment was initiated six years ago and is governed by the Development and Realization Workplace of Raw material Extraction and Treatment (VRP USZ) department at present. The VRP mission is the research capacities development and improvement in the area of the raw materials extracting and treating within the mining, metallurgical, chemical, and building materials production industry with the aim to ensure a rapid verification of new ideas, proposals and conceptions under laboratory and semi-operating conditions and their transfer into the practice in the form of an innovative projects with the market realizable outputs based on the higher added value. The VRP vision in very close future, as the Cooperation with Practice Centre in the area of raw materials extraction and treatment, is to become the Research Excellence Centre in relevant area and together with its partners to build up an excellent functional cluster to generate high-tech solutions, among other innovative solution based on the processes informatization and its deep knowledge (digital factory) and intelligent production development (SMART Factory). The VRP activities cover three complex areas: research and development, education and entrepreneurships. The portfolio of VRP activities include: research and development of the high-tech technological equipment for grainy materials heat treatment in the thin dynamic layer, optimization programs for rotary and shaft furnaces and for other heat equipment, corporate logistics and management systems design, environmental research program, specific apparatus, equipment and systems research, and complementary services. VRP solves several projects from structural funds, projects of applied research of the Ministry of education SR, governmental science and research projects, basic research projects, industrial cooperation projects, and international projects. Partners are from Technical University (TUKE) workplaces – faculty metallurgy, machinery and BERG faculty, from Komensky university (Bratislava) - faculty of natural sciences, from Economic university (Bratislava) – faculty of corporate economy and, of course from corporate practice area. VRP aims to be the leading centre of excellence within its effected research area in region and a serious partner to European Technology Platform for Sustainable Mineral Resources (ETP SMR) in the future and other European partners from FP7 projects like I^{2}Mine and ERA-MIN.

The concept of digital factory (DF):

The concept goal is to create a digital plant for the area of raw materials processing. The idea of digital plant will consist of main primary processes - technological and service processes and selected corporate supporting processes (auxiliary and control), so it can be utilized for production optimization in all phases of the product lifecycle. Within the proposed concept the digital plant creation will be focused on its utilization for innovations design, scheduling and management of production. The digital factory represents through its ICT integrated environment in which the reality is substitute by virtual computer models. These virtual solutions enable optimal preparation for the practical realization of production. In this environment digital models are dominated. Real company model creation is and the following it's processing is not a simple matter. It requires top prepared people, corporate processes knowledge, needed software and hardware support, but also patience and purposefulness. The structure of such a digital factory concept on the raw materials heat treatment is described on the Fig. 1.

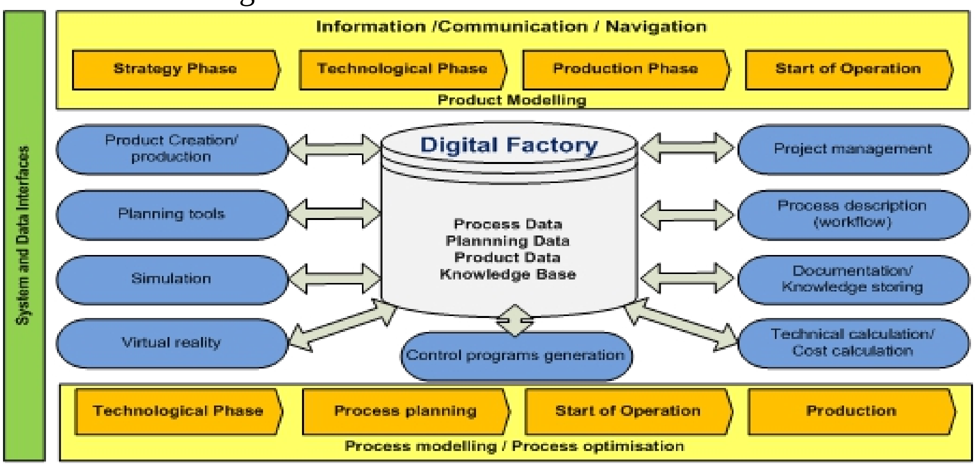

Fig. 1 Digital factory conception on the raw materials heat treatment

This solution will create a basis to build an intelligent production - the „SMART“ plant. It deals with the processes automation that is specified by the transfer of human activities to the area of information technologies. The goal is to increase the portion of information in the performed processes, followed by decreased costs with respect to the capital, material resources and human labor. In order to perform the qualitative changes in the business processes a critical information amount is needed. This information is collected from the respective objects and its surroundings. The purpose of the digital plant utilization is the increase of economic and production parameters mainly by means of cost decrease that are proved during the design and operating activities. The designed project refers mainly to the accomplishments achieved within the following projects:

- progressive logistic systems development and application for production processes innovation,
- functionality verification under operating conditions of integrated thermal apparatus in the process of magnesite caustification and its parameters optimization,
- design and utilization of virtual reality objects of raw materials extraction and treatment,
- integrated thermal apparatus for economic and ecologic raw materials effective treatment research and development,
- high-tech and new technologies for non-metallic materials extraction and treatment,
- digital factory for the raw materials heat treatment,
- Research Excellence Centre on Earth's sources extracting and treatment,
- Slovak innovation-technology platform on sustainable mineral resources.

The entire solution goal is to create a digital plant conceptual model and its components – corporate processes partial models; its verification in semi-operating (integrated thermal apparatus implementation in ATIM Kosice) and operating module (rotary furnace No. 2 implementation in SMZ Jelšava, Inc.). The aim is to create an effective system for a complex and system planning, designing, verification and preliminary improvement of all significant structures, processes and resources of an actual plant in relation to its products. The proposed solution is the first complex solution in the area of raw materials processing. By its verification in operating conditions there will be completed a pilot application. The authors have not come across any Digital Factory conception globally yet in the area of raw materials processing.

The solution output will be a designed structure of selected digital factory pilot cross process and its basic components, which represents key virtual technologic aggregates. Within the pilot solution verifying will be used the Integrated Thermal Apparatus ITA (SMART device) – the unique experimental technology of grainy materials heat treatment which has been developed also by VRP/BERG Faculty of Technical University of Kosice. The pilot concept solution principle based on re-usable components will be asserted also in next process and devices solutions within the whole corporate logistics chain. The concept will be used mainly as support of operating activities of operators and technologists. It can also be used as a training apparatus for the education of operators, innovation employees and students. Currently, very often the ultimate objective of the digital plant conception is the usage of virtual reality tools. However, the global development moves ahead. The conception covers the whole product lifecycle management cycle (PLM), since the digitalization integrates the activities comprehensively – from the design up to recycling.

Informatization and digitalization of processes:

Digital plant is an expression that is used to designate a virtual (digital) image of an actual plant. It represents an environment that is integrated by information and communication technologies to an optimum solution on the level of development, design, planning and performance of production processes. Virtual operations make it possible, even before the actual realization, to verify the conflict situations, propose optimal solutions and optimize the already existing solutions. There is a huge amount of information accrued during the whole production control life-cycle – we talk about process informatization. Current digital technologies add intelligence to every stage of the product lifecycle. These new embedded technologies are transforming manufacturing today. The innovative solutions are core elements of this transformation. By capturing raw data from distributed events and delivering actionable information to distributed decision points, these solutions create end-to-end visibility to enable lean operations.

In the digital factory each stage in the product lifecycle is transparent to every other. Information flows automatically between systems and processes, constrained only by policy. Real-time information and actionable insight replace latency and uncertainty, eliminating the most common sources of waste and inefficiency, setting the stage for automation. It's a transformational development made possible by open, standards-based ICT infrastructures that share several core features:

- a scalable network and hardware infrastructure based on high-performance platforms,
- an integrated application and data management software,

- a service-oriented infrastructure design that delivers software and data as services, organizes hardware as virtualized resources and offers services that cross firewalls and company borders,
- solutions that keep the enterprise securely and continuously connected to its material resources, production systems, employees, partners and products through a combination of local and wide-area broadband technologies.

Digitalization enables to increase the quality and at the same time expedite all works related to production preparation, primary production and following services in the total product life cycle. The digitalization was used first in the design – technological systems (CAD/CAM) and then in the enterprise planning and control systems (MRP, ERP). Currently it is being used also in the design of production base that is basically a bridge between two already digitalized areas of production preparation and corporate information systems. It is an extremely complex area, since in the production there is concentrated a huge amount of diverse information - order management data, sub-supplies purchasing, logistic processes and information of production technological preparation. By the influence of digitalization the production process is more tied up.

Modeling and optimization of the processes:

In general, the digital factory concept realization is driven by specific determinateness of company. The digital factory term is a name for extensive network of digital models and methods. Its aim is a detailed planning, realization, control and optimization and all important processes and resources continuous improvement within a company, together with a real process and product interconnection. The basic principle of the digital factory is model creation for the digital plant environment, corporate processes optimization and its real functionality in operation. The main technique, which uses digital factory solutions, is the computer-aided simulation. The exploitation of this is in various life areas and for the production systems design and reorganization, as well. The examples could be:

- various simulations (corporate processes, production, material flow, intra-corporate logistics and so on),
- visualizations: 3D, 4D animations (time dimension), 5D (costs, sources and completion state dimension),
- economic modeling (scheduling, cost analysis, time analysis, balance control, production disposition),
- real time predicate control and monitoring.

The thread of all process modeling and optimization is the virtual factory life cycle support till routine operation of real production process. The digital factory approach using simulation for operative production planning and control extends the one for plant design and optimization. The following objectives shall be reached:

- improve collaboration between production planning and execution,
- improve process control and reduce quality problems,
- adjust schedules and production processes in real time,
- deliver customer orders accurately (with good quality) on time,
- improve quality and reduce the cost of errors,
- reduce inventory, work in progress and scrap costs,
- improve the visibility of the production processes for supply chain planning.

This simulation based approach requires a steady feedback loop from the factory floor in order to update general data, model structure and model parameters with the actual situation from the plant. To deliver accurate results a model has always to be initialized with the actual WIP (work-in-process) and actual status of the resources.

New informatization architecture:

The digital factory concept requires the integration of design, engineering, planning, simulation, visualization, communication and control tools on all planning and factory levels. Each of the particular tools requires specific algorithms and specific data. The digital factory approach aims at using common data for all applications on different modeling levels in order to enable collaboration with virtual models for different purposes and different levels of detail. Therefore an open architecture is an important feature of the digital factory concept. For the integration of suppliers into development and supplier networks, open interfaces need to be developed with the exclusion of the proprietary ones. Open interfaces and interoperability are the key factors for implementing digital manufacturing concepts. Conversely, the lack of open standards within a digital factory environment creates significant integration and implementation effort for customers trying to deploy digital manufacturing.

1. **Open Plant Backbone** - an open plant backbone is a scalable digital corporate backbone to transform the process of digital manufacturing. It provides an open platform for the integration of independent software solutions that seamlessly interoperate with one another in a digital factory environment. Open XML technology gives a platform for factory wide data exchange;

2. **Plant Data Management** - manufacturing planning and execution involves a variety of complex and interconnected activities from part and assembly process planning to plant design, ergonomic analysis and quality planning. Information and data from product design, manufacturing engineering and production management have to be transparently handled for all applications in the digital factory environment;
3. **Plant Process Management** - plant process management tools establish the relationships and associations between product, process, plants and resources, which are the basis for the creation of a manufacturing plan. The overall goal is to allow all users to quickly assess the impact of their decisions on product, process, plant and resource requirements. Software tools are required for simulation, workflow, change management, integrated visualization, and configuration management as well as integration tools;
4. **Supply Chain Management –** solutions, which let manufacturers monitor supply pipelines in real time, replacing inventory safety stocks with accurate, up-to-the-minute information on material availability, location and delivery schedules. RFID technology (Radio Frequency Identification) and its tags on pallets and shipping containers, in raw material combined with scanners or readers on warehouse loading docks, storage racks, conveyor belts, aggregates, reservoirs or technological bridges track inbound and outbound shipments and monitor current inventory levels;
5. **Monitoring, product and production tracking tools** - capture and communicate real-time manufacturing data automatically from the shop floor and give a real--time view of the production environment. These tools provide the ability to view the data from several different perspectives, such as by product, work in process, route, tools, equipment, material, and labor. This ability helps to meet the requirements of diverse users in the organization. The monitoring, product and production tracking complement the ERP systems by capturing manufacturing data to a level of detail and precision that ERP systems cannot match. The resulting information allows for the rapid identification of problem causes and fast reaction to limit their impact;
6. **Linking the business system** - in a digital factory environment the operative production planning and control also require a link to the enterprise resource planning level ERP. The ERP connectors shall ensure such a interconnections, which can provide data import and export facilities for routes, consumptions, equipment and users and at the same time connect monitoring systems HMI, SCADA, and product management systems to the business ERP-systems. Their main goal is to update the ERP with real-time floor data.

New mine wide production system design:

Production lifecycle management

Designing a production lifecycle management (PLM) concept covers an integrated approach to enhance the product and production engineering processes. Within this concept the simulation is one of the key technologies and can be applied in virtual models on various planning levels and stages to improve the product and process planning. In the first phase of such a PLM concept the focus should be on integrated product engineering. In the case of new concept for sustainable row materials production it means integration and exploitation of processes in exploration, extraction, materials processing and recycling. For application of this type of integrated production engineering are many only a few tools already available in the market. The second phase includes the plant design and optimization in a collaborative environment concurrently with the product engineering. Couples of tools are available for specific purposes. However, there is still a lack of open integration possibilities between tools, planning levels, and optimization on a multi criteria level. The third phase of a PLM concept focuses on operative production planning and control down to the factory floor. This approach requires an extremely high effort and future research is needed to develop methods and tools for this approach.

Future work should focus on open standard interfaces available for integration of various tools from different software vendors into the digital factory system architecture. The realization of the digital factory concept needs various application components such as design and planning software, GIS, visualization or simulation tools [9]. All these have to function closely together. A single application system cannot cover the complete range of required functionalities; this can be achieved with the use of specialized software systems and their integration. Therefore, the requirements for each such a system include:

- networked system and data architecture with integration of processes and product development process,
- open system architecture with standard interfaces,
- modular architecture for expandability,
- efficient data management,
- consistent 3D and 4D-visualisation platform,
- advanced documentation and content management systems (DMS and CMS),
- knowledge management approach involving to the system.

The mine-wide production system concept or architecture in raw materials area requires the integration of design, engineering, planning, simulation, visualization, communication and control tools on all planning and factory levels. Each of the particular tools requires specific algorithms and specific data. The mine-wide production system approach aims at using common data for all applications on different modeling levels in order to enable collaboration with virtual models for different purposes and different levels of detail. Therefore an open architecture is an important feature of the mine-wide production system concept. In practical use a mine-wide production system applications require the use of diverse SW components. For the integration of suppliers into development and supplier networks, open interfaces need to be developed with the exclusion of the proprietary ones. Open interfaces and interoperability are the key factors for implementing digital manufacturing concepts. Conversely, the lack of open standards within mine-wide production system environment creates significant integration and implementation effort for customers trying to deploy a production lifecycle management.

Comprehensive platforms for production-relevant knowledge

The future concept and architecture of production-relevant knowledge and generally within mine-wide production system design of raw materials area, addresses the production lifecycle management through interoperable models, engineering platforms, computer-assisted product, process development and analysis, virtual prototyping and testing environments to reduce the need for physical mock-ups. Generally it covers four main areas to develop:

- comprehensive engineering platforms - that enable cross-disciplinary information sharing, workflow integration and the capture of production-relevant knowledge (e.g. manufacturing or treatment process knowledge embedded in the models and the engineering tools), supporting the reuse of knowledge across stakeholders and the product lifecycle (e.g. from use to design). The product lifecycle in raw material processing area should support the focus areas covering the whole lifecycle - from exploration and extraction until reuse and recycling. It should reach processes from the exploration, the identification of valuable mineral resources to the sellable products. All steps of the supply and production chain for mineral resources should be underlined with societal issues of various kinds;
- user-intuitive tools for simulation and virtual prototyping with forward and backward compatibility – that enable using of finer digital models to increase accuracy and integrating aspects such as functionality, forming, assembly. The work should also aim at interoperable models enabling the use of various aspects of design and engineering, model auto-generation and robustness (e.g. automated meshing and optimization) as well as the use of CAD, CAE, Virtual Reality, volume, fluid, structure, polygonal and process models in the various production stages. The future is the

adaptation to next-generation of high-performance multi-core computing clusters (cloud computing);

- modeling and simulation tools of full (holistic) complex products and processes – that enable using of multi-physics and support for tolerance changes in the models. The very important is the digital modeling and simulation of product and production process behavior, e.g., regarding material properties from micro to macro scale (from the atomic level upwards);
- costs-to-benefit monitoring offers the cost-to-benefit evaluation and monitoring of cost aspects accomplished by organizational, logistics and technology changes. Such a system should provide dynamic economic comparison of real data of the present state compared to data after technologic logistics optimization. Mining companies would benefit from such a cost monitoring system taking into account their specific production and financial goals. Overall costs will be reduced to enable exploiting lower grades, extending life of mine and overall profitability. The results are monetary statements to mine life cycle costs, mining costs, mining risks and performance of mining performance units. The benefits from cost monitoring are the following:
- the holistic and synchronous consideration of costs, risks and performance already during the strategic planning,
- the analysis and evaluation of technique and economic planning alternatives as well as the utilization analysis of multiple planning scenarios.

Conclusion

A presented facts are supported by own original research used in some structural projects and international projects which promote the above general presented facts. Our workplace is established in the European structures farthest from the Slovak R & D organizations. We are a member of European Technology Platform for Sustainable Mineral Resources (ETP SMR), where we are a member of High-Level Group and one of the founders of new platform. We are the member of the largest European research project - FP7 Program/Project I^{2}Mine: Innovative technologies and concepts for intelligent deep mine of the future. We are the member of another FP7 project: ERA-MIN dealing with building a European research network in industrial raw materials and of course this HU-SK workshop, which is part the cross-border co-operation programmer HU-SK: Virtual reality laboratory for factory of the future. Our workplace is a proactive member of the consortia for the new European Innovation Partnerships: European Innovation Partnership (EIP) on Raw Materials and KIC (Knowledge Innovation Community). The VRP potential results are the following challenges and projects in which VRP is an important part: ESEE Initiative for Knowledge Innovation Communities on Raw materials for Eastern and South-Eastern Europe established with Montanuniversity of Leoben, Magnesium Chloride Commitment with K + S and Esco-Salt, possible continuation of currently running FP7 I^2Mine project titled Commitment I^2Mine – 2 and continuation of the pilot implementation of I^2Mine project titled Commitment I^2Mine-pilot.

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