CONCEPT INDUSTRY 4.0 IN METALLURGICAL ENGINEERING

FRISCHER Robert, GRYCZ Ondřej, HLAVICA Robert

VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU
robert.frischer@vsb.cz

Abstract

Industry 4.0 Concept is current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, Big Data, cloud computing and more. Industry 4.0 creates what has been called a "Smart Factory design". The term Industry 4.0 it selves means the fourth industrial revolution. It incorporates emerging technical advancement to improve industry so as to deal with some global challenges. The aim of this paper is to describe the incoming changes, which must be made in short time in metallurgical industry to be compatible with “other world” systems. The Industry 4.0 implements new approaches to human resource management, automation, data networks interconnections, data storage, data mining and much more. The changes has already started, but implementations and human stance to new ideas will take decades.

Keywords: Industry 4.0, metallurgy, data processing, data mining, model, continuous steel casting

1. INTRODUCTION

The concept Industry 4.0 is a common expression, we are hearing every day, everywhere in every technical area. For why? What does it stand for? The fast, global, simple explanation is, that it means fourth technological revolution. The steam, Ford’s assembly line, industry automation and digitalization and smart factory design. This is not so simple. The concept Industry 4.0 originate from natural evolvement. The transition from previous “industrial revolution” isn’t sharp as it was in the past. Some (many) factories and production plants around a world has implemented modern technologies and approaches to its production chain. The main indicator of Industry 4.0 is digitalization. There is a force to production chain to be more optimized, to be interconnected each production devices (not only devices, but also systems) and product itself has all necessary data to its production. Also is paid attention to increase production devices (systems) lifetime throw the maintenance management. For Industry 4.0 is typical, that originate digital models of devices and processes to obtain more clear and transparent view to the processes. Cyber physical space includes production organization and optimization, communication between lifeless objects, system agents dispose of advanced artificial intelligent. As a trend originate so called digital twins, which are physical object and its digital copies. This feature can be seen commonly in automotive area. Each produced entity has its digital copy, which writes any service mission, sensor state, mileage, surrounding conditions and more. It is obvious, that all of mentioned features requires stabile, fast and robust data interconnection. [1][2]

Also it is generating huge amount of data, which has to be stored somewhere. Demands on transmission lines and communication protocols are enormous. Huge data sets are not readable, so arise new data mining methods and algorithms. For example, the SAP company spend more than €200 million into cloud infrastructure to be able to store operational data from many factories.

These all features (**Figure 1**) cannot be implemented directly to existing plants and production chains. Each technological area is unique and has its own advantages and weaknesses. We are focusing on metallurgical companies and we are also trying to implement new methods to meet new standards. [3]

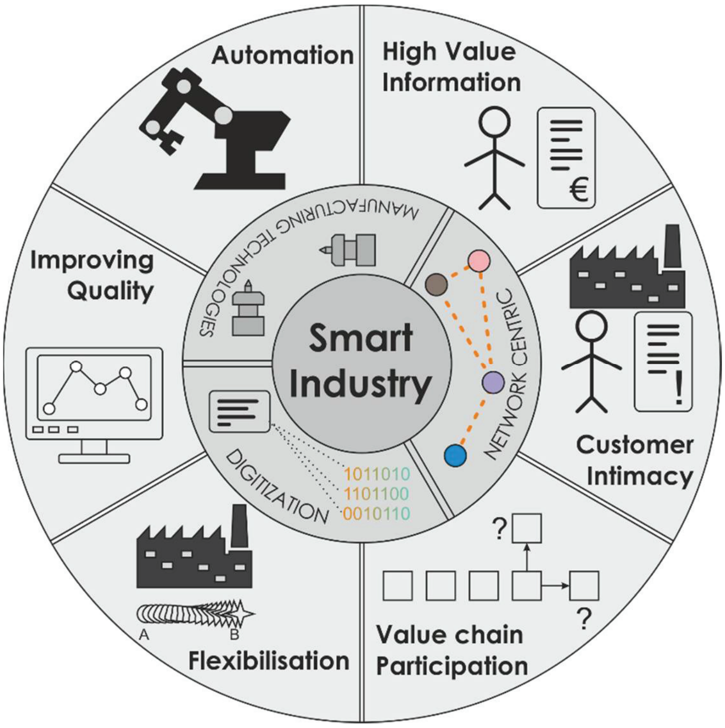

Figure 1 Concept Industry 4.0 in blocks

2. PROBLEM DEFINITION

Our team is developing a digital model of the mold as a part of continuous steel casting device. The digital model can be implement to production managing process and then act as a digital twin of real object. This approach has many advantages. For the first, if it would be accurate enough, you can minimize service actions, because you know the actual state of the device. This is unfortunately impossible. Not the model, but its precision. It is impossible to cover up all of the external condition and predict all random (stochastic) processes, which can impact real object. So the solution is to make standard precision model with maximum information we know (type of casting steel, amount of casted steel, temperature of steel, ambient temperature and so on) and other data replace by feedback from sensors. This combined model is much simpler, more effective, and less complex and can be implemented on standard computer machine. [4]

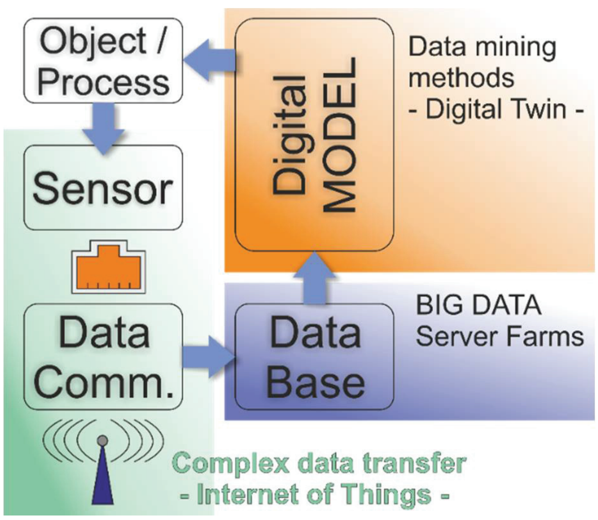

Figure 2 Digital model cover physical hardware and software implementation

As it was mentioned before, new concept (**Figure 2**) require more sensors interconnected between each other and of course, interconnected into database. Interconnection itself is very complex, especially in metallurgical premises. Essentially, the inner construction of structures are made from steel and concrete, which is basically RF (Radio frequency -WiFi etc.) proof. Also there are common high current power grids, which generates additional electromagnetic interference (EMI) and further disallow data communication. [5]

Gathered data are stored in huge server farms, which are not (usually) located in home company. Especially last statement is significant milestone, because most companies protect its own data as a know-how. But investment millions of Euro into server infrastructure is mostly unreal, or can't be accepted because of realization time. It is hard to imagine amount of stored data every day. If we want precise and relevant information about process or object (continuous steel casting device), it is needed to implement hundreds of small sensors around the machine. This sensor group can produce more than 50 GB of data per day which is more than 18 TB per year. And this is only one process, one production premise. [6]

3. USAGE OF ADVANCED DATA PROCESSING IN DATAMINING

The goal of our development was creation of algorithm, which can tell us, if operating continuous steel casting device working correctly and no threats is in short period of time. The continuous steel casting device is complex device, which can cool down liquid steel in mold to state, it has solid outer envelope. The blank surface can has 1200 °C and inner core is still liquid. Then the blank is cool down by secondary cooling stage, which is basically water mist fed to the blank surface. The mold's surface is very straining by abrasion. It is necessary to know how many tons was casted and what steel brand that was. If the abrasion is too intense, the mold surface has scratches. These surface faults are the cause of worsen blank quality, in other words, financial loss.

The precise, theoretical model can say, when the scratches has that level, that cannot be accepted because of blank quality. But in reality, only casted tons are significant quantity, which says "it's enough, stop casting and perform maintenance". This behavior is absolutely inefficient from all points of view.

We implemented a few sensors, which monitor vibrations of mold when casting (**Figure 3**). The data are stored in high sampling rate (about 100 k samples per second (kSps)). The principle is, that mold affected by scratches has another "sound", than the good one. So the standard model is now extend by feedback from algorithm working over the stored data.

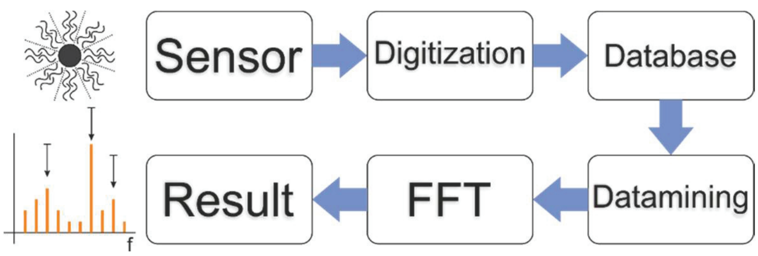

Figure 3 Standard model enhanced by advanced data processing algorithm

The goal of the test was determine, if the damaged mold surface emit some specific sound, respectively frequencies. The "sound" is derived from vibration data by Fourier transform, respectively Fast Fourier transform (FFT). After extraction of individual records, FFT is applied to data set and the results are saved into matrix. Each individual line of matrix corresponds to values of specific time. The calculation is composed of signal division into M segments which may partially overlap. From each segment is calculated amplitude spectrum. Then, the average value is calculated for all the segments. This average value is then used to remove deviation used by Windows. This method is called the Welch's method of modified periodograms. Simplified schema of calculation is shown on the (**Figure 4**). [7]

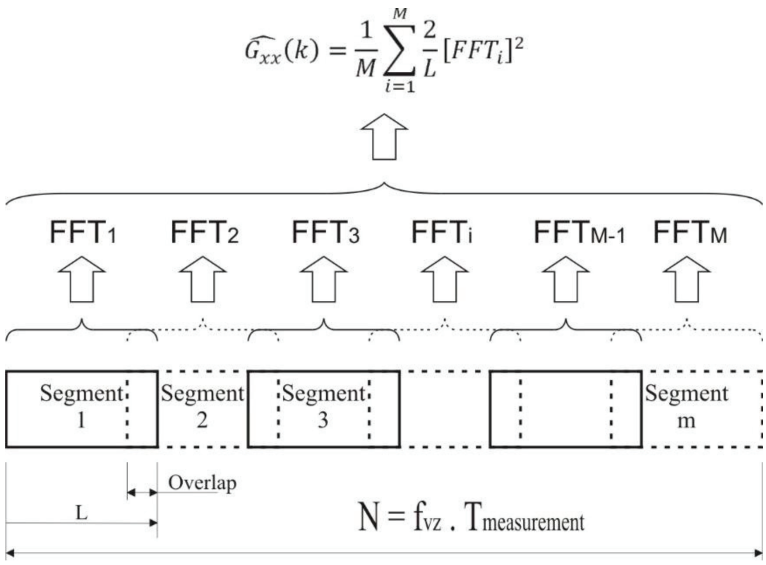

Figure 4 Welch's method of modified periodograms used in digital signal processing algorithm

Resulting power spectrum density (PSD) is then examined. Some vibrations (means its frequency) are significant, the other are meaningless. It is hard to say which one belong to certain process e.g. oscillations, water pump, cutting machine and so on. But it is no so important, if we know the sound of "good one" mold, or just renewed one. This one can be used to compare the sound during further operation and determine the changes. [8][9]

In first attempt we made 120 min vibrations record. In words of data storage we are talking about 4 GB of data space used. Data processing itself take about 30 min. the result is the picture, where on X axis is frequency and Y axis represent time of the process. Each line is then a single spectrum (PSD) calculated from the data set.

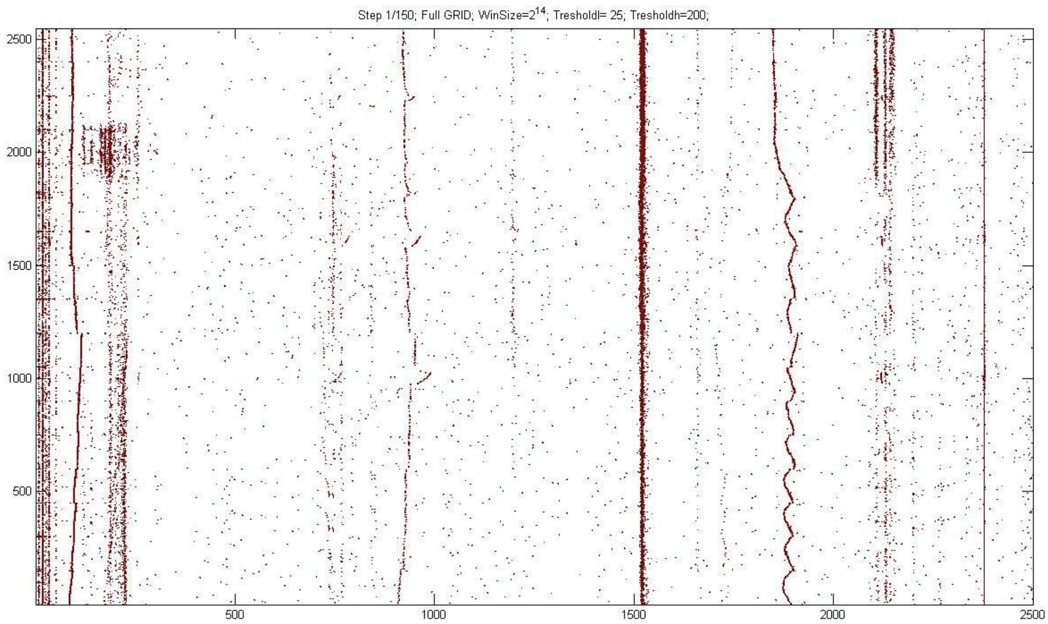

Figure 5 Power spectrum density of the process throw time

As we can see on (**Figure 5**), there are several significant noise sources, when casting steel. Some of them are stable, the other slightly change over the time. For better, transparent work with obtained data is necessary to modify them (means PSD). We are proposed a specific filter, which can detect a remove most fault fragments or remnants. The filter passes data (PSD) and search specific spectrum frequency, or frequency set. The most important to subsequent analysis are positions of these frequencies, respectively theirs value. The remnants are dots presented in the figure. To name all of the visible vibrations, respectively name all of the noise sources we need absolutely precise model of continuous steel casting device. To name the most significant noise sources it is needed only time form observations. Then we can name specific curve and say “the mold is severely damaged, perform maintenance”.

4. CONCLUSION

As it was mentioned in abstract, the Industry 4.0 cannot be implemented in short time. There are many technical segments, which has to cooperate together. Especially in metallurgical premises its implementation will not be easy and will demand great investments. As many specialists predict, there is no other way. The concept was set. This paper describe one vision, which has first tests passed. According to concept we are trying to improve standard mold model as a part of continuous steel casting device. Suggested improvement can be important element, when we consider some maintenance actions. It is only a small part of the whole picture, but important.

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