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# The effectively combined systems for intelligent production

## Efektywne łączenie systemów podstawą inteligentnej produkcji

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The paper illuminates the latest software and hardware concepts introduced to transform traditional manufacturing environments into new, flexible, smart, digital and Industrial 4.0 compliant factories. The technical innovations in the field of robots, programmable control, automation components which were presented at the EMO 2017.

**KEYWORDS:** Industry 4.0, control, process supervision, machine tools monitoring, smart factory, IoT, EMO 2017

Digital technologies are rapidly entering not only the industry, but all economic activities and social relations. As it seems, this is currently the only way of development. To maintain and improve competitiveness, enterprises need to intensively introduce digitization concepts into manufacturing environments. The immediate goal is to effectively connect the largest number of people and technological machines with network systems in order to be able to collect all relevant production information in detail and analyze it in a real time and more efficiently and transparently implement the production processes.

This idea was the keynote of the world trade fair of the EMO 2017 machine industry organized on September 18–23 in Hanover. Over 2,200 exhibitors from around the world presented their products in over a dozen exhibition halls. 42 countries were represented and the number of visitors exceeded 130,000 – over 50% of them were foreign guests. The reputation of the EMO trade fairs in the industrial environment is evidenced by estimated value of the contracts signed – at least EUR 8 billion. In addition to traditional presentations taking place at the stands, many scientific and technical conferences and popularizing lectures were organized [1].

### Not only "clouds"

The basic element guaranteeing the effective introduction of the digital factory concept is the implementation of systems that support the Internet of Things (IoT), the Industrial Internet of Things (IIoT), and the Internet of Autonomous Things (IoAT). Complex and multilayer structure of sensors collecting detailed data on all elements, systems, controllers, objects and devices is a very attractive vision of full monitoring of production [2]. It is a key element providing information to cloud systems, in which advanced

computing (cloud computing) takes place. According to the predictions of researchers from the Gartner Institute (USA), the number of devices of this type in 2020 will exceed 21 billion [3]. However, IoT also carries serious risks that can affect the efficiency and usefulness of calculations in the clouds. Following can be included:

- **Delay** – with large and often variable amount of data needed in finite communication systems, latencies will be created. They will be unstable (fluctuating), difficult to mathematically grasp, which may cause unstable behavior of monitoring systems. In extreme cases, the connection may be broken off temporarily, and even data may be lost [4].
- **Bandwidth** – a huge amount of data generated by sensors (for example, a jet engine monitoring system is able to produce 10 TB of information within 30 minutes) will require transmission buses with very high capacity – and hence – specialized, complex, energy-intensive and expensive. Necessary in these cases transmission structures will be a significant load (weight, assembly, maintenance) for monitored devices.
- **Security** – transmission of information between their source (IIoT) and destination, where they will be processed (cloud), will require taking actions related to security and confidentiality of transmitting sensitive data. Unfortunately, the recently growing number of effective cyber attacks on traditional networks raises concern about the effectiveness of available securities, especially as in the case of IoT, the negative effects of unauthorized access will affect a large number of important devices and facilities.

These threats result from the need to perform computational tasks in the clouds (strong processors and extensive algorithms). Two solutions are proposed, consisting in shifting "digital intelligence" and "computing power" from the cloud towards sources of information, i.e. sensors:

- **Edge computing** involves installing software for local data processing from IIoT devices (sensors, motors, relays, etc.) directly in PLC, PAC or CNC controllers. The basic calculations (e.g. fast Fourier transform in the case of vibration monitoring, determination of extreme signal values) are implemented in many places on the machine tool, and advanced reports in the clouds are sent, containing the selected data. According to the IDC report, in 2018 it is expected that over 40% of numerical operations related to the use of IoT data will be performed on local devices located "on the edge" of the network [5].
- **Fog computing (mist processing)** – because the key transmission devices from the point of view of the Internet

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are "jumper points", i.e. routers and switches, hence local computing centers should be placed there. This requires the use of specialized devices at network nodes, to which direct information from IoT is provided. Such data (e.g. collected in the controller in the form of an OPC structure/database) will be pre-processed (filtered, analyzed, combined), and the obtained results will be made available to cloud systems in the form of the http or MQTT protocol. Many nodal routers will create "fog" that is not an alternative to clouds [6]. Due to this, data transfer from devices to cloud systems will be significantly simplified. Cisco is already offering the first hardware solutions based on Linux applications installed in the IOS (Internetworking Operating System) environment.

### Sandvik Coromant

According to Sandvik Coromant, a common phenomenon in industry is the active monitoring of machine tools and technological machines. The next step is the introduction of precise monitoring of the cutting process itself. Does cutting edge/cutting wear progress in a gradual and controlled manner, is the cutting process not too fast or too slow or does it differ from the assumed parameters and indicators? – these are questions bothering every technologist. The company offers innovative tools from the Silent Tools™+ line, still in the prototype phase (fig. 1). A version for rotary tools is also foreseen (fig. 1, left of the photo).

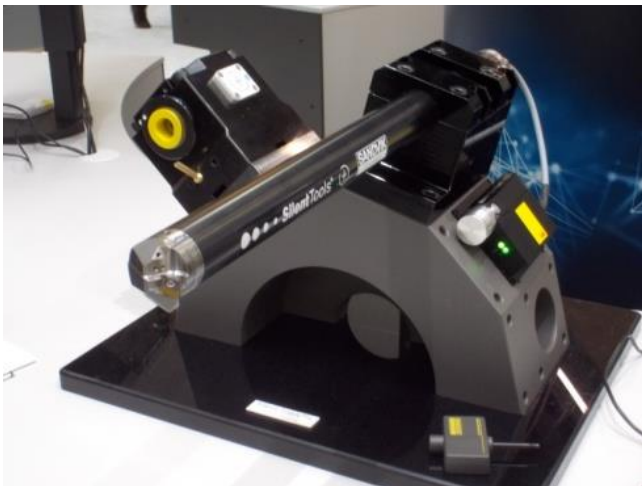


Fig. 1. Silent Tools™+ tools



Fig. 2. CoroPlus program screen (source: www.sandvik.coromant.com)

The concept consists in the integration of the connection into the adapter/frame to enable the collection and transmission of data (in real time) directly from the cutting zone. Measured values are: vibrations, deflection of the shaft and temperature of the damping module. In addition, the built-in angular position sensor allows the operator to position the tool in the recommended position. The measured values are transferred to the CoroPlus software,

where they are presented in the form of numerical data and charts facilitating analysis (fig. 2).

For example: the temperature of the damping module displayed on the control panel allows the operator to monitor the situation and prevent damage to the module that could be caused by too high temperature. A wireless connection in the Bluetooth standard (2.4 GHz) is used for data transmission outside of the machining zone. Power sources are rechargeable batteries.

### Doosan

Doosan company defines three goals of IT activities: cost reduction, increase of product quality, production timeliness. To achieve them, activities are carried out in parallel in four areas:

- automation (independence of control systems, system engineering, remote monitoring),
- intelligent generation (anticipation of problems and failures, safety, anticipation and avoidance of dangerous states),
- efficiency (multifunctionality, acceleration, interaction),
- optimization (energy, precision of operation, work cycle, programming).

The digital/clever factory of the future will be based on the continuous implementation of the four basic activities presented in fig. 3.

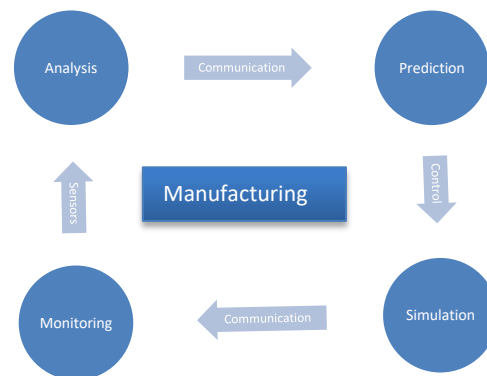


Fig. 3. Information control (source: www.doosan.com)

The company presented the concept of a systematic approach to modern, information control of production carried out in intelligent factories. The individual stages of activities are mutually dependent and practically permeate (simulation, monitoring, analysis, prediction). This type of data processing structure is only possible if there are adequate means of communication ensuring effective information flow.

### Fanuc

The company in its activities strongly supports the IoT concept and artificial intelligence AI (artificial intelligence). Understanding the multitude of data exchange standards existing on the market, forms of their acquisition and management, which occur in machine tools and manufacturing systems, it proposes a new, universal FIELD concept – the Fanuc Intelligent Edge Link & Drive system (fig. 4).

The heart of this concept is an open platform that is designed to effectively integrate IIoT, technological parameters, machines, robots, drivers, sensors and effectors. The software connects machines of all kinds using an interactive network, allowing the access to detailed data and generating effective analyzes (e.g. prediction of component machine tool failures).



Fig. 4. The Fanuc Intelligent Edge Link & Drive system (source: www.fanuc.com)

The FIELD system can also be combined with higher-level environments, ERP (Enterprise Resource Planning), SCM (Supply Chain Management) and MES (Manufacturing Execution Systems). Here are some features of the FIELD system:

- access to the environment for all machine operators and engineering and management staff,
- collection and statistics of work and operator loads,
- detailed data about the machine's load and machining operations,
- machine time estimation,
- scheduling and comparing the use of machines,
- logging of alarms and warnings from machine tools,
- acquiring real-time data from internal vibration monitoring systems, temperature, etc.,
- data analysis using artificial intelligence, self-learning to ensure prevention and improve the quality of production,
- automatic and by the operator sending data (feedback) to machine controllers,
- independent cooperation with CNC controllers of all well-known manufacturers, as well as with older NC and any sensors mounted in machine tools,
- support standards: OPC UA, LINKi, MTConnect, Heidenhain Status reporting interface,
- cooperation with PCs and tablets.

### Okuma

Okuma offers comprehensive machine park management that combines not only machine tools, but even production plants around the world to obtain information on the availability of individual machines.



Fig. 5. Okuma OSP-P300 Suite driver (source: www.okuma.co.jp)

Visualization of equipment status, data collection and storage (e.g. technological parameters, reports, alarms) is to lead to continuous improvement of production. The presented intelligent management concept is referred to as MEIK, which means an effective collection of mechanics, electronics, information technology and knowledge (Mechanics-Electronics-IT-Knowledge). Fig. 5 presents the latest CNC controller OSP-P300 Suite designed for the needs of intelligent manufacturing.

The modern CNC controller includes:

- 5-axis Auto Tuning System – 5-axis automatic machine error compensation system for geometric machine tools that allows to increase machining accuracy up to 3  $\mu\text{m}$ ,
- Collision Avoidance System – collision prevention system operating in the prediction mode,
- Machining Navi – an active system preventing the occurrence of self-excited vibrations, selecting the optimal cutting parameters, which improves the appearance and quality of the treated surface [7],
- Servo Navi – automatic compensator of the servo operation parameters allowing for continuous adjustment, e.g. acceleration of the drive, to shorten the machining cycle, avoid jumps in the direction of movement, path kinks and drive vibrations.

### Mazak

The iSMART Factory™ concept combines machines, production systems and customer service interfaces in the spirit of the idea of Industry 4.0. The goal is to achieve full interoperability and transparency of production information in order to decentralize the decision-making process. The basic action, however, is to obtain as complete a description as possible of the current state of the machine park. The company offers two independent hardware solutions:

- Sensor Box – used on older machines, also from other manufacturers. It allows to acquire information from light columns, temperature sensors (e.g. coolant), as well as from measuring the electrical power of drives,
- Smart Box – is a platform that works with machine tool drivers (not only Mazak) supporting the MTConnect standard (it is an open, free data exchange protocol – in XML format – between technological devices). It allows access to various technical and control information. For data transfer over an Ethernet/Internet network, it uses Cisco's latest secure network technologies and the concept of 'fog' processing.



Fig. 6. Smart Box platform and the latest Mazatroll Smooth X driver (source: www.mazak.com)

The main software module is the Smooth Monitor AX environment (fig. 6), processing and analyzing information received from controllers. Four main modules (screens) are separated: machine use (working time, waiting time), machine monitoring (machining, setting, changing tools, alarms, feed rates, spindle revolutions, spindle loads, parameter overloading, electricity consumption, necessary maintenance), process analysis (tool utilization, spindle load) and maintenance. All data can be exported to ERP class management support systems.

## HAAS

According to the concept of the HAAS company, full digitization of production, understood in accordance with the idea of Industry 4.0, is not a necessary requirement for all users. Large amounts of data generated during remote monitoring can create an accurate and multiparameter image of production, but these are difficult to analyze and evaluate. The necessity of sending, collecting and processing can generate very high costs and undermine usability. This situation applies especially to small companies with a limited park of CNC machine tools.

The HAAS company offers special software (available for all new NextGen controllers) HaasConnect (fig. 7) for monitoring the status of machine tools, which is limited to the most important parameters (implemented program, machine condition, diagnostic messages, usage, etc.). The driver connected to the Internet (wired or wireless) sends data to the cloud (producer) and from there they are transmitted directly to the mobile device of the registered user (tablet, smartphone, etc.), where the application presents relevant data on the screen. It is also possible to send short text messages (failures, warnings) or e-mails (statistics, explanations).



Fig. 7. HaasConnect – the idea and appearance of the remote machine condition monitoring screen (source: int.haascnc.com)

In HAAS machine tools, where the latest generation NGC controller (Next Generation Control) is used, the vibration sensor is standardly installed for the current monitoring of

the machining status. The user (as the person with the greatest knowledge about the behavior and condition of the machine) can choose one of four options of the controller's reaction to vibrations (off, low, medium, high).

## Mimatic

Another example of a tool monitoring system is eltimon (Electronic Live Tool Integrated Monitoring). It is used for continuous monitoring of the use of the tool mounted in the frame – also rotary tools. The following are tested: temperature, rotational speed and working time [8]. The microcontroller, sensors and energy elements are built into the frame. The data is encrypted and sent to the cloud.

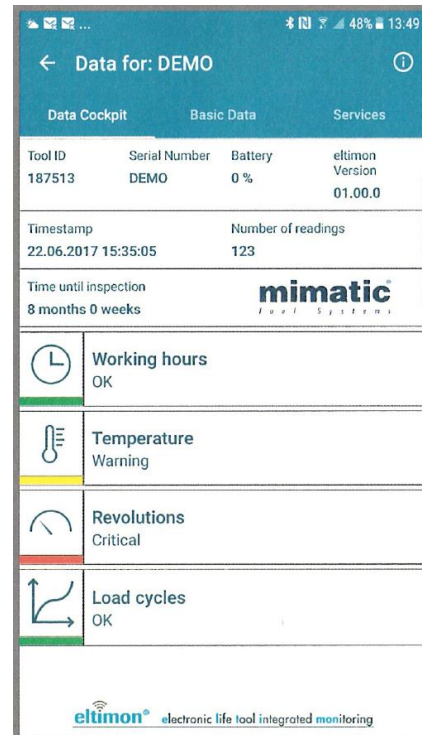


Fig. 8. Information screen of the eltimon application (source: www.mimatic.de)

The system does not require additional actions on the part of the user. The information can also be presented on the screen of the mobile device (smartphone). The transmission is carried out using NFC (Near-Field Communication) technology at the frequency of 13.56 MHz; while the battery with guaranteed working time of 10 years serves to support the memory of the built-in microcontroller.

## Campro

IT activities supporting the idea of Industry 4.0 are not the domain of only large and recognized machine tool companies. The offer of smaller companies is getting wider and wider.



Fig. 9. Campro's production management system (source: www.campro.com.tw)

An example may be a Campro product – Smart Manufacturing (fig. 9). It supports the concept of IIoT and CPMS (Cyber-Physical Manufacturing Systems). This is software for machines equipped with Fanuc, Mitsubishi and Heidenhain drivers. It allows remote control of the machine tool, transmission of NC programs, generation of reports in the CPK standard (Process Capability Index), process status control, prevention of traffic maintenance, service work management and transmission of messages (about alarms, errors, warnings) on mobile devices.

**B&R**

The support for OPC DA and UA open communication standards by manufacturers of NC controllers is becoming more and more frequent. This allows for the free use of machine data by production and monitoring systems. The B&R company offers universal I/O modules (X20 series) extending the scope of processing status observation with advanced vibration analysis.



Fig. 10. Fast and easy programming of traffic control (source: www.br-automation.com)

Data from the NC controller and module enable comprehensive monitoring, anticipation of fault conditions and increasing the utilization of the machine. The Mapp Motion development environment (fig. 10), due to the wide use of web applications, facilitates the construction of control systems and drives.

**Bosch**

A well-known manufacturer of automation and hydraulics components and systems offers comprehensive IT support for manufacturers of machine tools and technological devices, allowing for a significant increase in OEE (Overall Equipment Effectiveness) machine utilization – from the design, execution, sales and service support (fig. 11).

Complete monitoring of electrical and hydraulic components (e.g. pressure, temperature, oil level, condition of filters), linear drives, etc. is carried out by a new Data Analytics Server (DAS) to support the IIoT concept. It is installed on a standard PC computer, processes the real-time data (Sercos, Profinet). It requires 16 GB of RAM, 200 GB of hard disk space and Windows 10 (64 bits) for work. The data sampling frequency is less than 10 ms. Through a secure (encrypted) connection, it is delivered to the cloud environment (Bosch IIoT Cloud), where they are constantly analyzed for possible failures. The system also works with advanced linear drives, allowing you to track displacements and accelerations to avoid collisions.



Fig. 11. Easy data analysis in real time (source: www.boschrexroth.com)

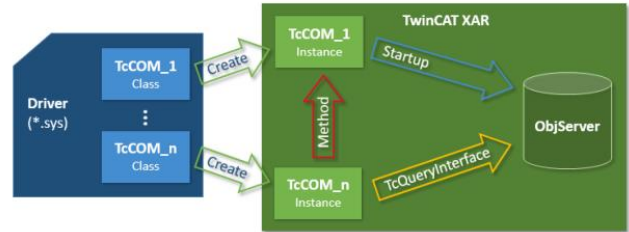


Fig. 12. Concept of the object model of the TcCOM environment (source: infosys.beckhoff.com)

**Beckhoff**

The advanced algorithms and data processing models used in modern control and supervision systems require the use of processors with ever-increasing computing powers. An additional problem is development of easy implementation of such complex, multi-parameter issues in multivariate hardware environments (PLC and CNC controllers).

The Beckhoff company proposes an open software model – TcCOM – cooperating with the TwinCAT system. Object-oriented TcCOM libraries facilitate the creation of new CNC programs (for machine tools, robots and transport systems) with personalized properties. Code sharing with C/C++ and Matlab/Simulink is accepted. Special procedures ensure securing the confidentiality of generated result code. This concept facilitates the optimization of new software, increases its efficiency and significantly shortens the delivery time to the customer. The scalable CX2000 system provides the appropriate computing power, which in the highest version allows for the simultaneous cooperation of 12 independent processors mounted on a 35 mm DIN rail.

**Chiron**

The concept of a modern, computerized factory – Chiron – is based on three cooperating IT platforms as part of the SMARTLine package (fig. 13):

- **DATALine** – allows to integrate machines and conduct diagnostics. It is primarily intended for machine tools equipped with NC controllers from Heidenhain, Siemens and Fanuc, but the manufacturer also offers support for controllers from other manufacturers. It allows to visualize and control the progress of manufacturing. It allows you to define your own reactions to emergency situations. It increases the efficiency of using the machine park by analyzing (pointing) bottlenecks and keeping active monitoring of maintenance activities. It tracks (online) the implementation of a technological processing program (POT), manages different versions of the POT, presents the values of the current feed, spindle speed and instantaneous load. Current data analysis is to minimize downtime and optimize production.

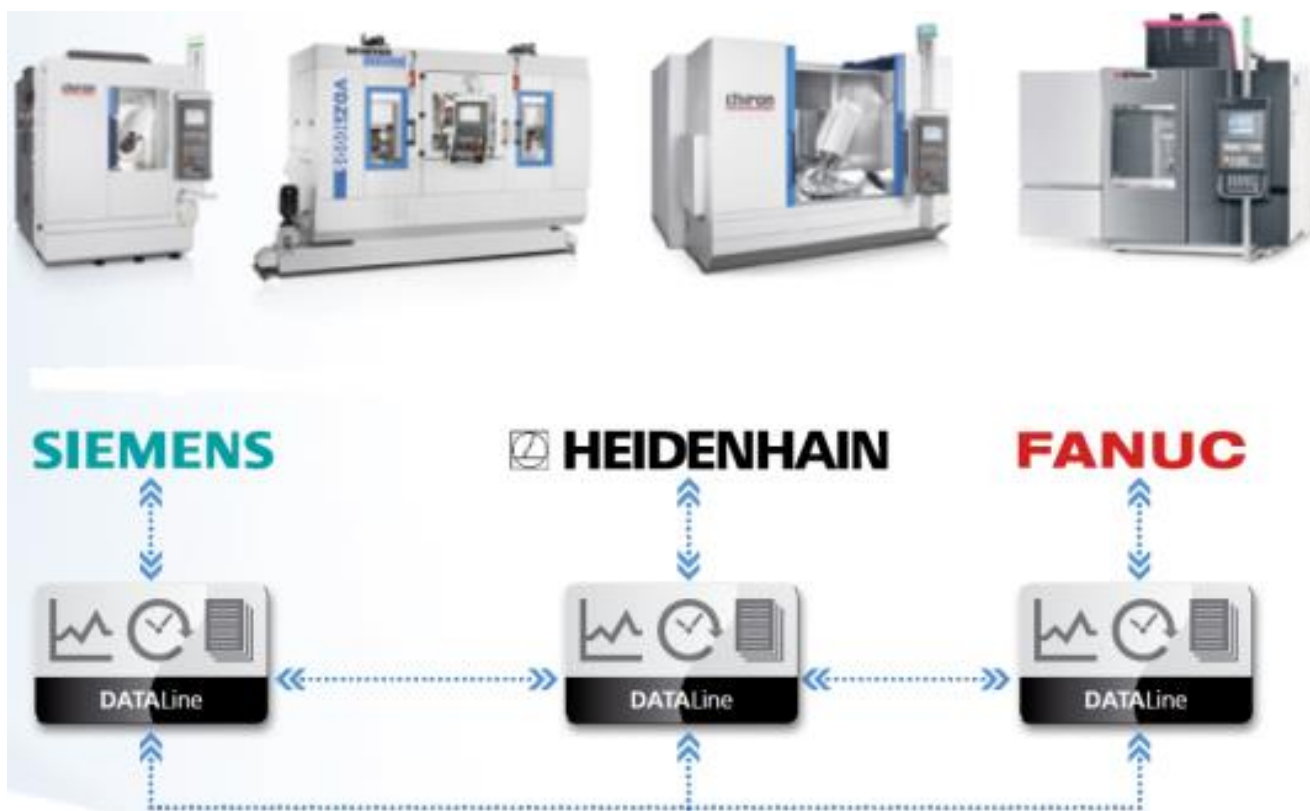


Fig. 13. Chiron's SMARTLine package (source: [www.chiron.de](http://www.chiron.de))

- REMOTELine – allows remote monitoring of the machine tool with a secure and flexible "teleservice". It allows sending e-mails and text messages with the current status of the machine. It tracks PLC parameters to detect and archive the causes of error messages; exchanges data with the NC controller. It records and remotely provides parameters from various sensors installed in the machine (temperature, drive loads, vibrations, etc.).
- PROCESSLine – an integrated CAD/CAM environment with simulation elements allows modeling and programming of the technological process. It consists of postprocessors, virtual machines, analysis and collision avoidance modules, as well as optimization formulas that use online data from machine tools, which according to the manufacturer allows to shorten the production launch time by 80%. Bi-directional communication between packages and machine controllers is carried out via the Internet and WEB services.

## Conclusions

An increase in the importance of information technology in the monitoring and management of production is observed. The offers of companies presenting their own programmatic studies during the EMO 2017 trade fair focused on the effective processing of large data volumes (big data) coming from sensors and control systems of modern machine tools and technological machines. Currently, the most serious task – limiting the effective implementation of the idea of digital manufacturing – should be considered the development of advanced algorithms and sophisticated strategies allowing for the real use of a detailed picture of the state of machine park and the process implemented from IoT, IIoT, IoAT. It seems that the actions in this direction are still at the initial stage. The next EMO trade fair will take place in Hanover on September 16-21, 2019.

## REFERENCES:

1. "EMO 2017 – after show report". <http://www.emo-hannover.de/en/facts-figures/recap-emo-hannover-2017/infographic.html>.
2. Szulewski P. „W kierunku samoorganizujących się środowisk wytwórczych”. *Mechanik*. 7 (2017): pp. 494–500.
3. Perkins E. "Securing the Internet of Things". Gartner Inc. 2017, <https://www.gartner.com/doc/3316617?ref=SiteSearch&stkw=inter%20net%20of%20things&fml=search&srcl=1-347892254>.
4. Shea S. "IoT predictions 2017: Revenue, data, latency issues top the list", <http://internetofthingsagenda.techtarget.com/blog/IoT-Agenda/IoT-predictions-2017-Revenue-data-latency-issues-top-the-list>.
5. General Electric 2017. "Edge Computing: Driving New Outcomes from Intelligent Industrial Machines", <https://www.ge.com/digital/sites/default/files/Edge-Computing-Driving-New-Outcomes.pdf>.
6. Sam G. "Microsoft and Cisco enable Azure IoT Suite to connect to Cisco Fog Deployments". Maj 2017, <https://azure.microsoft.com/pl-pl/blog/microsoft-and-cisco-enable-azure-iot-suite-to-connect-to-cisco-fog-deployments/>.
7. Szulewski P., Śnieguska-Grądzka D. „Systemy automatycznego monitorowania drgań w obrabiarkach”. *Mechanik*. 3 (2017): pp. 170–175.
8. Mimatic. "Free Your Tool Monitoring", [http://www.eltimon.de/Portals/3/PDF/eltimon\\_EN\\_LowRes.pdf?ver=2017-10-09-115156-400](http://www.eltimon.de/Portals/3/PDF/eltimon_EN_LowRes.pdf?ver=2017-10-09-115156-400).

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