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Marek HAWRYLUK
Marcin KASZUBA
Zbigniew GRONOSTAJSKI
Przemysław SADOWSKI

SYSTEMS OF SUPERVISION AND ANALYSIS OF INDUSTRIAL FORGING PROCESSES

SYSTEMY NADZORU I ANALIZY PRZEMYSŁOWYCH PROCESÓW KUCIA*

The work presents the concept of a multifunctional automatized forging station with a supervisory system of the process and the production management, with the option of application mainly at forging shops (with somewhat outdated machines) equipped with older-generation devices and forging units. The concept of such a station, which applies the, already partially, implemented construction and technological solutions, is a result of an extensive analysis of the current needs of forging plants and it has been supported by the acquired knowledge and experience of the authors, who specialize in the construction of measurement systems and other devices for the forging industry. The systems built by the authors makes it possible to measure and archive as well as fully monitor the most important technological parameters of the process, such as: the course of the forging forces in the function of time/shift, correlated with a measurement of the temperature of the preforms and dies as well as the number of the produced forgings. The elaborated systems, owing to their inclusion in the general production management system (which plays a supervisory role over the whole process), also allow for an analysis of the occurring changes during the process, including the proceeding wear of the forging tools as well as an analysis of the parameters determined throughout a long period of time, management of the machines and equipment (the work of the machines, their breakdowns, repairs etc.), and the human resources, as well as adaptation of the production organization to the increasing market demands. The presented concept of a complex approach to the issue of automatization of the forging line is a reply to the constantly developing forging technology, caused by market competitiveness, which requires automatization of the production, with the purpose to produce forgings of a higher quality, and, at the same time, reduce the costs.

Keywords: *supervisory systems, industrial forging process, measurement & control systems.*

W pracy przedstawiono koncepcję wielofunkcyjnego, zrobotyzowanego stanowiska kuźniczego wraz z systemem nadzoru procesu i zarządzania produkcją, z możliwością jego aplikacji przede wszystkim dla kuźni (z nie najnowszym parkiem maszynowym) wyposażonych w starsze urządzenia i agregaty kuźnicze. Koncepcja takiego stanowiska, wykorzystująca częściowo wdrożone już autorskie rozwiązania konstrukcyjno-technologiczne, jest wynikiem szerokiej analizy aktualnych potrzeb zakładów kuźniczych oraz poparta została zdobytą wiedzą i doświadczeniem autorów zajmujących się budową systemów pomiarowych i innych urządzeń dla przemysłu kuźniczego. Budowane przez autorów systemy pozwalają na pomiar i archiwizację oraz pełny monitoring najważniejszych parametrów technologicznych procesu, m.in.: przebiegów sił kucia w funkcji czasu/przemieszczenia, skorelowanych z pomiarem temperatury wstępniaków i matryc oraz ilości wyprodukowanych odkuwek. Opracowane systemy, dzięki ich włączeniu w nadrzędny system zarządzania produkcją (pełniący funkcję nadzoru nad całym procesem), pozwalają również na analizę zachodzących zmian podczas procesu, w tym postępującego zużycia narzędzi kuźniczych oraz analizę rejestrowanych parametrów w długim okresie czasu, zarządzania parkiem maszynowym i zasobami sprzętowymi (pracą maszyn, ich awariami, naprawami, itp.), zasobami ludzkimi oraz dostosowaniem organizacji produkcji do rosnących wymagań rynkowych. Przedstawiona przez autorów koncepcja kompleksowego podejścia do zagadnienia robotyzacji linii kuźniczej jest odpowiedzią na nieustanny rozwój technologii kucia, spowodowany konkurencyjnością rynku, wymuszający na kuźniach zautomatyzowanie swojej produkcji, w celu wytwarzania odkuwek o lepszej jakości przy jednoczesnym obniżeniu jej kosztów.

Słowa kluczowe: *systemy nadzoru i kontroli, przemysłowy proces kucia, systemy pomiarowo-kontrolne.*

Introduction

The industrial processes of die forging (depending on the production scale and the forging mass), are realized on machines with high forming forces, most often on presses and hammers, and also, possibly, upsetting machines. The performed analyses of the level of technological solutions in the die forging processes show that, in a great majority of processes, the die forging production takes place in the traditional non-automatized way, on separated forging unit stations, where all the

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl*** working actions, including: removing the charge from the heater and placing it in the die impression, relocating the formed forging on the successive impressions, are performed manually. A consequence of the level of the applied traditional die forging technologies are problems resulting from the low repeatability of the performed actions as well as the significant effect of the human factor on both the production process itself and the conditions of machine work, which significantly affects the activity of the enterprises and the speed of development of this branch of industry [12, 13, 14, 15, 16, 17, 21].

At present, forging shops, to manufacture a given product, often use old machines, without monitoring systems of the working parameters, which, due to their age, easily fail, and the wear of the cooperating movable elements, as well as the clearances, cause big problems in stabilizing the production process. Additionally, one should consider the character of the forging process and the relatively low life of the forging tools, connected with their wear, due to big temperature changes and high pressures. For financial reasons, forging plants rarely decide to purchase a new device dedicated to a specific production line. The commonly applied forging machines and devices are usually equipped with simple control and measurement systems, which merely allow for the control of: the maximal forging force, the machine's work speed, the number of forgings and the initial temperatures of the preforms [6, 9, 18, 22, 23]. Such measurement and control systems, which monitor the whole process, have been successfully applied in factories (so-called, assembly shops, involving the process of joining, bonding, welding, painting and others) as well as in automatized stamping presses. On the other hand, in the case of industrial forging processes, these systems are only beginning their development.

The changes observed on global forging markets, the high competition and the constant technological progress create demand for products of increasingly high quality and reduced costs from the forging producers [20]. They consist mainly of matching production to the requirements associated with changes in materials and technological products and to increase production flexibility while maintaining its competitiveness [33]. Frequent changes of produced assortment and conducting production using fixed assets machine requires the use of complex systems of measurement and control, which will allow for rapid diagnosis process, in order to adapt and optimize and, thanks to constant analysis, ensure the safety of machinery, low failure, and finally the profitability of production . Using the existing machine park, whose work is monitored by the relevant systems provides greater the universality of machines, allows for quick start production and significantly reduces implementation costs of the new product [15,25,29].

This also directly affects the development of the die forging technology, in respect of the currently constructed and installed measurement and control systems (which only slightly affect the production management), as well as automatization and robotization of the production line.

1. Supervisory measurement and control systems

A measurement system can be defined as a set of functional units which form an organizational whole included in the common regulation for the realization of a specific metrological purpose. The system regulation is usually realized by means of a superior functional unit called the controller, which works according to a programmed algorithm. Most measuring systems characterize in algorithmization of the measuring processes and integration of equipment and software. Depending on the general application, measuring systems can be divided into: research systems, measurement and control systems and measurement and diagnostic systems. In industrial applications, the measurement and control systems have found their special application. These systems use large numbers of sensors installed all over the controlled object, owing to which they are universal and allow for a measurement, control and analysis of nearly all the quantities. Such systems provide the possibility of continuous monitoring of the technological process parameters and the work of the participating machines during the implementation of the industrial production processes (measurement, archiving and advanced analysis of the correlated quantities).

The measurement and control systems, known as ICS (Industrial Control Systems) of extended functionality, which include SCADA (Supervisory Control And Data Acquisition Systems), DCS (Distributed Control Systems) as well as less technologically advanced systems realized with the use of PLC controllers, allow for a fast flow of information concerning the production process, the appropriate process parameters and the machine work, an analysis of the production history and the effect of the particular factors on the process, as well as a conscious technological development supported by the measurement results and a reduction of the production costs. Their basic purpose, in the case of forging processes, is the measurement and detailed analysis of the forces, temperature field distribution of the tools and preforms, the acoustic emission events, the forging tool life, as well as analysis of the state of machines, movable element lubrication, vibrations of the rotators which store the energy, aiming at improving the operation of the forging units [2, 4, 5, 8, 9, 24].

It should be noted that the most extensive and developed area of application of such systems are industrial processes of sheet forming as well as in factories assembling parts and subassemblies, mainly for the automotive industry, which is partly due to the extreme conditions that prevail in the industrial processes of forging hot. For example, the work [29] presents a system of monitoring and control of the pressing process through feedback, allowing for the reduction of defects and the number of corrections as well as a better quality of the end products in the form of collar drawpieces. As regards the die forging processes, such systems are still beginning to develop, which is partly caused by the extreme conditions of the industrial process of hot die forging. A description of the systems dedicated strictly to forging processes and their applications can be found in [7, 9, 18, 19, 23, 30]. For example, the work [30] develops a real time control system of placing the forgings in the consecutive dies by a manipulator, which allows for very fast changes in the introduced algorithm. The work [33], in turn, performs an analysis of the forging quality by way of applying visual measurement and control systems, especially visual systems. The literature extensively discusses the application of the measurement and control systems in the analysis of the state of the forging tools [4, 5, 8, 24, 30]. For example, the work [8] analyzes and points to (mainly based on the numerical calculations) the most crucial points, for different types of presses, where the highest stress concentrations occur, as well as the areas where one should expect failure. The measurement and control systems can also be used for controlling, measuring and analyzing selected parameters on semi-industrial stations testing the abrasive wear of the forging tools in the case of high pressures [19].

Obviously, such systems, after the verification of their work under industrial conditions and modification of their application, can constitute not only specialized measurement and control tools used, for example, for an advanced analysis of the tool life, but also specific systems of supervision over the work of the forging tools as well as analysis of the industrial forging process in respect of monitoring the parameters of the process itself, the work efficiency of the machines, monitoring the efficiency of the forging plant, the machine shutdowns and breakdowns as well as the machine operation schedules and the management of the machine maintenance costs. What is more, IT applications dedicated for specific industrial plants, especially forging shops, allow for on-line monitoring of each machine and forging unit, provide a whole spectrum of information on the current production, orders and duties, as well as deficiencies, shutdowns, and scheduled machine inspections and repairs. The increasing market requirements concerning the efficiency and quality of production, also at forging shops, enforce the introduction of new solutions to optimize the whole production process. An important part of these solutions are the popular Andon (Japanese for ‘light signals’) systems, which are part of the, mentioned earlier, larger systems: SCADA and DCS. Fig. 1 shows exemplary schematics of how such a system operates.

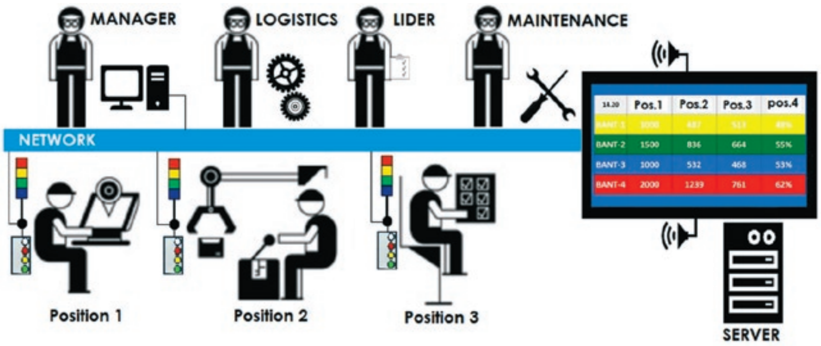

Fig. 1. Schematics of an application of the Andon system for the optimization of the whole production process

Such systems, being part of the concept of ‘lean production’, provide the possibility to increase the control over the production process, improve the quality, discipline the workers as well as record and analyze the events. At present, the classic Andon systems resemble a board with the numbers of zones of the operator’s work or the names of the machines. When a problem occurs, the worker, by pushing the appropriate button, signalizes the occurrence of a non-standard situation at his work station and his need of assistance in its elimination. More advanced systems based on the original Andon concept, beside the information on non-standard situations, also use signals from the measurement and control systems, owing to which the non-standard course of the process, resulting e.g. from the technological parameters of the process, the work of the machines, the selection of the product etc., is signalized much sooner.

2. The concept of a multi-functional robotized forging station with a process supervising system

The development of the forging branch directly affects the development of the used devices and the applied technologies. The continuous technological progress enforces increasing the production elasticity, as well as increasing its competitiveness and product quality. An improvement of competitiveness can be achieved by way of production automatization. A popular way of automatizing the forging processes is the application of transfer presses. Automatization of this type is offered by press producers such as Schuler, Komatsu, AIDA, MEER and ThyssenKrup. At present, for the big lot production of medium and large forgings, there are three available systems, i.e. press lines, transfer presses with 3-axis transfer devices and transfer presses with a cross transfer system. This technology is, however, significantly limited to the specific type of press and assortment of the forged elements. This solution is dedicated to the automatization of big lot processes and it significantly limits the possibility of changing the forging assortment. Most of the companies which offer their solutions for automatizing the forging processes limit their offer only to the technological lines with relatively new machines and devices, which are usually equipped with sets of sensors, drivers and systems, allowing for mutual communication as well as communication with the superior systems. Applications of the companies specializing in automatization of the forging processes are mostly based on using the existing robots and manipulators of such global potentates as: FANUC, KUKA, ABB, Kawasaki and Comau [1, 3, 10, 11, 26, 28, 31, 32]. They are mostly ready, advanced, units with many levels of tolerance and a construction allowing for universal applications, mainly on assembly lines of sheet elements and, sporadically, robots working under hard forging conditions (high temperatures, vibrations, dustiness). There are also a few small companies specializing in the construction of robots for the operation of presses, e.g. Copren [11] which offers ROBOCOP with three axes, or Oriimec [31], which offers a simple three-axial robot G-50 with the PTP-type control, designed for the operation of presses of low tonnage. This robot can be mounted on rails with the purpose to be moved between presses. In Whirpool plants in the USA, between October 2004 and June 2005, on three press lines, 21 five-axis robots SP80X by Motoman were applied [28]. The presses are used for door elements, frames and casings made of sheets of different sizes. Robotization of these presses has increased the capacity by 50 % and improved the quality of the drawpieces. In Europe, Jaguar Cars, Great Britain, is the most robotized factory [27] – it uses over 400 robots at different stages of the production process, e.g. in the press section, where aluminium elements of the luxurious Jaguar XJ car are pressed.

Application of such type of devices requires a large financial investment, due to the price of the robot itself, the advanced control system and the following operation and maintenance costs. Also, solutions proposed by those companies, despite being universal in character, concern only a specific part of the technological process. Integrator companies focus mainly on the manipulator arm together with the grabbing unit, which transports the material to the heater, as well as the consecutive forging operations, followed by cutting and assigning the detail to the following operation. Installation of such devices only rarely includes other important aspects which determine the whole forging process, such as the life of the forging instrumentation, connected with the tribological conditions. For example, ABB reports that, in 2001, in Great Britain, it assembled 18 production robots and 80 different elements [1]. This robotized line is a whole complex including automatic tool replacement, security control, diagnostics, visualization of the course of the production process, inspection of selected operations, collecting information on daily production, elaborating reports and analyses, device and system diagnostics, tracking of the process history etc. All this is, however, only a selected fragment of the whole technology, focusing mainly on the area of operation of the robot itself, or the manipulator arm, while the whole investment exceeded 12 mln euro (the cost of one robot is about 350 thousand Euro).

Based on the performed research concerning elaboration and construction of measurement and control systems for the analysis and control of industrial process of die forging [18], the authors developed a concept of an innovative, integrated, multi-functional die forging station. Beside the option of application in modern technological lines, the station is mainly dedicated to forging shops equipped with older machines and devices. One of the main assumptions of the station is modernization of the currently used machines in the existing technological line in order to adapt them to automatization. Modernization in respect of adaptation to automatization is undoubtedly innovative and is especially attractive to companies whose financial situation does not allow for big investments, such as a purchase of new forging units. This certainly constitutes an advantage of the proposed concept in respect of the very expensive free market solutions. The elaborated concept assumes that the station will be synchronized with the work of the forging unit, equipped with a dedicated measurement and control system. Additionally, the whole station will be connected with a superior production management system.

In the proposed innovative solution, constituting a complex approach to the issue of automatization and robotization of the forging line, the key (component) elements will be the following (Fig.2):

– a manipulator arm with a grabbing unit, transporting the charge material from the heater to the die impression,
– a cooling and lubricating device assuring a constant dose of the lubricant and implementing the assumed process of ‘maintaining’ long life of the forging tools,
– a measurement and control system installed on the forging unit, synchronized with a simultaneous, separated, work of the arm and the cooling and lubricating device,
– a superior production management system, which will play a supervisory role over the whole process.

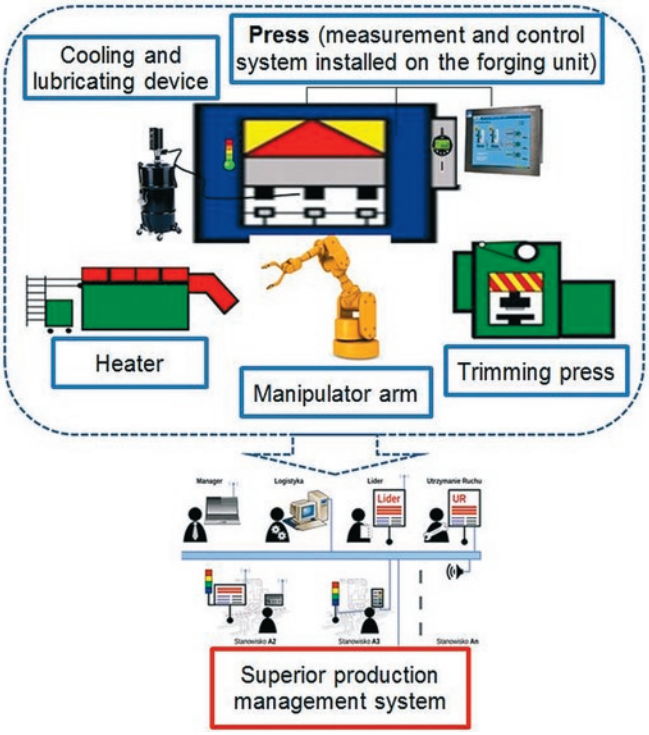

Fig. 2. Schematics of an integrated, automatized die forging station

In the opinion of the authors, the proposed solution thoroughly covers the whole process, considering all the existing factors. Each part of the station needs to be designed in such a way which will guarantee its autonomous, proper, functionality and cooperation with the rest of the system. The idea of the authors is combining the particular elements, taking advantage of the synergy effect, which will bring much more measurable benefits, in both the scientific and the financial aspect. Presented below is the innovativeness of the key elements of the station in respect of the currently applied solutions.

2.1. Manipulator arm with grabbing unit

A key element of the developed position is simple keypad with the least number of degrees of freedom, allowing for completing the tasks related to the forging processes which are currently performed by man. The use of a simple, and thus inexpensive, construction- and operation-wise, robot is possible owing to the complex approach of the authors to automatization. One of the basic conditions for applying a simple manipulator is elimination of the possibility of the forging’s being jammed in the impression and assurance of a precisely repeatable position of the preform and the forging. The industrial robot market is separated into the sector of ready units of many levels of tolerance, of a construction which assures universal applications, and the manipulator market allowing for the implementation of similar tasks when the number of the tolerance levels and the universality of application are limited. A manipulator, used for removing the material from the heater and placing it in the press, must face the environmental conditions of the production hall. That is why the producers of advanced and complicated robots offer various solutions to this problem, from protective covers, to compressed air blowthrough, to paint covering for the protection against dust and humidity. Beside the low price, another advantage of the proposed manipulator will be, owing to its simplicity, the lack of elements which are especially sensitive to the proximity of heat sources, and so, protection of this type will not be necessary. The main rotation axis mounted on the foundation will assure the required rigidity of the manipulator, which will allow for a dynamic movement, with the loads of up to 5 kg. The main executive elements, i.e. pneumatic actuators, will be used to drive the arm and assure the work of the holder. The applied actuators, equipped with high temperature seals, and high temperature and splinter resistant conduits will increase the system’s strength against the environmental conditions. In the forging process with the use of the discussed manipulator, it is very important to assure the appropriate positioning of the treated material at each stage of the process (upsetting, blocking, final forging), which allows for grabbing and transporting of the forgings. And so, an important element of the manipulator is the grabbing unit, which must be adapted to the shapes of the products of the given plant. This will be a gripping device connected with the universal arm of the manipulator. The gripper, made of inconel, in the form of the “C” system, with mobile arms, will guarantee the appropriate gripping ability, which has been confirmed by many laboratorial tests. The currently applied industrial robots perform such tasks properly; however, their price significantly exceeds the financial capabilities of the companies [32].

2.2. Cooling and lubricating devices

The authors are planning to use the elaborated and implemented, proprietary, cooling and lubricating system [12]. At present, one of the devices being part of the system is already working in a Polish forging shop, and others are being tested at other plants from the forging branch. The elaborated lubricating and cooling device, constructed as a low-pressure one, is safer than the commonly applied devices of this type with pressure vessels. Assuring the optimal work and lubrication temperature of the forging tools is very important from the point of view of the optimization of their life and the quality of the forgings. In order to stabilize and control these parameters, the constructed device assures a constant dose of the lubricating and cooling agent and the time of its application (Fig. 3).

Such a device, beside the lubrication and cooling of the tools, also performs other tasks related to assur-

a)

b)

Fig. 3. A dosing and lubrication device controlling the amount of the lubricating and cooling agent: a) view of the controlling panel, b) view of the container [12]

ing the optimal working conditions of the tools, such as additional drying off of the accumulator water, which can cause the formation of ‘pockets’, which, in turn, may result in incomplete filling of the impression and non-uniform cooling of the tool surface. This device allows for adapting, depending on the need, the dose of the fluid ejected on the upper and lower tools as well as the time of its supply. The basic functional elements assuring repeatability of the lubrication cycles are: a peristaltic pump driven by a stepper motor, which precisely controls the fluid dose, a set of valves controlling the flow of the air which atomizes and pushes the fluid, cleaning the fluid distribution system, and a head spraying the applied liquid agent on the surface of the dies. The change of the supply time allows for controlling the water content in a volume unit of the ejected air-water-graphite mixture. Longer supply times allow for more effective cooling of the surface layer of the tools and leave it dry after the cycle completion. A properly selected time of the lubricating agent ejection favours the appropriate atomization of the fluid, thus hindering the process of graphite accumulation in the bends of the dies and the process of water accumulation on their surface. The regulation of the content of the liquid phase in the lubricating and cooling mixture consists in changing the opening time of the spraying valve and the rate of the liquid’s flow to the spraying head. The device is also equipped with an anti-depositional mixer, which allows for maintaining uniformity of the graphite suspension in the water, which, in turn, assures a constant amount of the lubricating agent. It is crucial to select the appropriate moment of atomizing the agent. At present, in a majority of cases, it consists in activating the spray shower after a given forging operation, which causes the risk of spraying the hot forging before it leaves the die impression. Such a situation results in a part of the scale being left in the impression and the impression being insufficiently cooled (lubricated). The authors have elaborated special pyroelectric sensors with a regulated threshold of operation, set in such a way so that the path of removing the forging can cross the sensor beam, which guarantees elimination of the problem (Fig. 4). Additionally, this system will make it possible to count the number of the forged products. At present, most forging shops which do not own control systems perform this task by approximation, i.e. by determining the number of forgings by weight or by counting the mean number from a particular shift (8 hrs). Also, counters of the number of press cycles are often used, which is justified only is the case when each work cycle finishes with manufacturing a product (instead of e.g. testing the movement of the press or positioning the tools).

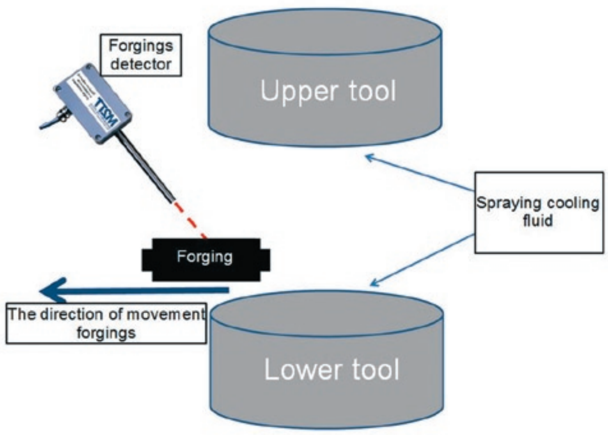

Fig. 4. Schematics of the elaborated tool lubricating system, which also assures removing of the scale and drying of the tools

2.3. Measurement and control system

Within the frames of the performed long-term research, the authors have elaborated and constructed measurement and control systems for the analysis and control of industrial die forging processes, which have been used e.g. in the process of forging of catches used to move concrete blocks on an eccentric press in the TR device (INOP, Poznań), and in the process of hot forging of a CV joint casing on a crank press in closed dies (GKN Driveline Oleśnica) [18]. The elaborated systems are built of an industrial computer (a real time controller, a fast multi-channel measurement card, an operational memory chip, high capacity hard disks, a set of amplifiers and converters) and appropriate measurement sensors (of the force, shift, pyrometers, thermocouples, encoders, accelerators, piezoelectric sensors etc.). Fig. 5 shows a fragment of the recording of the force from four operations

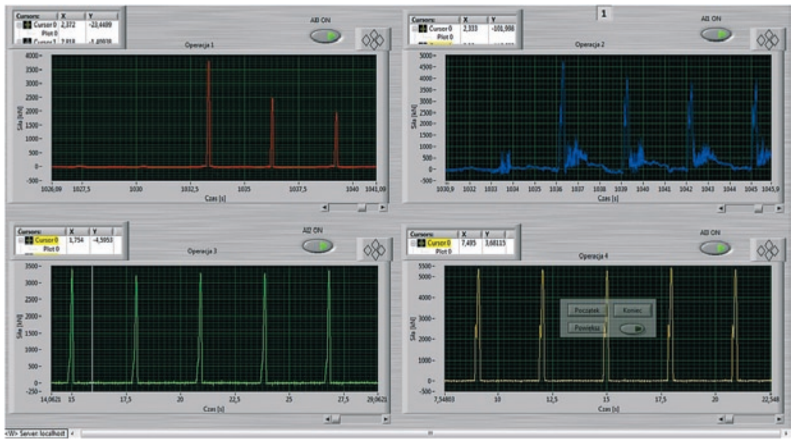

Fig. 5. Panel with displays of forces for four operations of forging a CV joint casing

a)

b)

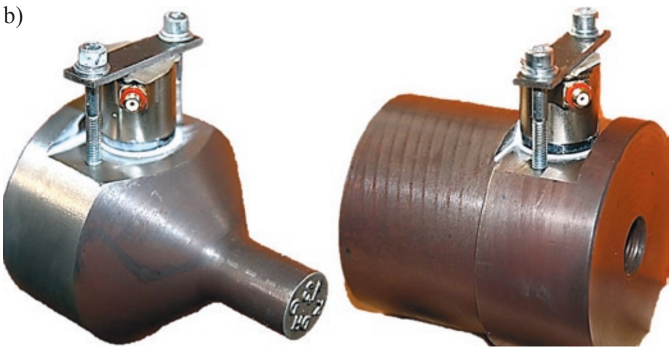

Fig. 6. a) View of the TR device b) punches for 2nd and 3rd operation with an AE sensor

obtained by the system built to monitor and archive the force in the process of forging a CV joint casing.

Also, tests with the use of the elaborated measurement system for the analysis of the acoustic emission (AE) signal were performed. The tests included the process of forging a catch for moving concrete blocks, realized on an eccentric press in the TR device in INOP, Poznań (Fig. 6a). The system was used for the pioneering research of the acoustic emission signal, which allowed for the determination of the wear of the tools used in the second and third operation of forging the catch. The tools were equipped with AE sensors (Fig. 6b).

The sensor mounted on the surface of the punch receives elastic waves, which originate from other parts of the machine as well as from the treated material. Next, the acoustic emission events are plotted on the force diagram corresponding to the analyzed forging operation (Fig.7).

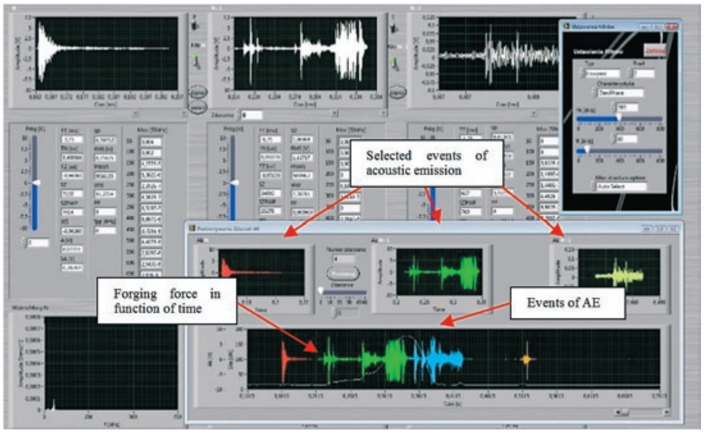

Fig. 7. View of the main panel for the analysis and selection of acoustic emission events [18]

After the verification of most of the acoustic emission events, it will be possible to search the signal and recognize the new occurring events and next replace the broad band sensor with a resonance one. The narrowing of the signal frequency will increase the signal sensitivity, thus detecting the events responsible for the microcracks of the punch material or its wear.

The concept of a measurement system within the frames of a multifunctional, robotized, forging station, beside the component elements of the systems constructed by the authors, which were mentioned before, also assumes installation of a rotational speed converter on the flywheel shaft of the press crank, which allows for an energy analysis of the machine and correlation of the results with the results of the force measurements. Such a system will provide the possibility to measure the physical quantities, such as the forging forces, the tool temperature, the mobile element location etc. It is crucial to properly distribute the measurement sensors, as well as determine of their dynamics and fault tolerance. What is especially important is the possibility of calibration, which guarantees accuracy in the whole range of the measured values (Fig. 8). A significant part of the system is constituted by a system for measuring the tool temperature. The latter is crucial from the point of view of the production process itself, as well as the life of the tools. Owing to a common data server, such information can be used to control the cooling intensity and the amount of the lubricant, which are regulated by a device designed to cool and lubricate the tools.

The calibration process, which has been the subject of a few years of research, is fully recognized and it guarantees obtaining accurate measurement results. The commonly applied calibration methods assume calibration with the use of hydraulic actuators, which stretch the body of the frame, or forging metal cylinders of the appropriate size. These methods, while justified, do not provide good results, mostly because they are performed under static conditions and thez require completing additional actions. The force measurements are made directly by means of tensometric strain gauges, extensometers glued to the press columns as well as sensors based on the piezoelectric phenomenon and the systems integrating the charge (Fig.9).

All the signals, after conditioning in the measurement area, which guarantees resistance to interferences caused by the presence of drivers and the induction heater, as well as the interferences coupled on the supply network, will be transmitted to the measuring server, which, in turn, will send them to the main server, at the same time determining the parameters for the control system of the machine and the production process, constituting the superior (IT) system of production management.

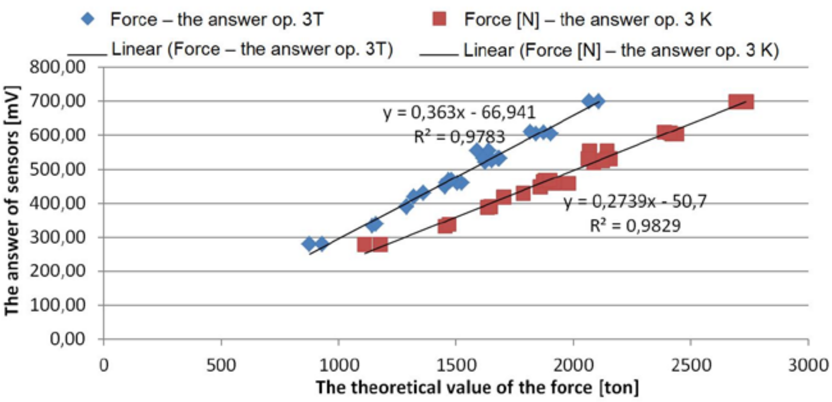

Fig. 9. Results of measurement system calibration for tensometric gauges and piezoelectric sensors

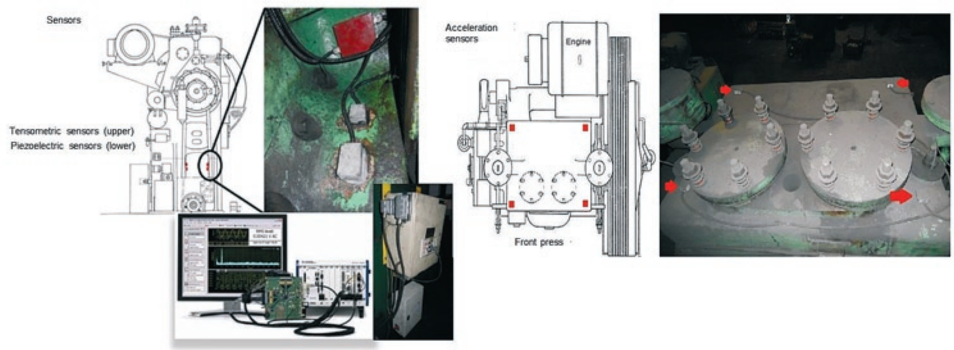

Fig. 8. Measurement and control system with an example of sensor distribution

By using high-performance computing machines, Real Time`s systems, many parameters and analysis will be made on the spot measurements. This will ensure the independent operation of each of the subsystems, some functionality and make it independent subsystems of failure of other components of the position.

2.4. Superior production managemenet system

The authors are also planning to elaborate an IT system which will play a supervisory role over the whole process. Monitoring systems, such as ANDON or similar solutions, are commonly available, being implemented by many companies. On the other hand, it is difficult to find such operation compatibility of the measuring system mounted on the unit and the system monitoring the breakdowns and contributing to the production schedule. The reason for this is the lack of specialized solutions adapted to the needs of the particular production processes implemented by companies with a high understanding of the problem and the values of the given process indicators. Integration of all the production stages and the supervision of the production machines in one superior system elaborated by a consortium specializing in forging and measuring technologies. The elaborated superior system will also allow for an analysis of the recorded parameters throughout a long period of time, which provide the possibility of development, in the area of the applied technology, of the management of the equipment resources (machine work, breakdowns, repairs etc.) and the human resources, as well as adaptation of the production organization to the increasing market demands. This will also allow for the construction of a complete and universal tool for the supervision of the process and the development of the forging technology.

Fig. 10 shows a practical implementation of the tool work supervision system and the analysis of the industrial process by the system developed by the authors.

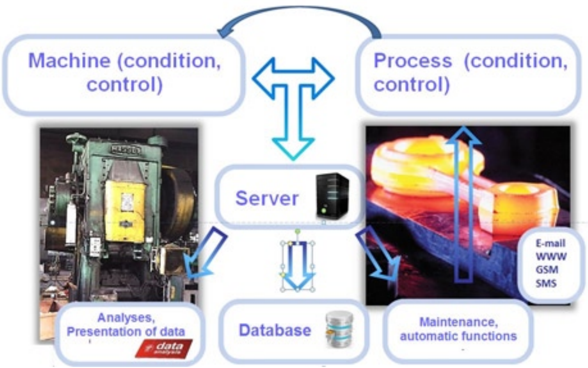

Fig. 10. Schematics of a practical implementation of the tool work supervision system and the industrial forging process analysis. The application working on a dedicated data server performs real time monitoring of the conditions of the production process (right) and the work of the machines taking part in the production.

Such a system is constructed of few modules, which communicate with each other, owing to which each event occurring in the forging process carries information causing a specific reaction in the whole system. The whole is connected by means of a special IT system, which plays a supervisory role over the process. What is innovative about this solution is the integration of the measurement and control system with the system of monitoring breakdowns as well as production and machine efficiency, which will allow for breakdown prevention and will help with scheduling technological breaks and the necessary repairs. The system will also make it possible to automatically assign temporary work parameters to the given event in the form of a breakdown or manufacturing defect and to improve the technology.

Owing to the application of efficient calculation machines and Real Time systems, many parameters and analyses will be performed in the area of the measurement. This will assure an independent work of each subsystems and high functionality, and will prevent the subsystems from being affected by the breakdowns of other component parts of the station.

One of the modules of the elaborated solution is a module which integrates the production and the movement maintenance, making it possible to record and analyze a very large number of production parameters. Fig. 11 shows an exemplary 'screenshot' of how this module works, where one can see the current production plans, with the (reference) codes of the forgings, the applied instrumentation, its life and other parameters.

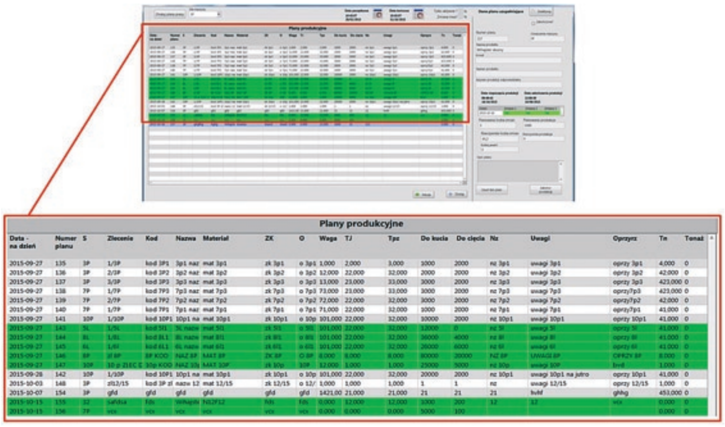

Fig. 11. Application panel with the major production schedule parameters

The planner, while defining the production for the given machine (or machines), assigns a set of tools and human resources, and enters the data on the production itself. Fig. 12 shows selected technological parameters referring to the forging force in time and in the function of the angular position of the shaft.

View of the panel of the data analysis from the sensors monitoring one production process. The system analyzes, in a continuous mode, the values of the forces and the temperature of the tools, the forging and the preforms. It counts the elements at each production stage and recognizes the operation number in the multi-operational forging process. At the same time, it enters the analysis results into the data base, so that they can be used later for the analysis of the technology, identification of the breakdown causes or breakdown prevention.

It is also possible to perform a complex analysis of the current production, with respect to its efficiency, shutdown times, number of manufactured forgings, defects etc. (Fig. 13a). Often, such information can be found in a few screens located in the central part of the forging shop. (Fig. 13b).

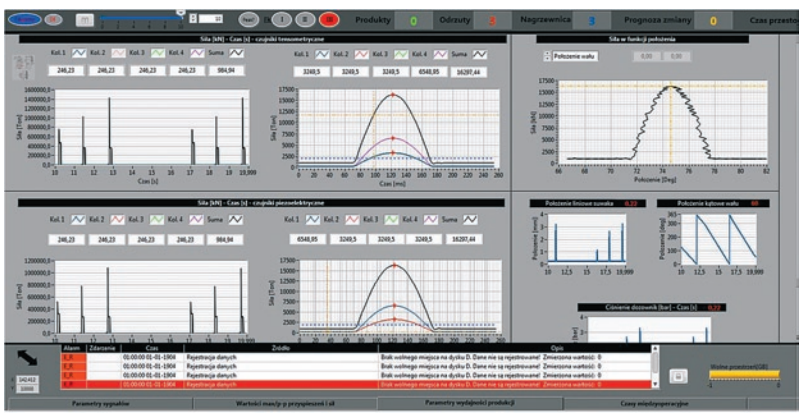

Fig. 12. Application panel with the major technological parameters of the selected forging process

a) b)

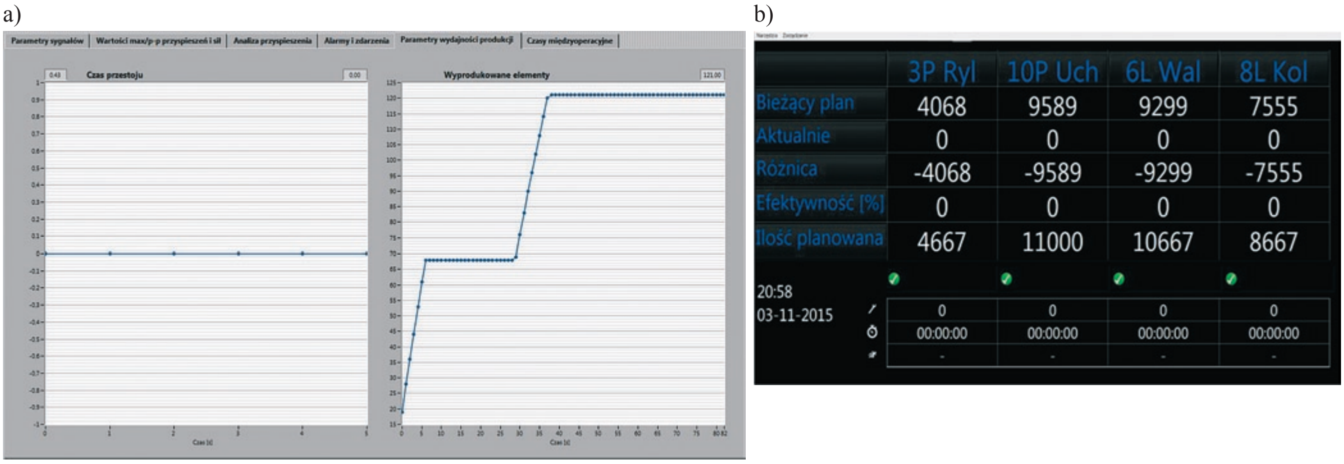

Fig. 13. a) Application panel with the major technological parameters of the selected forging process, b) information monitor/board

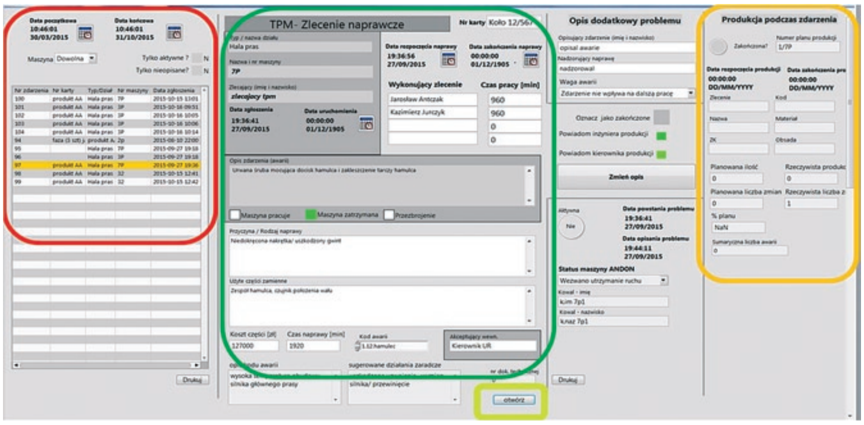

Fig. 14 'Screen shot' from the breakdown monitoring system application

Fig. 14 shows a 'sreenshot' of an application of the breakdown monitoring system, where one can see: the time of occurrence of such a breakdown event, the location, the production parameters during the event etc.

The breakdown monitoring system allows for an immediate action (based on a special procedure algorithm), e.g. repair order, review of the repair documentation of the given breakdown based on the previous events or the documentation prepared beforehand, which significantly shortens the time of solving the problem and resuming the production process.

Achieving the highest global standards of production quality and competitiveness requires improving the forms and methods of production management. Undoubtedly, nowadays, this is connected with the use of IT technologies, which include: advanced measurement systems, electronic devices, communication technologies and other peripheral devices for collecting, processing, analyzing and transmitting information. All this as a whole favours the improvement of production management and its structural elements.

The implementation of an integrated, multi-functional die forging station into the production process will also contribute to stabilizing the current production, increase the efficiency and productivity of forging units and significantly broaden the production capabilities of the whole company. The authors are also planning to introduce such an integrated, multi-functional die forging station to other forging units – presses as well as hammers. The scheduled, very high, functionality level of the station assumes the option of its reconfiguration and elastic adaptation in respect of the changing machines and production schedule of the given company. The station elaborated by the authors will constitute a unique solution, as similar solutions encountered in forging shops both in Poland and the world are usually dedicated to one machine or process, and their modernization is impossible or unprofitable. It will increase the control and automatization of the currently realized forging processes, and the given forging shop will benefit e.g. in the form of robotization and automatization of the production process.

What is more, owing to its innovativeness, it will significantly affect the fulfillment of the increasing needs of the clients and thus increase the competitive level of the company, as it will characterize in the following elements:

a) Extended control and stability of the current production.
b) Increased production efficiency, owing to the applied manipulator transporting the forgings.
c) Robotization and elaboration of universal forging and trimming technologies in the selected work center with the consideration of the series of types of the forging group.
d) Significant increase of the life of the applied forging tools, owing to the integrated lubricating and cooling device (constant and directed lubricant dose).
e) Process mapping at all production stages.
f) Fast analysis of the effect of the applied changes in any location of the applied technology on the whole process and the machine (verification of the possibility of press overload due to a die shape change), which will accelerate the technology development and lower the implementation costs.

3. Conclusions

The measurement and control systems elaborated and constructed by the authors allow for continuous monitoring (measurement, archiving and analysis) of the most important industrial forging parameters, such as: the forging forces in the function of time/shift and the tool temperature. The performed verification of the work of such systems under industrial conditions and their appropriate software and equipment development makes them a unique system of supervision over the work of the forging tools and analysis of the industrial forging processes in respect of monitoring the parameters of the whole manufacturing process. Additionally, through the elaborated dedicated IT applications for specific industrial/forging plant, they allow for an online monitoring of each machine, device and unit (scheduled inspections and performed repairs), and of the work efficiency of the particular plant sections or stages of the production process, thus providing a broad information spectrum on the current load and the state of the machines, as well as the current production, orders, deficiencies, shutdowns, and in this way, providing the possibility of production management. Another aspect of applying such type of systems is the option of verifying the simultaneously performed numerical modeling of the processes, with a special consideration of the tool life.

The continuous development of the forging technology makes the forging plants automatize their production in order to meet the demands of the market. This leads to the introduction of new construction and technology solutions. An answer to this state of affairs is the presented concept of an innovative solution, which constitutes a complex approach to the issue of automatization and robotization of the forging line. The concept assumes the construction of an integrated, multi-functional die forging station, whose key elements will be:

- a manipulator arm with a set of grippers, which transports the charge material from the heater to the die impression,
- a proprietary (already constructed) cooling and lubricating device which assures a constant dose of the lubricant and realizes a complex process of 'maintaining' long life of the forging tools,
- a measurement and control system elaborated by the authors and installed on the forging unit, synchronized with a simultaneous and independent work of the arm and the cooling and lubricating device,
- a superior system of production management (partially built), which will play a supervisory role over the whole process.

The intention of the authors is, however, combining the particular elements and taking advantage of the synergy effect, which will provide much more benefit, of both scientific and financial kind. This solution will contribute to an even better and more thorough control over the forging processes. Introducing an integrated, multi-functional die forging station into the production process will stabilize the current production, improve the conditions of operation and productivity of the forging units as well as significantly increase the production capabilities of the whole company. At present, the benefits of a synergy of the particular elements of the elaborated, integrated, multi-functional station are difficult to determine. Such assessment will be possible only when the station is practically implemented.

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Marek HAWRYLUK
Marcin KASZUBA
Zbigniew GRONOSTAJSKI
Wroclaw Technical University of Technology,
ul. Lukasiewicza 5, 50-371 Wrocław, Poland

Przemysław SADOWSKI
Measurement and Medical Technologies Transfer
ul. Piękna 64C/2, 50-506 Wrocław, Poland

E-mails: marek.hawryluk@pwr.edu.pl, marcin.kaszuba@pwr.edu.pl, zbigniew.gronostajski@pwr.edu.pl, m2tt@m2tt.com