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AUTOMATION OF TECHNOLOGICAL PROCESSES IN A COAL PREPARATION PLANT AND USEFUL SYSTEMS AND DEVICES FOR MONITORING OF COAL QUALITY

Coal mines preparation plants, playing key role in the coal production process, have been significantly neglected in terms of modern equipment provision. Ad hoc and short-term spending on modernization and new investments have been usually forced by extremely bad technical conditions of the facilities and the impossibility to achieve proper quality parameters of coal. The results of too few technical investments in mechanical coal preparation plants were visible as early as in the initial phase of the mining sector reorganization, after significant reductions of the personnel. Too few employees with respect to the necessary level of human resources in coal preparation plants caused a situation when a usual seasonal increase in coal mining was a great hazard for smooth functioning of the whole mining plant.

The main conclusion drawn from the survey and analyses of the technical state of coal preparation plants of that time was the necessity to immediately begin the process of modernization and development of processing machines, equipment and complex control systems of coal preparation technological lines. It was necessary especially due to the restrictive requirement to lower the coal production costs as well as the increasing demands of coal consumers with respect to meeting the required quality parameters of a product.

The prepared program of research and development works assumed a dynamic development of modern control and measuring devices to monitor quality and quantity production parameters and to be applied in automatic regulation devices and control systems of coal preparation technological processes.

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The following chief objectives were defined:

— maximizing coal recovery,
— improving the efficiency and quality parameters of products,
— increasing the efficiency of machines along with production costs reduction,
— adaptation to market demands,
— increasing work safety and minimizing negative impact on the environment.

It was agreed that the above objectives could be quickly executed through partial or complex automation of technological production lines by means of the following applications:

— systems which monitor the work of the plant equipment, systems which balance and control the achieved quality and quantity parameters of products,
— advanced dispatch systems for managing coal production processes.

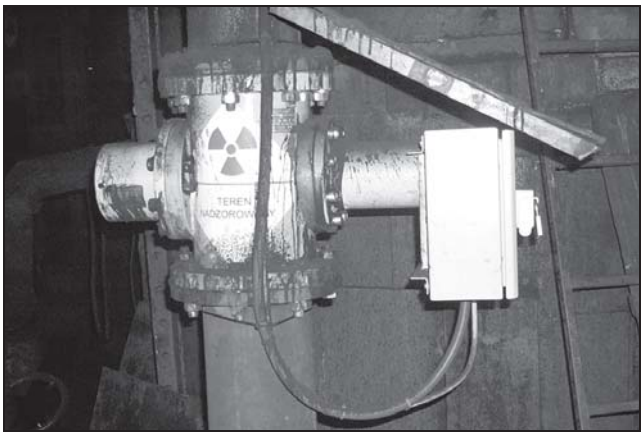
1. The research works within devices and systems for the automation of coal preparation processes realized by EMAG

In the first phase of the R&D work the focus was put on thorough technical modernization of the basic coal preparation sections: jigs and DISA separators. In the technical assumptions of the projects, apart from the formulated high requirements with respect to technical and operational parameters, special attention was paid to the possibilities of applying the constructed automatic control devices and systems in interactive dispatch systems for the production management in a coal preparation plant. This results from the concept of process automation practical application in a coal preparation plant with a view to perform complex or partial automation of coal production processes in particular technological lines.

1.1. Coal processing by heavy media separation(200-20(13) mm)

Most applications of suspension separators in Polish coal preparation plants are Polish machines DISA. There have been only few industrial implementations of automatic systems for the control of heavy media density, and they have been working properly. However, their application in the complex automation systems of the separator technological line has faced significant limitations: the process is disturbed, i.e. there is the so called erroneous medium solids. In the ITI EMAG a method for identifying the phenomenon of densimetric composition of the working liquid and the method for automatic control adequate content of magnetite medium solids in the working cycle of the machine was developed. Currently, the R&D works are continued to carry out industrial implementation of a modern system for regulation and stabilization the heavy media density and a complex system of the DISA separators section work automation.

a)



b)

Fig. 1. C-type density meter on a pressure pipeline of heavy media (a), operator station of the DISA separators section (b)

1.2. Coal processing in fine coal (20–0) and grain jigs

The ITI EMAG has been involved in automatic regulation and control of coal preparation processes in jigs since 1980s [6]. There were the PULS heavy medium receivers installed in plants where coal preparation with the use of this method was performed. The users expressed their needs for modern, more efficient devices for machine work control. Therefore an innovative solution was developed, i.e. the BOSS-2000 automatic products discharge unit of coal cleaning products which significantly modified the existing approach to control of coal processing in jigs.

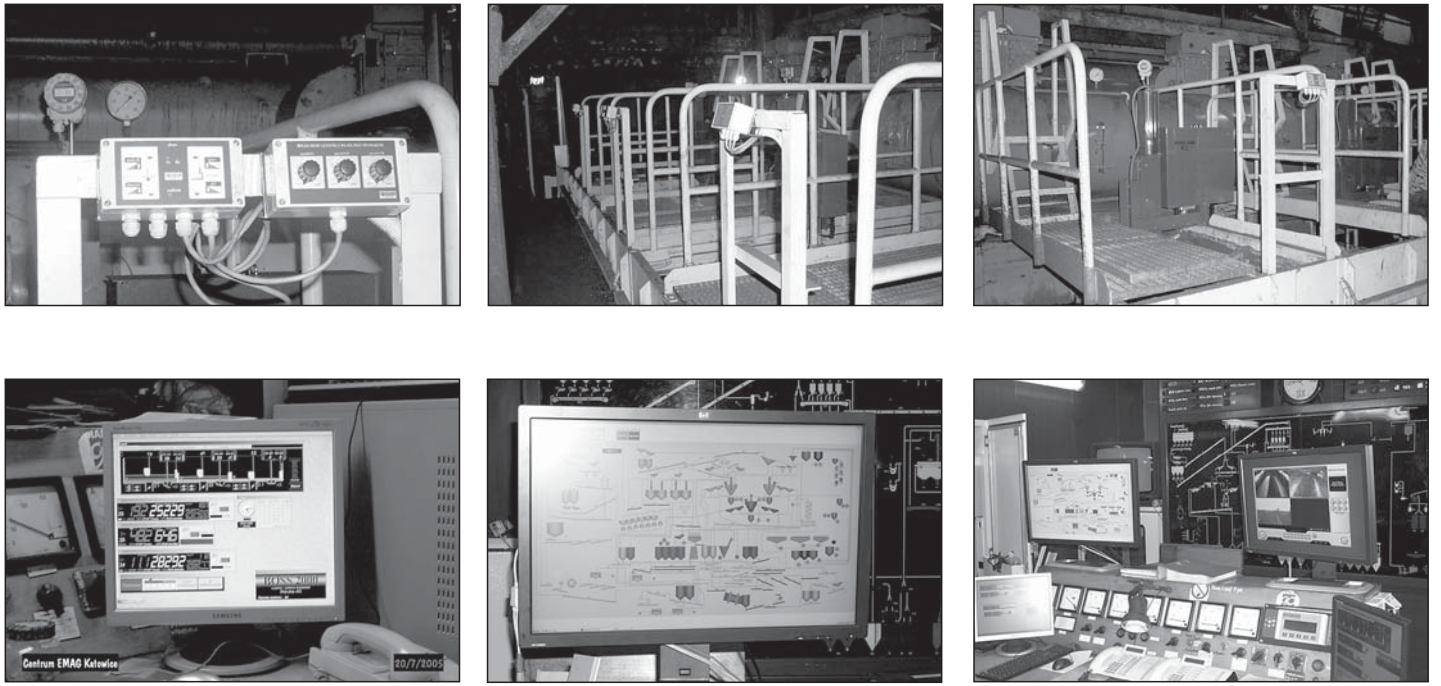


Fig. 2. Jig control system based on the BOSS 2000 automatic products discharge unit

Business and operational effects of the device, which had been implemented in several preparation plants, confirmed the accuracy of the formulated main assumptions and objectives of the project:

— significant reduction of combustible substances losses in waste,
— increased work safety and comfort,
— possibility to shape the quality parameters values of final products at the level of the machine,
— significant reduction of negative impact on the environment.

The BOSS 2000 automatic products discharge unit of products of coal washing meets all technical conditions indispensable to configure both the local control and monitoring system within the dispatch supervision system, and the complex system for the management and monitoring of the coal production process in a mechanical coal preparation plant.

1.3. System for dispatch supervision and production control in a coal preparation plant

The supervision system to monitoring and control mechanical coal preparation processes, as well as to prepare and deliver quality-classified power blends, encompasses the following functions:

— complex (or partial) automation of coal preparation lines and a water- and slurry-cycle devices,
— automation of the process of preparation and delivery of quality-classified power blends,
— advanced monitoring and control systems for heavy-industry technological processes and for devices working within the technological line of a plant.

2. Monitoring coal quality parameters: development of methods and devices for control basic coal quality parameters and current state of the art

The works related to the development of methods and devices for coal quality control began in 1950s. However, it was not until 1980s and 1990s that their significant development began along with industrial deployment of many state-of-the-art measuring devices and methods. This was connected with a huge progress in the field of electronics, nuclear radiation detectors and computer techniques [5, 8]. The works were realized mainly in the USA, Germany, Australia, UK, former USSR, and Poland. Here, the first system for on-line control of coal quality was deployed in 1970 at the „Wujek" Coal Mine by the ITI EMAG. This was the ALFA-01 system applied on the so called quick coal loading to wagons.

Since then this original Polish system, based on „scattering" methods (backscattering of gamma radiation — measuring the ash content; microwave radiation reflection — measuring the moisture), has been continuously improved due to the technological development and better access to the world-class latest-generation elements and subassemblies. Currently, the ALFA-06 system is offered to clients.

Fig. 3. ALFA-05 and ALFA-02/2E systems for continuous control of basic coal quality parameters

For the last few years the demands of customers with respect to coal quality have grown significantly, thus the coal production technology had to change too in order to enable the production of coal of a demanded class [9].

The devices deployed so far could not always be used in new measuring conditions, especially in the coal blends preparation systems where the transported coal was layered on a belt conveyor. At the end of 1990s, after conducting relevant research and development works, EMAG began to offer new devices based on absorption methods (gamma radiation absorption — measuring the ash content; microwave radiation attenuation — measuring the moisture), enabling the gamma radiation transmission over the coal of different quality layered centrally on the belt. The GAMMA-2E ash meter was developed, followed by the ALFA-05/2E ash meter. Both devices, together with the absorption moisture meter make up the ALFA-05/3E system (now ALFA-06/3E).

Due to the arising difficulties related to the users' providing adequate measuring conditions on the belt — especially with respect to the central layering of coal on the belt, another ash meter was developed – ALFA-05/2EW with the so called fan-beam collimation of gamma radiation.

The above mentioned ash meters are developed to measure small-size coal, especially fines, and are used, among others, in quick coal loading to wagons as well as in control systems for coal preparation processes in jigs.

To measure the mine of run (0–200 mm) and to measure the quality of brown coal, the ALFA-05/T radiometric under-belt ash meter was developed (its former version, GAMBIT, was used in the 1990s in the „Bełchatów" Brown Coal Mine), along with the RODOS ash

meter without isotope which did not contain artificial radiation sources (coal mines: „Wujek", „Bogdanka", „Janina", „Murki", „Borynia", „Zofiowka", Russia — in a quality and quantity control system thanks to the co-operation with belt scales) which was based on the measurement of natural gamma radiation of coal. These devices can be used for regular day-to-day control of coal output in the underground of mines. Particularly the RODOS ash meter without isotope, due to its fully safe operation method, is dedicated to work in potentially hazardous conditions which are likely to occur underground [7].

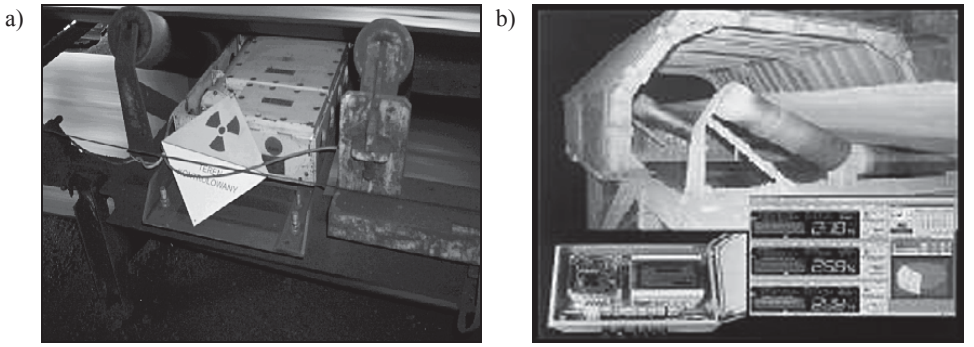


Fig. 4. ALFA-05/T and RODOS on-line ash meters

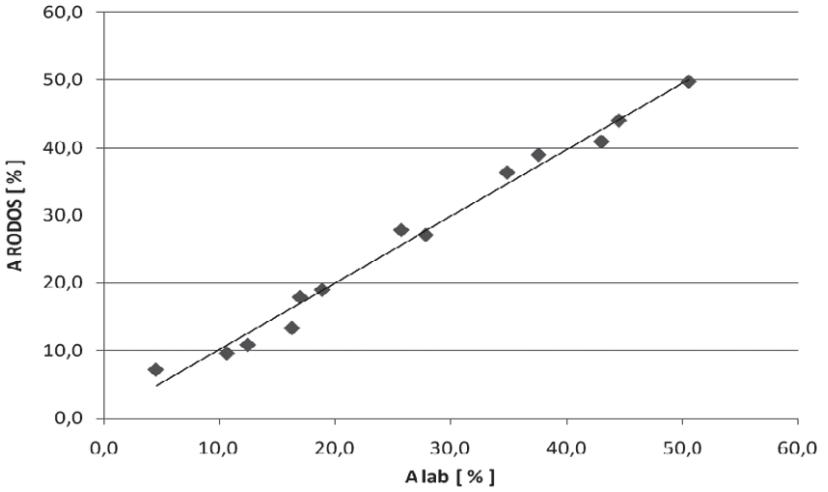


Fig. 5. Calibration curve for coal mine in RUSSIA

In the course of many years spent at developing and deploying devices for continuous measurement of coal quality parameters, one of the priorities was to take into account different technical, technological and climatic requirements of Polish coal preparation plants [5, 8].

Now the ITI EMAG offers ash meters which can be applied in practically any place of mechanical coal preparation plants. Recently, the issue occurring only in Polish processing plants has been solved — the possibility to properly carry out measurements on belts consisting of several sections with different thickness, quality and width (absorption ash meters work very well on homogenous belts; the belt quality does not matter only in the case of the RODOS meter).

TABLE 1

Calibration curve for brown coal in power station

Sample number	A^r, % lab.	A^r, % RODOS	ΔA^r, %
1	5.07	6.83	–1.76
2	9.10	8.42	0.68
3	6.40	5.85	0.55
4	8.87	8.42	0.45
5	7.37	7.14	0.23
6	6.10	6.68	–0.58
7	9.07	8.34	0.73
8	5.23	4.64	0.59
9	6.83	7.23	–0.40
10	8.63	9.10	–0.47

2.1. Control system for loading coal of required quality to cars

The commonly used blends preparation systems are installed on technological lines where components are provided by belt conveyor flights. The application of tanks filled by loaders does not guarantee to have a homogenous blend composition while loading one car. The solution which enabled to make a system for preparing coal blends of required quality loaded to particular cars, is the application of ash meters which measure the quality of components shortly before the coal pour-out to the tank. The selection of adequately short measurement times allows to get an indication related to the material which is currently the component of the blend. The proposed solution of the blends preparation system is presented in the figure below.

The issue of changing quality of components was solved thanks to the installation of ash meters without isotope at the outlets of auxiliary tanks. The measurement time was fixed so that the meters could indicate the parameters of the material which is provided as a component of the blend at the very moment. The change of proportions in blend components is regulated

by changing the speed of feeder belts coming from the tanks. As the volume of material coming from the tanks depends not only on the feeder belt speed but also on the size of the outlet hole and physical coal qualities (viscosity, graining, etc.), additional feedback of high time constant was used, derived from product quality measurements. The control of the blend quality is ensured by an ash meter for continuous measurement, installed on the blend belt which is also a loading belt providing coal to the cars. On this belt there are also dosing scales installed which allow to prepare a determined portion of the blend.

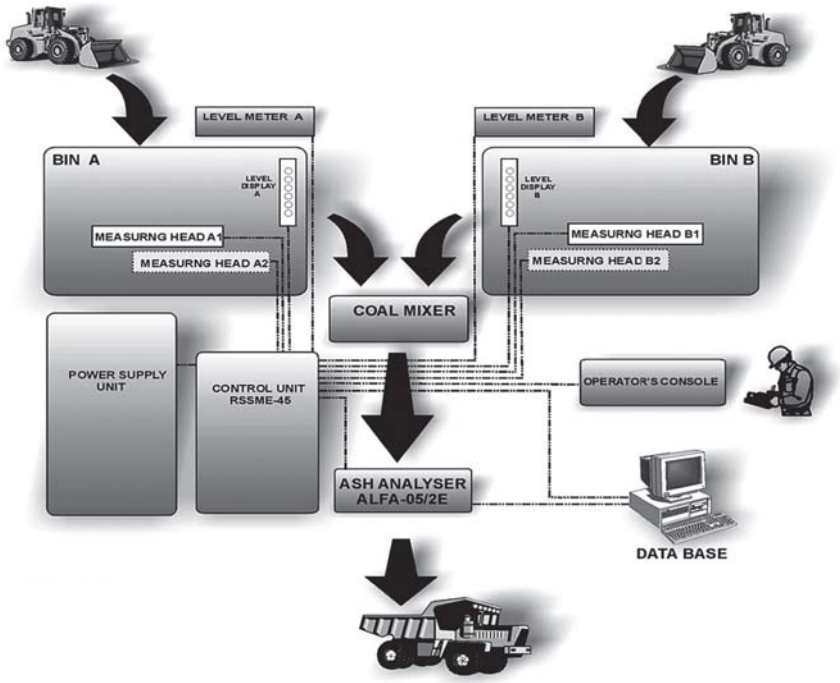


Fig. 6. The structure of a system for preparing blends of demanded quality

Programming the quality parameters of the loaded fines is performed by the dispatcher in a remote-supervision mode.

The installed system for automatic preparation of fines blends allowed to significantly increase the efficiency of the sales system up to 40 cars per shift. There is also a possibility to prepare blends of a determined class and to store them in the selected places of the dumping ground. This allows to perform the loading quickly, simultaneously with preparing a blend of different parameters for a different client. The system allowed to reduce the waiting time of the clients' cars and ensured homogenous composition of the purchased product. The application of continuous ash measurement in tanks and on the loading belt ensures that the achieved product is in accordance with the clients' requirements [3].

3. Laboratory and portable analyzers for coal without isotopes

Portable ash meter WALKER, based on the same measuring method as the RODOS — it also contains no radioactive sources. WALKER has been elaborated in 2004 and put into the market in 2005. Using this device it is possible to make fast measurements of ash content in coal piles, bunker, in wagons and truck [2].

Fig. 7. Portable ash meter WALKER

Up to now the ash meter WALKER is applied by 70 users in Poland and in the World — and has become our most popular system.

Test on wide range of coals from many of coal mines in Poland, Russia, Ukraine, Turkey and Vietnam have shown that the WALKER can measure the ash content to closer than 1% (1σ) ash. In some cases better than 0.5% (1σ) accuracy has been achieved.

The last achievement was development of a laboratory Analyser of type GAMMA NATURA made within a targeted project. That Analyser has been based on the natural γ radiation measurement method as well. Furthermore there have been used the following units: a microwave head allowing a measurement of moisture content in a sample and an extensometer balance designed for precise determination of a mass of a sample to be analysed. The sample of 0–20/30 mm grain size for measurement using GAMMA NATURA has not to be prepared. Performed in coal mines laboratories tests show, that GAMMA NATURA accuracy of ash content measurements is the comparable with the accuracy of isotopic analyser, sometimes is better [2].

TABLE 2

Results of measurements made in Vietnam

Item	***A* lab.,** %	***A* WALKER,** %	**Δ*A*,** %
1	22.88	23.42	-0.54
2	32.78	31.81	0.97
3	37.98	37.64	0.34
4	30.07	30.17	-0.10
5	16.55	16.30	0.25
6	19.00	19.01	-0.01
7	10.47	10.19	0.28

Fig. 8. Laboratory analyser GAMMA NATURA

Standard (mean) errors of the Analyser for the above presented results are:

— for ash б = 0.75% A%,
— for moisture б = 0.66% W,
— for calorific value б =355 kJ/kg.

TABLE 3

Comparison of results of coal analyses made in a laboratory and by means of the GAMMA NATURA Analyser in the one of coal mine in Poland

Sample number	Lab results			Values determined during calibration of GAMMA NATURA			Differences between Lab and GAMMA NATURA values		
	A^r, %	W^c, %	Q, kJ/kg	A^r, %	W^c, %	Q, kJ/kg	ΔA, %	ΔW^c, %	ΔQ, kJ/kg
Sample 1	4.58	7.4	28305	5.69	7.91	27673	–1.11	–0.51	632
				5.35	7.84	27826	–0.77	–0.44	479
				4.50	7.89	28113	0.08	–0.49	192
Sample 2	4.21	8.8	27887	4.94	8.25	27801	–0.73	0.55	86
				4.93	8.18	27836	–0.72	0.62	51
				5.38	8.06	27726	–1.17	0.74	161
Sample 3	25.16	10.2	19710	25.86	10.09	19549	–0.70	0.11	161
				25.54	10.22	19610	–0.38	–0.02	100
				23.88	10.08	20259	1.28	0.12	–549
Sample 4	10.6	9.6	25230	9.65	8.97	25818	0.95	0.63	–588
				10.35	9.04	25538	0.25	0.56	–308
				10.30	8.80	25656	0.30	0.80	–426
Sample 5	5.01	7.9	27992	3.13	8.17	28485	1.88	–0.27	–493
				3.67	8.15	28300	1.34	–0.25	–308

TABLE 3 cd.

Sample number	Lab results			Values determined during calibration of GAMMA NATURA			Differences between Lab and GAMMA NATURA values		
	A^r, %	W^c, %	Q, kJ/kg	A^r, %	W^c, %	Q, kJ/kg	ΔA, %	ΔW^c, %	ΔQ, kJ/kg
Sample 6	24.08	10.8	19830	24.94	11.47	19301	–0.86	–0.67	529
				24.27	11.25	19635	–0.19	–0.45	195
				24.74	11.46	19378	–0.66	–0.66	452
Sample 7	4.7	7.4	28248	4.62	7.88	28069	0.08	–0.48	179
				5.69	7.83	27711	–0.99	–0.43	537
				5.13	7.77	27935	–0.43	–0.37	313
Sample 8	4.48	8.2	28064	5.27	8.21	27699	–0.79	–0.01	365
				5.40	8.13	27689	–0.92	0.07	375
				5.30	8.28	27663	–0.82	–0.08	401
Sample 9	6.63	7.5	27382	6.99	8.12	27123	–0.36	–0.62	259
				6.98	8.04	27160	–0.35	–0.54	222
				5.77	8.13	27557	0.86	–0.63	–175
Sample 10	24.35	8.7	20538	23.54	9.31	20701	0.81	–0.61	–163
				23.46	9.14	20804	0.89	–0.44	–266
				23.60	9.07	20782	0.75	–0.37	–244

TABLE 4

Comparison of results of coal analyses made in a laboratory and by means of the GAMMA NATURA Analyser in the one of coal mine in Ukraine

Sample number	A^r lab., %	$A^r_{G\text{-}N}$, %	ΔA^r, %	S_t^r lab, %	$S_t^r{}_{G\text{-}N}$, %	ΔS_t^r, %
Ukraine 1	36.2	35.6	0.6	1.09	1.00	0.09
Ukraine 2	19.1	19.9	–0.8	1.80	1.63	0.17
Ukraine 3	19.5	19.2	0.3	1.25	1.37	–0.12
Ukraine 4	26.0	25.3	0.7	1.03	1.08	–0.05
Ukraine 5	26.5	25.5	1.0	1.55	1.64	–0.09
		σ =	0.7		σ =	0.12

4. The development prospects of monitoring and control systems for technological processes in coal production

Further progress of control and test systems in coal preparation plants is directed at the development of a dispatcher system of balancing the volume and quality of coal production with the above described ash meters and belt scales.

The concept of the system for registration and storage of data from particular coal production stages in a mining plant technological lines is part of the dispatcher supervision and control system of technological processes in a mechanical coal preparation plant.

The objective of further development of mine face machines control and monitoring systems will be to increase mining efficiency through better use of the machines production potential. The focus will be put on better use of measuring data by the application of state-of-the-art wireless diagnostic techniques, and the application of predictive control schemes in order to detect early the states which might cause production hold-up.

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