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Technologies used in the manufacture and repair of machinery and equipment at ZRP "Bieruń"

The following paper presents the use of various technologies in the manufacture and repair of mining machinery carried out by the ZRP "Bieruń" plant, all of which complement each other in order to provide the customer with a product of the highest quality. The systematic expansion of the machine park and the necessary technical facilities over many years has focused on numerically controlled machines, welding robots and, in product preparation, CAD/CAM computer programs. The issue is presented using the example of the production of the ZRP-15/35-POz powered roof support section.

Key words: *modern technology, powered roof support sections, welding methods, CNC machines, CAD/CAM computer programs*

1. INTRODUCTION

Zakład Remontowo-Produkcyjny "Bieruń" is a specialized organizational unit of Polska Grupa Górnicza SA providing services for PGG SA mines in the scope of repairs, modernization and production of powered roof supports, the repair and production of power hydraulics, completion of control hydraulics, production of suspension railway route components and other current repair and production services in accordance with the needs of the mines. Since its inception, it has systematically and consistently expanded its machine park, introduced modern production technologies based on numerically controlled machines, developed designs using specialized computer programs and ensuring continuous training for its employees. The plant has obtained a number of certificates in accordance with PN and ISO standards, guaranteeing the highest quality of the manufactured products. It is currently the largest producer of powered roof support sections in Poland and among the most important in Europe. Particularly noteworthy is the cooperation with scientific bodies and the organization of its own welding training centers. The ZRP plant employs more than 600 people, including specialists in welding, CNC machine software, engineering design and manufacture control. The plant mainly specializes in the repair, modernization and production of powered roof support sections, the repair and production of power hydraulics and the production of suspension railway route components. By investing in new machinery and equipment, the plant is gradually increasing its production capacity and expanding its range of activities. Close cooperation between the design and production departments makes it possible to realize the full production cycle – from design through production preparation to the finished product. The simplified production idea of "design-production preparation-product" is used to present the technologies used at the ZRP plant using the example of the process of manufacturing a section of ZRP-15/35-POz type powered roof support.

2. DESIGN AND DIGITAL PROTOTYPING OF A PRODUCT

The digital design and prototyping process is illustrated using the production of a new section of powered roof support as an example. This is a multi-stage process, which is graphically depicted in Figure 1.

The client's requirements depend on the geological and mining conditions prevailing in the respective operating area. They are usually defined by the mines taking into account the opinions of research units, available literature [2] and normative documents [3–5].

At this stage, the basic requirements for the sections are established, i.e. section type, support, working and geometric heights, special requirements due to deck conditions [6]. The initial requirements adopted enable kinematic and kinetostatic analyses of the sections to be carried out, for which the ZRP plant uses the PrsLab (Powered Roof Support Laboratory) proprietary calculation program [7]. The PrsLab interface is shown in Figure 2, while an example of the completed analysis of a ZRP-15/35-POz section in the form of a kinematic chain is shown in Figure 3.

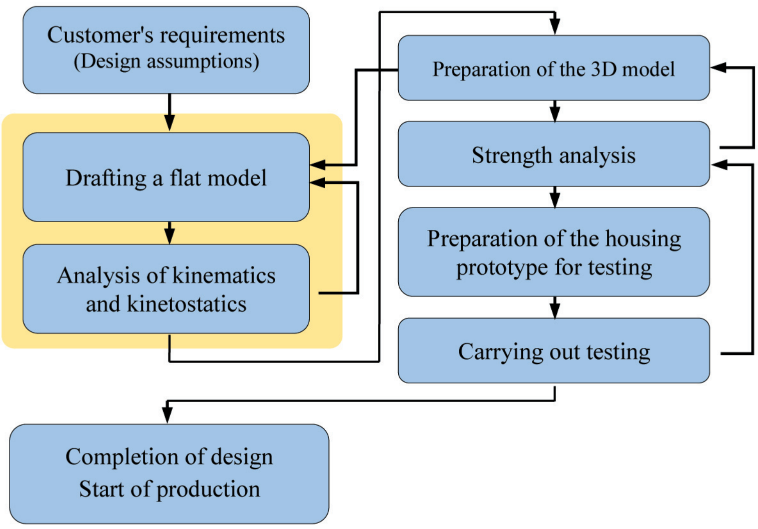


Fig. 1. Steps in the design and digital prototyping process of a new section of powered roof support

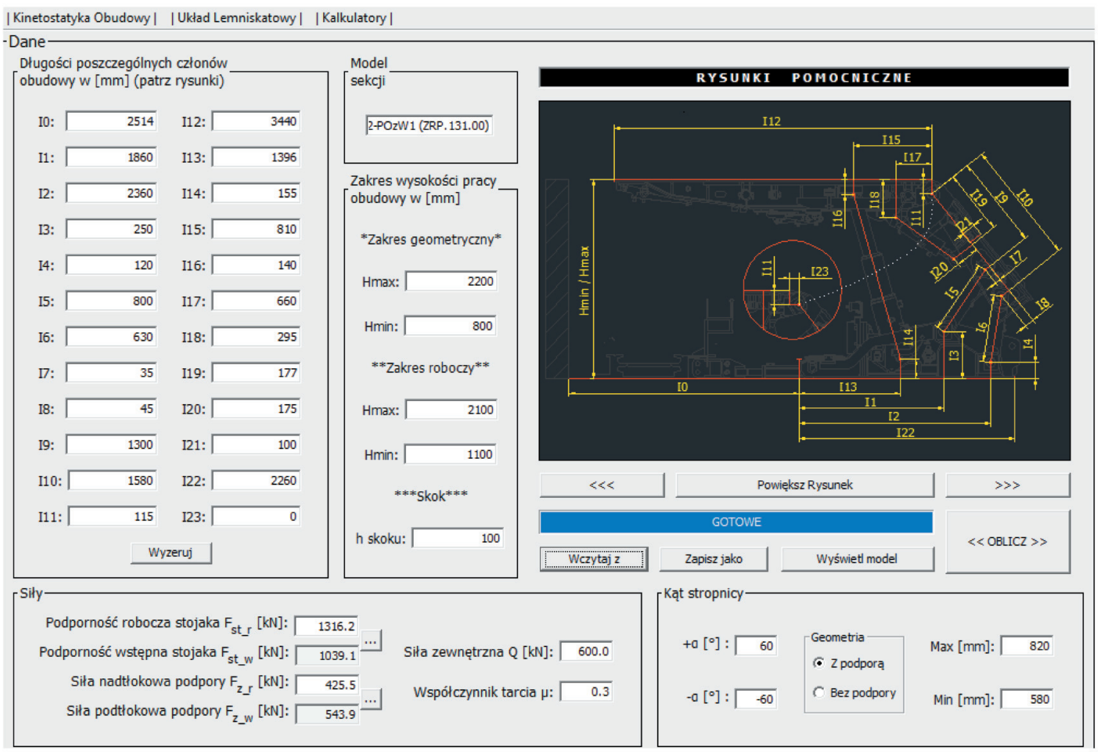


Fig. 2. PrsLab interface (in Polish)

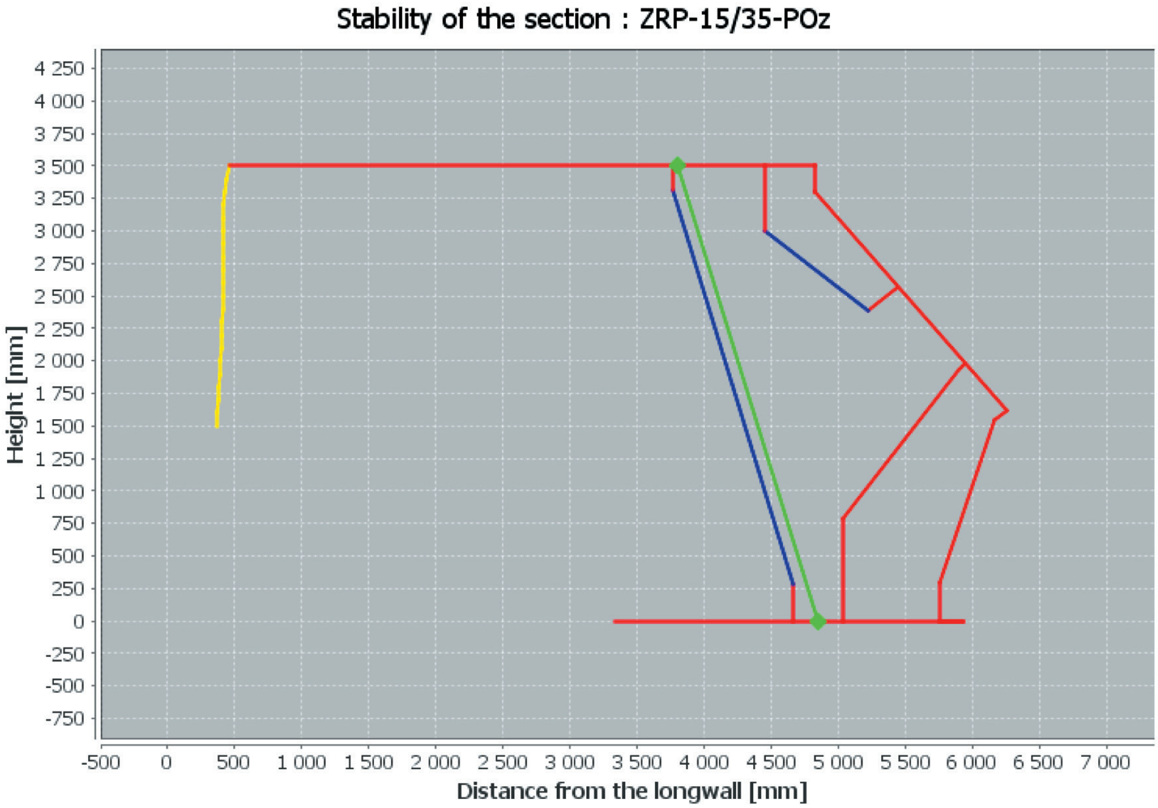


Fig. 3. Kinematic chain of the section model with a marked roof opening path (yellow)

An important element of PrsLab is that it automatically searches for the optimum section geometry and maximum forces at the section's kinematic nodes. The analyses carried out make it possible to design a 3D virtual model of the roof support in the Autodesk Inventor CAD computer program and its strength verification in the ANSYS computer program in accordance with PN-EN 1804-1:2021-05 [3].

Figure 4 summarizes the design of the ZRP-15/35-POz powered roof casing section created in Autodesk Inventor and the results of the strength analysis in the form of a reduced stress map according to the Huber–Mises–Hencky hypothesis, created by loading the roof support structure in ANSYS.

The main objective of the strength calculations is to design a roof support that will ensure the safe operation of machine components and structures while minimizing manufacturing and operating costs. The main factor in minimizing costs is the appropriate choice of materials and geometry of the designed roof support parts.

a) *b)*

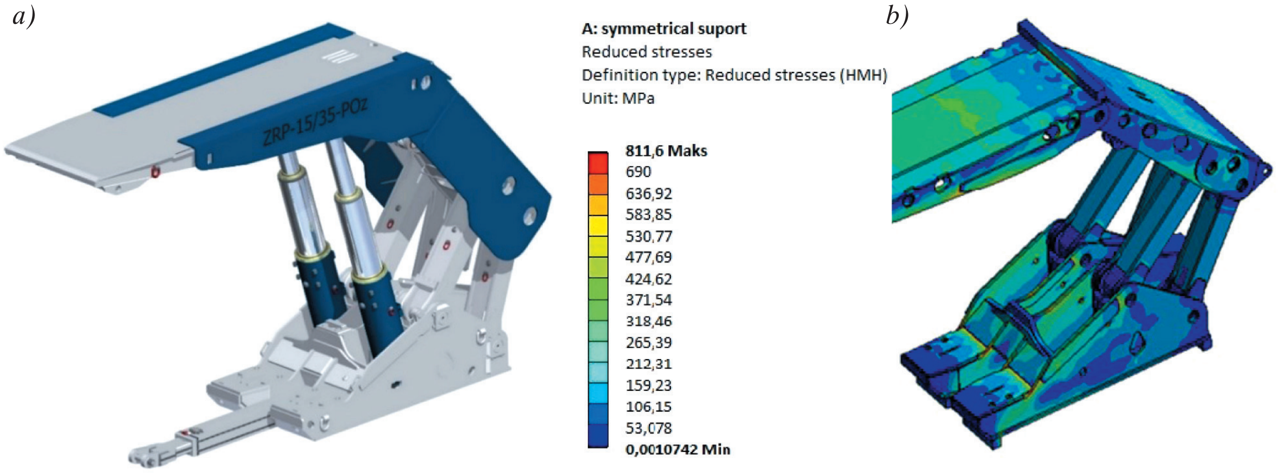
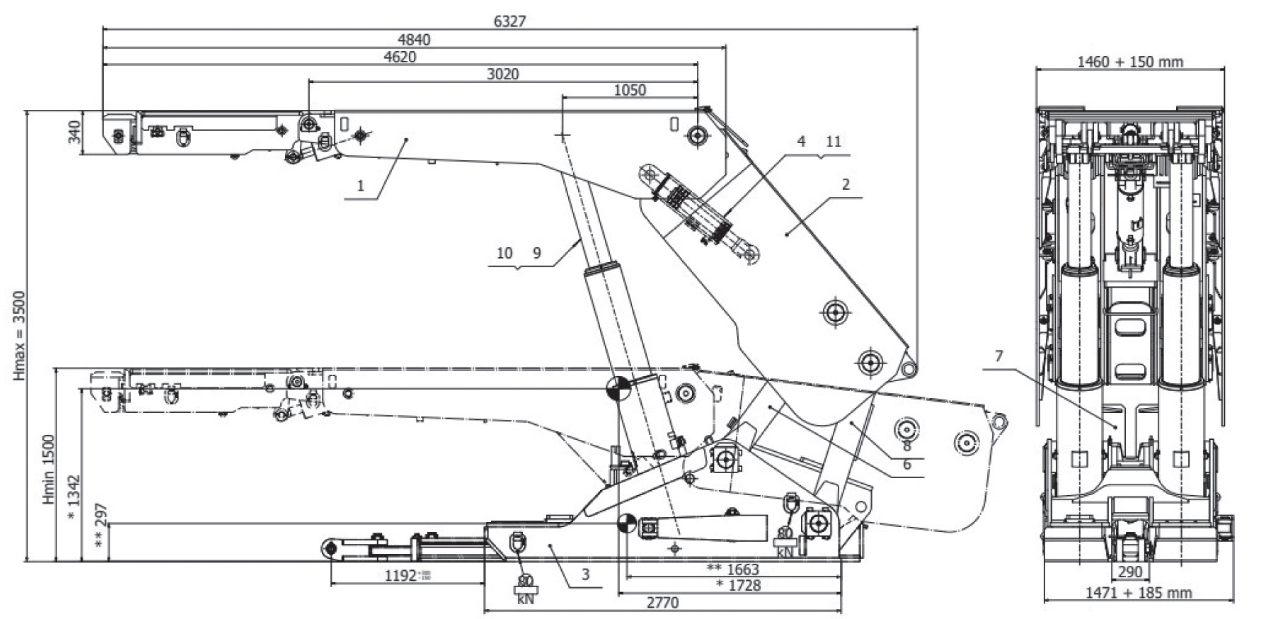


Fig. 4. ZRP-15/35-POz powered roof support designed in Autodesk Inventor (a); load stress map of the ZRP-15/35-POz roof support structure drawn in ANSYS software (b)

The analyses carried out enable the development of the correct 2D construction documentation for the section (Fig. 5), which in turn forms the basis for the development of technological documentation, enabling the programming of CNC machines and welding robots.



TECHNICAL CHARACTERISTICS		
PARAMETER	VALUE	UNIT
Roof support height range	1,5 ÷ 3,5	[m]
Working range of roof support in seams without rock burst hazard	1,7 ÷ 3,4	[m]
Working range of roof support in seams with rock burst hazard	1,8 ÷ 3,4	[m]
Unit scale	1,5	[m]
Roof support step	0,8	[m]
Longitudinal longwall inclination	do 35	[°]
Transverse longwall inclination	±20	[°]
Props initial support capacity (for 30MPa)	2x 2120	[kN]
Props working support capacity (for 43 MPa)	2x 3039	[kN]
Unit working support capacity (for 43 MPa)	4277 - 5801	[kN]
Average unit floor pressure	1,537 - 2,083	[MPa]
Average unit roof pressure	0,988 - 1,339	[MPa]
Advancing force of unit (for 30 MPa)	603	[kN]
Advancing force of conveyor (for 30 MPa)	291	[kN]
Feed pressure	25 ÷ 30	[MPa]
Working fluid	HFAS lub HFAS	
Weight	~ 21 000	[kg]

- carrying capacity of transport grip
- centre of gravity of the roof support

1	End canopy assembly	ZRP.110.10.A	1	7191,37 kg
2	End shield system set	ZRP.110.12	1	3902,38 kg
3	Foot piece set	ZRP.110.03	1	4814,36 kg
4	Canopy support	ZRP.015.04	1	139,17 kg
5	Sliding system W7	ZRP.110.05.W7	1	1153,88 kg
6	Front connector	ZRP.110.06	2	443,77 kg
7	Rear connector (left)	ZRP.110.07	1	430,30 kg
8	Rear connector (right)	ZRP.110.08	1	430,30 kg
9	Two-telescopic prop	ZRP.110.13	2	937,43 kg
10	Hydraulic system W1 (end section)	ZRP.110.14.BSN.W1	1	
11	Canopy actuator lock	ZRP.110.15	1	26,95 kg

Fig. 5. 2D construction documentation of ZRP-15/35-POz powered roof support

3. TECHNOLOGICAL PRODUCTION PREPARATION

3.1. Material analysis

The repair, modernization and production of powered roof supports require the provision of materials with strictly defined parameters and in compliance with the standards of the series: PN-EN 1804 [3–5] and PN-EN ISO 12100 [8]. In the research laboratory at the ZRP plant, tests are carried out to verify the materials in terms of their strength parameters to ensure the required reliability and durability of the manufactured structural components. In order to select the appropriate steel grade and welding technology for the powered roof support intended for repair and modernization, a material analysis of the base structure must be carried out. The tests are carried out by employees of the Quality Control Department and include preliminary testing of the hardness of the structure's plates and analysis and testing of the chemical composition of the steel using portable spectrometers that make it possible to determine the chemical composition of the steel (Fig. 6a). This method makes it possible to determine once, in a non-destructive manner, the content of the individual chemical elements in a material. At the same time, in order to increase the accuracy of the analyses performed in the laboratory, strength tests on steel materials are carried out using a testing machine with a maximum force of up to 100 kN (Fig. 6b).

In the case of the production of new powered roof supports, the use of particular steel grades is determined by the designer based on numerical calculations. At the ZRP plant, S355J2+N, S690QL and S700MC steels are currently used for the manufacture of the structural components of the powered roof supports. Welding of these steels is carried out in accordance with welding technologies approved by the Welding Institute in Gliwice, with the appropriate welding regime maintained. Failure to use the correct welding technology can lead to plastic deformation of the components, which can result in a poor test result for the roof support prototype on the test bench.

a) *b)*

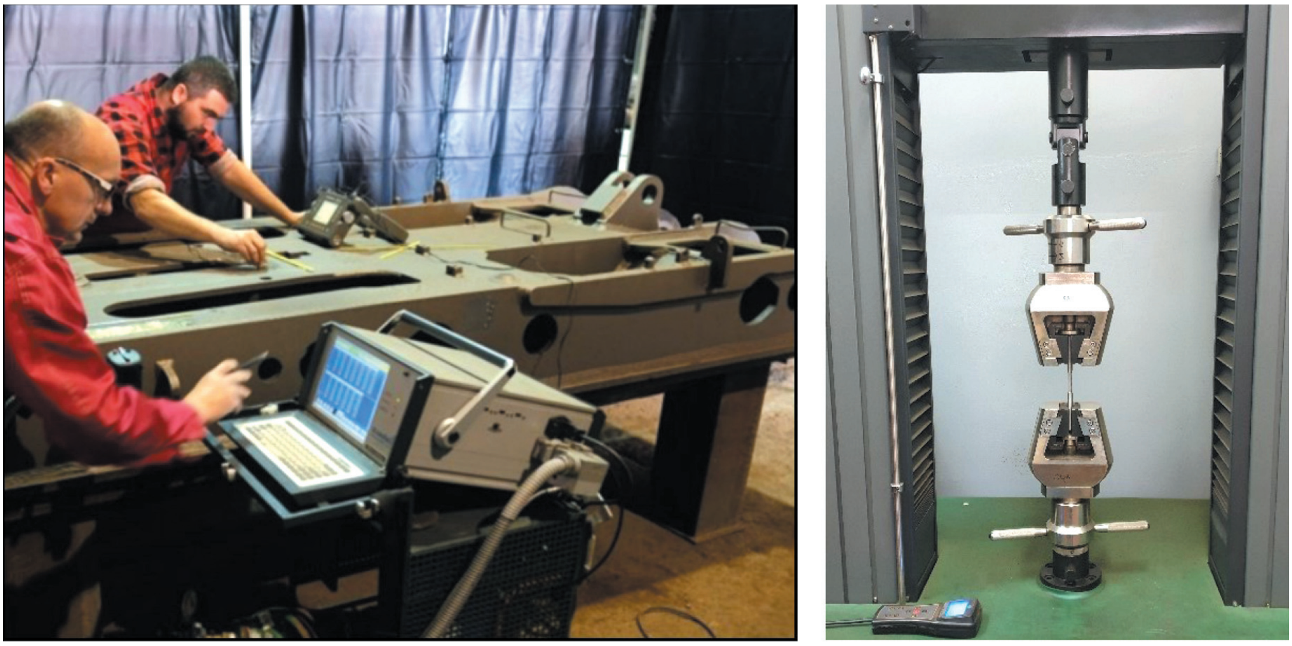


Fig. 6. Spectrometer examination of the chemical composition of structural components (a); tensile machine for tearing metal samples (b)

3.2. Welding techniques

At the ZRP site, the most commonly used welding method is the MAG (Metal Active Gas) method with the number 135, i.e. welding with active chemical gas, i.e. carbon dioxide and argon. In addition, Submerged Arc Welding (SAW), which involves joining metal parts by means of an electrode in a coating of granular flux, is also used. The choice of welding process must be closely related to the following factors: the geometry of the workpiece to be welded, the availability of welding positions, the capability of the welding robot, the accuracy of the final workpiece, the type of weld and the number of workpieces.

When a workpiece is qualified for robotic welding, two methods of programming the welding robot are used: online or offline. The online method involves programming the robot directly at the workstation by «teaching» it the correct sequence of welding movements. The operator uses a device called a «teach pendant» to indicate points on the workpiece that determine the path of the individual sweeps of the robot arm, i.e. the path of the weld. In contrast, the second offline method uses Cloos' RoboPlan simulation program to program the welding robot. A 3D model of the workpiece is loaded into the program and positioned in the virtual welding station, then the welding and travel paths (all the other auxiliary paths that are responsible for driving the robot arm to the welding area) are plotted. Once the relevant welds and auxiliary movements have been correctly plotted, a code is generated and uploaded to the machine. The use of the offline program increases the functionality of the welding robot's use by adapting it easily to changing conditions and facilitating the programming of its more complex movements. An additional advantage of the software is that the machining program can be tested in computer simulation before it is implemented in production. Welding robots at the plant are mainly used for chamfering sheet metal detailing and welding structural components (Fig. 7) and for hardfacing work on armored conveyor troughs.

a) b)

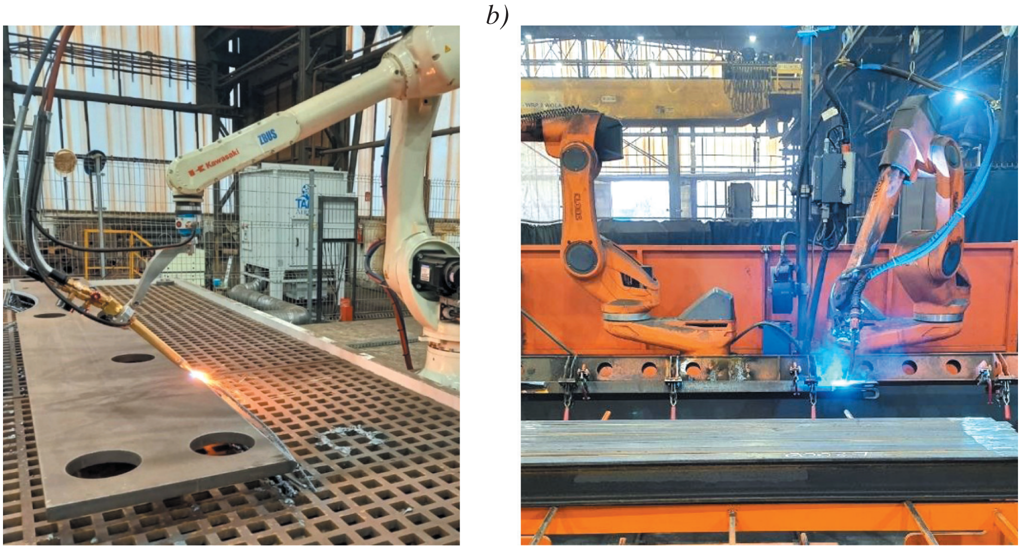


Fig. 7. Example of the use of welding robots for: a) chamfering metal sheets; b) welding of structures

3.3. Machining

Once the 2D construction documentation has been completed, the development of technological processes, i.e. the technology for machining workpieces and the generation of CNC machine control codes, begins. For example, under the conditions prevailing at the ZRP plant, numerically controlled burners supported by CAM software (Wrykrys and NestFab) are used to cut specific parts from sheet metal. These programs make it possible to create firing plans and optimize the distribution of the parts on the sheets, which reduces waste and maximizes the use of the material at hand. Similarly to numerically controlled lathes and milling machines, they are operated by Siemens NX software, which executes the technological process indicated by the technologist and generates automatic code, which in turn is uploaded to the machines. This code is a record of a sequence of actions, i.e. commands for the machine, which carries out CNC machining according to this plan.

Zakład Remontowo-Produkcyjny has an extensive machine park equipped primarily with metal cutting machines: saws, milling machines, lathes, machining centers and robots for chamfering sheet metal and welding structures. Recently, the plant's production capacity has been enhanced with the addition of two CNC-controlled machines – a honing machine and a deep-hole drilling machine – which have significantly increased the efficiency of the production of power hydraulics. The deep-hole drilling machine makes it possible to drill holes with a diameter range of 3–30 mm to a maximum depth of 1,600 mm, such parameters were unattainable before the machine was purchased. Figure 8 shows an example of a CNC machining center and a deep-hole drilling machine.

a) b)

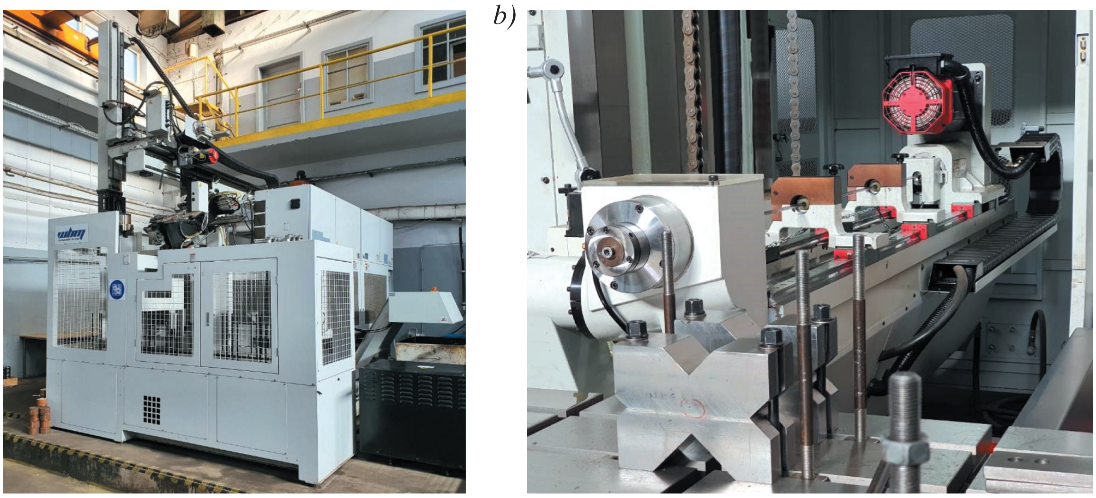


Fig. 8. CNC machining center for machining (a); CNC machine for deep-hole drilling (b)

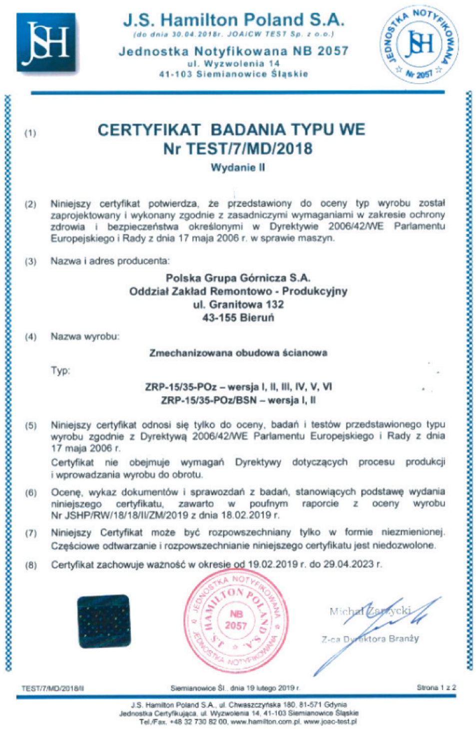
4. PROTOTYPE STRENGTH TESTING AND CERTIFICATION

According to the Regulation of the Minister of Economy of 21 October 2008 on essential requirements for machinery (Dz.U. [Journal of Laws] No. 199, item 1228), new and modernized sections of powered roof supports must undergo EC-type testing [9]. EC-type testing is a procedure in which a notified body examines and then certifies that the model of machinery, referred to as the «type» (in our case, the powered roof support section), submitted for testing by the manufacturer meets the requirements of the Regulation referred to.

Testing of the prototype powered roof support section must be carried out in an accredited laboratory in accordance with the requirements of the Machinery Directive [10] and the PN-1804 series of standards [3–5]. A positive result of the EC-type test is the basis for applying to the certification body for a certificate, which confirms that the roof support complies with the technical documentation and is fully checked in terms of its safe use. Figure 9 shows a prototype of the ZRP-15/35-POz roof support on the test bench in the TLO Opava laboratory, which was successfully tested and released for production on the basis of the certificate issued.

a)

b)



J.S. Hamilton Poland S.A.
(do dnia 30.04.2018r. JOAICW TEST Sp. z o.o.)
Jednostka Notyfikowana NB 2057
ul. Wyzwolenia 14
41-103 Siemianowice Śląskie

(1) CERTYFIKAT BADANIA TYPU WE
Nr TEST/7/MD/2018
Wydanie II

(2) Niniejszy certyfikat potwierdza, że przedstawiony do oceny typ wyrobu został zaprojektowany i wykonany zgodnie z zasadniczymi wymaganiami w zakresie ochrony zdrowia i bezpieczeństwa określonymi w Dyrektywie 2006/42/WE Parlamentu Europejskiego i Rady z dnia 17 maja 2006 r. w sprawie maszyn.

(3) Nazwa i adres producenta:

Polska Grupa Górnicza S.A.
Oddział Zakład Remontowo - Produkcyjny
ul. Granitowa 132
43-155 Bieruń

(4) Nazwa wyrobu:

Zmechanizowana obudowa ścianowa

Typ:

ZRP-15/35-POz – wersja I, II, III, IV, V, VI
ZRP-15/35-POz/BSN – wersja I, II

(5) Niniejszy certyfikat odnosi się tylko do oceny, badań i testów przedstawionego typu wyrobu zgodnie z Dyrektywą 2006/42/WE Parlamentu Europejskiego i Rady z dnia 17 maja 2006 r.
Certyfikat nie obejmuje wymagań Dyrektywy dotyczących procesu produkcji i wprowadzania wyrobu do obrotu.

(6) Ocenę, wykaz dokumentów i sprawozdań z badań, stanowiących podstawę wydania niniejszego certyfikatu, zawarto w poufnym raporcie z oceny wyrobu Nr JSHP/RW/18/18/II/ZM/2019 z dnia 18.02.2019 r.

(7) Niniejszy Certyfikat może być rozpowszechniany tylko w formie niezmienionej. Częściowe odtwarzanie i rozpowszechnianie niniejszego certyfikatu jest niedozwolone.

(8) Certyfikat zachowuje ważność w okresie od 19.02.2019 r. do 29.04.2023 r.

JEDNOSTKA NOTYFIKOWANA J.S. HAMILTON POLAND S.A. NB 2057

Michał Zarzycki
Z-ca Dyrektora Branży

TEST/7/MD/2018/II Siemianowice Śl., dnia 19 lutego 2019 r. Strona 1 z 2

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Fig. 9. Prototype of the ZRP-15/35-POz roof support on the TLO Opava test bench (a); certificate confirming a positive result of the EC type-examination (b)

5. SUMMARY

Zakład Remontowo-Produkcyjny (part of the PGG SA structures) has been expanding its design, production, training and testing capabilities for products and materials used for many years. It specializes in the production of powered roof support sections and suspension railways. Product design is carried out using numerical methods, and the created virtual models of the developed products are tested in terms of kinematics, strength, and collision. Only positive results from numerical testing of the product form the basis for the creation of documentation, particularly technological documentation, which forms the basis for machine software. The ZRP plant uses only CNC machines for sheet metal cutting, welding (using robots), hard-facing, cylinder honing and long drilling. The software for the machines mentioned is executed exclusively by the plant's employees. The product is subject to in-process inspection during its manufacture. The finished (final) product is tested by a notified body for compliance with EU directives and is placed on the market with a DTR and applicable certificate. The plant has an extensive training system, particularly in the field of welding, and is keen to cooperate with scientific and research bodies. The methods described are combined in the production cycle to create a product of the highest quality, as in the presented case of the ZRP-15/35-POz powered roof support section. More than 1,200 sections with different working heights were produced in the version shown. The plant is also prepared to undertake the production of other machines of similar design. It conducts systematic market research into technological, machine and design innovations and replenishes its equipment within its financial capabilities.

Zakład Remontowo-Produkcyjny has overhauled the sections of powered roof supports currently in operation at PGG SA and, on this basis, verified and standardized them. Roof supports with divisions for the low (ZRP-12/24-POz), medium (ZRP-15/35-POz), and high (ZRP-19/41-POz) longwalls have been designed. Figure 10 shows the range of powered roof supports manufactured by the ZRP plant.

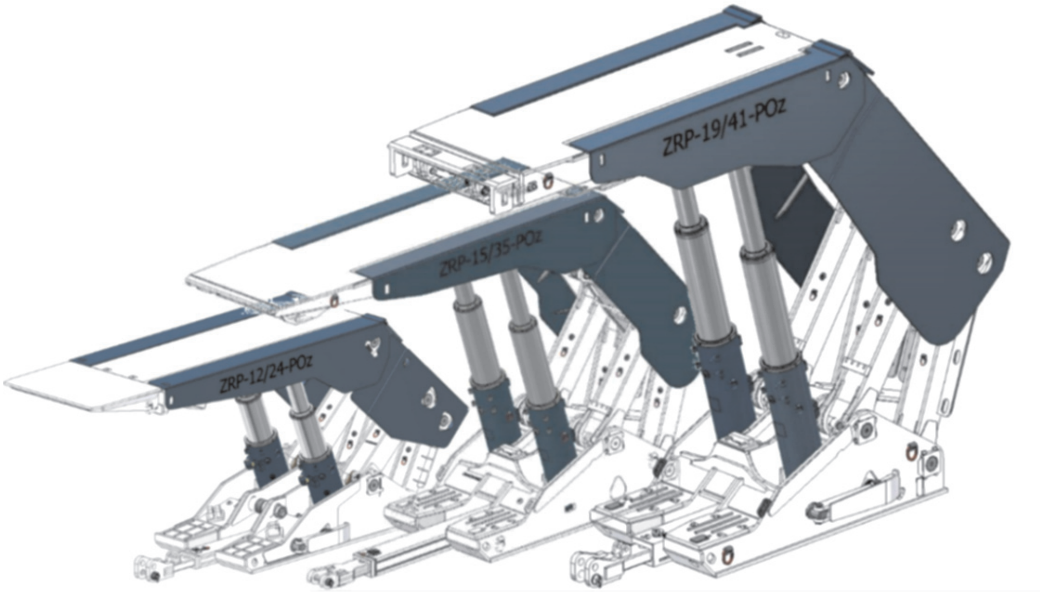

Fig. 10. A range of powered roof supports designed by ZRP for PGG SA (ZRP-12/24-POz, ZRP-15/35-POz, ZRP-19/41)

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