EVALUATION AND CHOICE OF A WRAPPER FOR PACKING PRODUCTS USING THE AHP METHOD

Ocena i wybór rozwiązania do pakowania urządzeń elektrycznych z zastosowaniem metody AHP

Robert CIEŚLAK ORCID 0000-0002-1320-0410
Julia KAŁUŻNA
Katarzyna PETA ORCID 0000-0002-9915-838X
Marcin SUSZYŃSKI ORCID 0000-0001-7926-0574
Marcin WIŚNIEWSKI ORCID 0000-0001-7187-159X

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Abstract: The article presents the assessment and selection of wrapper for packaging the products in an electrical industry company according to the method of analytical, hierarchical decision making process (AHP). The decision making process was based on the available technical and operational parameters of wrappers from the leading manufacturers based on the selection criteria and their weights. The last part of the thesis contains a hierarchical structure of assessment and conclusions.
Keywords: AHP – Analytical Hierarchy Process, wrapper, assessment

Streszczenie: W artykule przedstawiono ocenę i wybór owijarki do pakowania produktów w firmie branży elektrycznej według metody analitycznego, hierarchicznego procesu decyzyjnego (ang. Analytical Hierarchy Process – AHP). Proces decyzyjny przeprowadzono w oparciu o dostępne parametry techniczno-eksploatacyjne owijarek czołowych producentów na podstawie przyjętych w pracy kryteriów wyboru oraz ich wag. Końcowa części pracy zawiera strukturę hierarchiczną dla przeprowadzonej oceny oraz podsumowanie.
Słowa kluczowe: AHP – Analytical Hierarchy Process, owijarka, ocena

Introduction

Packaging is an important element of the production process in every enterprise. It performs two important functions: it allows protecting the product during loading and during transport against mechanical damage and corrosion, and also gives it an aesthetic value.

The purpose of the work is to become familiar with the previous process of packaging the finished products in an electrical industry company. Currently, it is done manually by a group of employees who, when wrapping high switchgears, must climb ladders to properly pack products. When packing in the company, the finished products are found in the final assembly hall. They are wrapped by the employees in stretch foil, which is hard and uncomfortable work. The analyses show that the packaging time is far too long and the process itself is chaotic and unprofessional.

The solution of this problem is to improve it by using an automatic pallet wrapping machine, which shortens the packaging time of finished products, significantly improves comfort, employee safety and the organization of the work. The device was selected by comparing several of the most suitable machines for the company, especially taking the most important parameters into account. The AHP method was used to analyze the selection of the most optimal wrapper. The AHP method can be helpful in making decisions and determining the requirements relevant to the construction of work station [6]. The pallet wrapper is a machine that, using a roll with stretch film and a properly set program in an easy to use control panel, wraps ready-made products for the customer; the device significantly improves the efficiency of the packaging process and reduces the cost of the used materials.

Characteristics of the AHP method

The AHP method was developed by the American scientist Thomas L. Saaty [4, 5] in 1970 and has been constantly modified since then. It is based on mathematical calculations and takes into account the impact of human psychology in its assessment, supporting the making of complex decisions with a fixed number of their variants. It provides a comprehensive and structured way of dividing the problem into factors independent of each other.

The basic assumption of the AHP method is Satty's statement [4] that human judgements are relative, depending on the assessment approach, their personal characteristics, their role and the value system they profess. The result of such reasoning is a multi-faceted approach to the decision-making problem, manifested in determining the weights of significance (utility) of

individual variants included in the assessment criteria. These decision options are analyzed as part of the comparative assessment. Aggregation of partial grades, taking into account their type, is based on the calculation of the ordered vector of a set of points. The method has been used in many decision situations with different risks of a failure, e.g. in business, industry, statistical decisions [2]. Many companies have developed their own computer programs based on the AHP method, supporting their introduction in a specific application. Using this method you can:

- choose the decision variant,
- assess the quality of e.g. computer software,
- determine the usefulness of safety of technical devices,
- support financial decisions,
- make purchase decisions,
- evaluate construction solutions,
- carry out corrections and organizational changes.

It can be stated that the method is particularly useful [1] in cases of:

- the existence of a hierarchy of evaluation criteria showing different levels of detail, linked to a hierarchy of goals, or expected benefits,
- determining the criteria for assessing options that do not focus on the quantitative but qualitative approach, where the majority of the assessor's (decision-maker)'s ratings are subjective,
- the occurrence of full comparability of variants, i.e. comparison and evaluation are carried out on a set of variants in the same class.
- Making decisions according to the AHP method [1] involves:
- building a hierarchical model - spreading the decision problem and the description of the hierarchy of criteria,
- assessment - comparison of pairs of criteria and decision variants using the relative scale of Satty dominance,
- setting global and local preferences - mutual priorities (materiality) in relation to criteria and decision options,
- classification of decision variants - ordered due to their participation in meeting the requirements of the primary goal.

Parameters of wrappers of the selected manufacturers

Depending on the specific application in the industry, many types of industrial wrappers are available. The leading ones include the following wrappers:

- disk wrapper ROBOPAC type MASTERPLAT PLUS,
- self-propelled ROBOPAC type ROBOT MASTER PLUS,
- semi-automatic self-propelled SPIDER – PACK,
- vertical ROBOPAC type ECOWRAP PLUS XL.

The basic technical parameters that distinguish industrial wrappers are:

- maximum height of items,
- maximum dimensions of the pallet,
- charging time,
- weight of items on the pallet,
- performance,
- film thickness.

AHP analysis of choosing the wrapper

The general algorithm for proceeding according to the AHP method is presented in Fig. 1. It enables evaluation by expert groups. A large number of assessments of the importance of individual factors may introduce inaccuracies due to a natural discrepancy in the preferences of the assessors. Therefore, in this case it is necessary to calculate – the value of the CI inconsistency index (formula 1). Failure to meet this condition is associated with the reintroduction of the assessment into the comparison matrix to meet the requirement of maintaining object dominance relations - the value of the CR compliance ratio (formula 2). The algorithm consists of several stages. The first is to present the problem and set the criteria. Next, the rating scales (according to Satty) are determined – by comparing them in the comparison table. The next stage is determining the weight values (priorities) and checking the correctness of the results obtained (matrix consistency test). The final stage is the compilation of results in the form of a hierarchical structure.

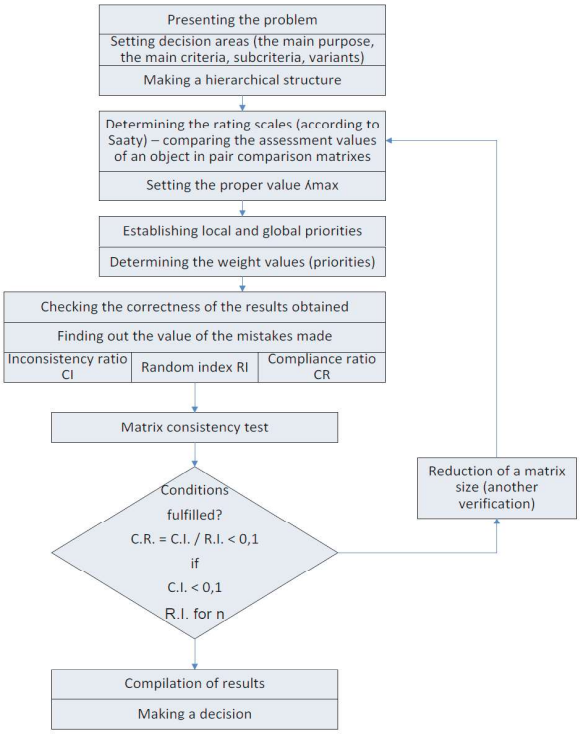

Fig. 1. The algorithm for management according to AHP method applying to a greater number of elements [1]

The paper presents, for example, the choice of an industrial wrapper for packaging products for a company from the energy sector (first stage). Therefore, according to the authors, the most important parameters for this type of application are presented in Table 1.

In the second stage, in order to compare the possible application of industrial wrappers, the following criteria were adopted for assessment: maximum height-KA, maximum dimensions of the pallets-KB, loading time-KC, weight of the item on the pallet-KD.

The comparison of each pair of criteria is recorded in the matrix N x N, where N is the number of elements at a given level. The matrix constructed in this way has the following properties: on the diagonal of the matrix all words a_{ii} = 1, above the diagonal a_{ij} = comparison, and below the diagonal the value of the inverse of these comparisons a_{ji} = 1. The comparison procedure is presented in Tab. 2.

The procedure for calculating local weights is as follows:

Table 1. Chosen parameters – criteria for industrial wrapping machines [7,8,9,10,11,12,13,14,15]

No.	Disc wrapper ROBOPAC type MASTER-PLAT PLUS	Self-propelled ROBOPAC type ROBOT MASTER PLUS	Semi-automatic self-propelled	Vertical ROBOPAC type ECOWRAP PLUS XL
1. Maximum height of items	2000 mm –optionally 3100 mm	2200 mm – opcjonalnie 2400 mm	SPIDER – PACK	2000 mm – optionally 2400 mm
2. Maximum dimensions of the pallet	1200x1200mm	2200x2200 mm	Without limitations (without the column)	1200x1200mm
3. Charging time	5-8 hours	5-8 hours	8-10 hours (without the column)	10 hours
4. Weight of items on the pallet	2000 kg	Any	Any (without the column)	Any
5. Performance	Up to 25 pallets/hour	Up to 20 pallets/ hour	Up to 20 pallets/ hour	Up to 30 pallets/ hour
6. Film thickness	17-35µm	17-35µm	35-80µm	17-35µm

Table 2. A pairwise comparison of parameters – criteria importance [self study]

		KA	KB	KC	KD	KE	KF	total	KA	KB	KC	KD	KE	KF	weight	rating
Maximum height	KA	**1.00**	2.00	2.00	3.00	3.00	4.00	**15.00**	0.34	0.19	0.45	0.28	0.40	0.27	**0.322**	**1**
Maximum dimensions of the pallet	KB	0.50	**1.00**	0.33	0.50	0.50	2.00	**4.83**	0.17	0.10	0.07	0.05	0.07	0.13	**0.098**	**5**
Charging time	KC	0.50	3.00	**1.00**	4.00	2.00	3.00	**13.50**	0.17	0.29	0.23	0.37	0.27	0.20	**0.253**	**2**
Weight of an item on the pallet	KD	0.33	2.00	0.25	**1.00**	0.50	3.00	**7.08**	0.11	0.19	0.06	0.09	0.07	0.20	**0.120**	**4**
Performance	KE	0.33	2.00	0.50	2.00	**1.00**	2.00	**7.83**	0.11	0.19	0.11	0.18	0.13	0.13	**0.145**	**3**
Film thickness	KF	0.25	0.50	0.33	0.33	0.50	**1.00**	**2.91**	0.09	0.05	0.07	0.03	0.07	0.07	**0.062**	**6**
TOTAL		**2.91**	**10.50**	**4.41**	**10.83**	**7.50**	**15.00**	**51.15**							**1.000**	

a) adding up the scores for each column and then saving them in the sum column,
b) each grade in columns KA to KG is divided by the sum of the grades for this column and the result is entered in the following columns, as appropriate,
c) calculating the weight for a selected criterion is made by adding up the values recorded in the fields from KA to KG, then the sum obtained is divided by the number of elements and the result is saved in the weight field,
d) checking the correctness of calculations by adding weights of all elements of a given level (the sum of weights is always equal to 1); when using the AHP method, it should also be checked that the results obtained do not violate the principle of constancy of preferences; for this purpose, the inconsistency factor λmax must be calculated. [4].

The choice of criteria is always dictated to a large extent by the availability of information on the selected wrappers and the significance of parameters, which is why the authors based their decision on the most important factors of choosing an industrial wrapper quoted in chapter 3 [3].

Checking the correctness of the results obtained

Using the algorithm of the AHP method, check in the next step whether the results obtained do not violate the principle of constancy of preferences (checking the correctness of the results obtained). For this purpose, the inconsistency factor λmax was calculated (Table 3). In the Saaty method, the necessary condition is to obtain the required conformity of assessments, expressed by the value of the compatibility ratio of the CI comparison matrix (formula 1) and the CR compliance ratio (formula 2), whose value should not exceed 0.1.

Table 3. Checking the correctness of the results obtained [own study]

Criteria	Total value	Weights	Inconsistency index
KA	2.91	0.32	0.94
KB	10.50	0.10	1.03
KC	4.41	0.25	1.12
KD	10.83	0.12	1.30
KE	7.50	0.14	1.09
KF	15.00	0.06	0.93
Total			6.40

The following procedure is used to check that the preferences are stable. The inconsistency index for individual criteria is calculated as the product of the sum of the scores and weights of individual criteria.

After substituting the values of λmax = 6.40 and n = 6 into the formula (1), the values of the compliance index CI = 0.0642 and the compliance ratio CR = 0.0518 calculated according to the formula (2) were obtained.

$$CI = \frac{\lambda_{max} - n}{r(n-1)} = 0{,}0642 \quad (1)$$

where
n – the value of a random index according to Saaty (*n* = 6),
r – the matrix index (*r* = 1.24).

Table 4. The value of „r" index for the size of an array „n" [4]

n	1	2	3	4	5	6	7	8	9	10
r	0.0	0.0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

and:

$$CR = \frac{CI}{r} = 0.0518 \quad (2)$$

In the above example, two conditions are met; CI <0.1 and CR <0.1, i.e. the preference stability has not been affected. Then the weights were calculated and a ranking was established for each of the adopted parameters - the criteria of an industrial wrapper. In Tab 5-7, in accordance with the procedures for comparing the criteria given above, for example, the method of creating a partial

Table 5. A chosen parameter, „maximum dimensions of the pallet" [one's own study based on materials 7-15]

Industrial wrappers	Maximum pallet dimensions
Disc wrapper ROBOPAC type MASTERPLAT PLUS	1200x1200 mm
Self-propelled ROBOPAC type ROBOT MASTER PLUS	2200x2200 mm
Semi-automatic self-propelled SPIDER – PACK	Without limitations (without the column)
Vertical ROBOPAC type ECOWRAP PLUS XL	1200x1200 mm

Table 6. A pairwise comparison for the „maximum dimensions of the pallet" [own study]

	WA	WB	WC	WD	WE	WF	total	WA	WB	WC	WD	WE	WF	weight
WA	**1.00**	0.33	3.00	3.00	3.00	3.00	**13.33**	0.19	0.12	0.34	0.26	0.18	0.36	**0.242**
WB	3.00	**1.00**	2.00	3.00	4.00	3.00	**16.00**	0.56	0.36	0.23	0.26	0.24	0.36	**0.336**
WC	0.33	0.50	**1.00**	2.00	3.00	0.50	**7.33**	0.06	0.18	0.11	0.18	0.18	0.06	**0.128**
WD	0.33	0.33	0.50	**1.00**	3.00	0.50	**5.66**	0.06	0.12	0.06	0.09	0.18	0.06	**0.094**
WE	0.33	0.25	0.33	0.33	**1.00**	0.33	**2.57**	0.06	0.09	0.04	0.03	0.06	0.04	**0.053**
WF	0.33	0.33	2.00	2.00	3.00	**1.00**	**8.66**	0.06	0.12	0.23	0.18	0.18	0.12	**0.147**
TOTAL	**5.32**	**2.74**	**8.83**	**11.33**	**17.00**	**8.33**	**53.55**							**1.000**

Table. 7. Checking the correctness of the results obtained [own study]

Maximum pallet dimensions			
Criteria	**Total value**	**Weights**	**Inconsistency index**
WA	5.32	0.24	1.29
WB	2.74	0.34	0.92
WC	8.83	0.13	1.13
WD	11.33	0.09	1.06
WE	17.00	0.05	0.90
WF	8.33	0.15	1.22
Total			**λmax = 6.53**

ranking for the „maximum pallet dimensions" criterion was presented

$$CI = \frac{\lambda_{max} - n}{r(n-1)} = 0.0856 \quad (3)$$

and:

$$CR = \frac{CI}{r} = 0{,}0691 \quad (4)$$

The final stage of assessment and selection of an industrial wrapper according to the AHP method is the

Table. 8. Checking the correctness of the results obtained [own study]

Industrial wrappers		Maximum height	Maximum pallet dimensions	Maximum pallet dimensions	Weight of an item on the pallet	Performance	Film thickness	Total	Rating
ROBOPAC type MASTERPLAT PLUS	**WA**	0.32	0.24	0.15	0.38	0.22	0.07	1.36	1
ROBOPAC type ROBOT MASTER PLUS	**WB**	0.13	0.34	0.08	0.14	0.39	0.06	1.14	2
SPIDER-PACK	**WC**	0.17	0.13	0.14	0.09	0.06	0.19	0.77	4
ROBOPAC type ECOWRAP PLUS XL	**WD**	0.05	0.09	0.14	0.06	0.11	0.36	0.83	3

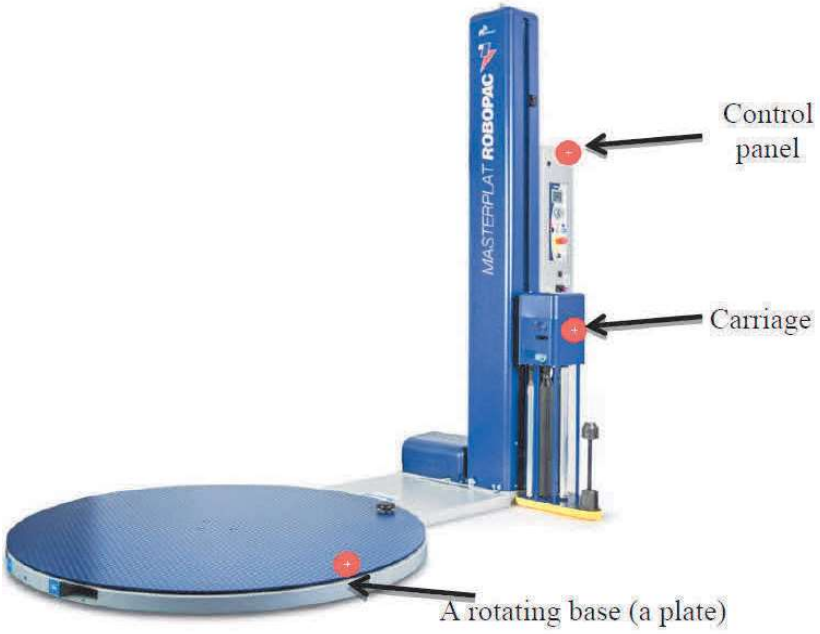

Fig. 2. A ROBOPAC disk wrapping machine MASTERPLAT PLUS

development of a hierarchical structure. The results obtained are presented in Tab. 8.

The presented analysis shows that the ROBOPAC MASTERPLAT PLUS disc wrapping machine should be selected [Fig. 2].

Partly automated packing process

The packaging process with the applied Robopac Masterplat plus disc wrapping machine will take place in the following order:

- loading the product on a pallet truck,
- placing the product on the wrapper,
- applying polystyrene corners,
- starting the program in the control panel,
- transporting the wrapped object by forklift to the warehouse of products ready for shipment to the customer.

An additional innovation is the use of polystyrene corners, which significantly better protect finished products during loading and transport. To save time of packing products, both polystyrene corners and rolls with stretch foil will be located on individual shelves at the wrapping machine. Below is an illustrative packaging process in one of the halls in a company using a ROBOPAC MASTERPLAT PLUS disk wrapper in 3D structure using the SolidWorks program [Fig. 3].

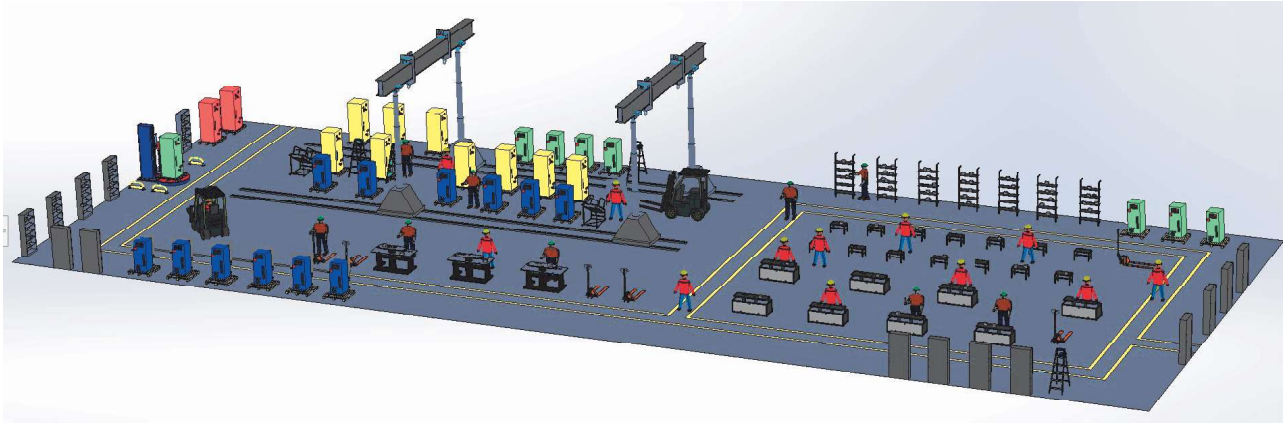

Fig. 3. 3D hall structure made in SolidWorks

The improved process of packing finished products by using a ROBOPAC MASTERPLAT PLUS disk wrapper made in a 3D structure (Fig. 4), which allows a detailed presentation of the work process. All products will be transported by forklifts to the wrapping position; the employee will set parameters in the control panel and control the operation of the machine. Packaged products will be transported to the warehouse or directly to the customer. A space was created for the wrapping machine in one of the halls in the energy company (Fig. 4). The machine meets the ergonomic requirements. To ensure work safety, protective barriers are attached around the device. To set the parameters wrapped in the control panel and to control the entire work process of the device, only one properly trained employee is sufficient.

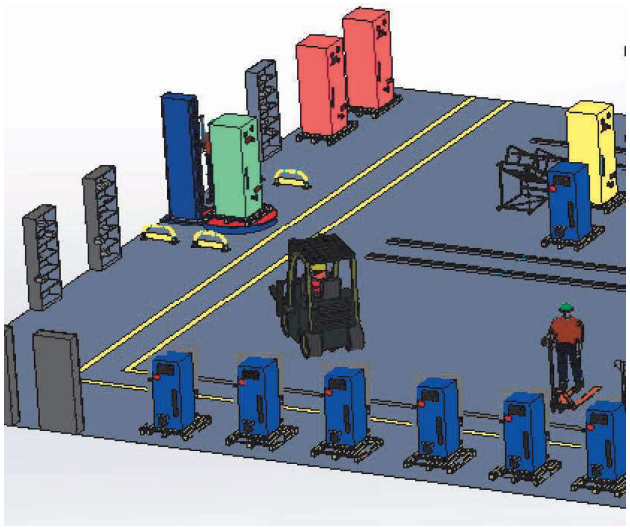

Fig. 4. An approximate packaging process in the hall in 3D made in SolidWorks

Conclusions

The study attempted to show that the AHP method allows evaluating the decision variants within one of their product classes. A formal approach is used to acquire and process expert assessments. It is a flexible method and can be adapted to various classes of the examined objects, including their specifications.

The obtained results indicate that on the basis of parameters - criteria specified by experts, the ROBOPAC type MASTERPLAT PLUS disk wrapping machine should be selected, followed by ROBOPAC type ROBOT MASTER PLUS. Relative values obtained as a result of calculations indicate that the advantage of the ROBOPAC MASTERPLAT PLUS wrapper over the others is large. This is the latest solution of ROBOPAC, thanks to which the operator operating the wrapper has an access to each side of the machine. In addition, it is equipped with a thin plate with a thickness of 30 mm, increasing safety at work and facilitating loading onto the wrapping plate, and the system of patented discs significantly increases the reliability of the machine.

The authors intend to analyze the advantages and disadvantages of the AHP method in the construction of more complex technological processes. To convince themselves that this method is justified for use by engineers, the authors intend to analyze more complicated assembly technological processes (choice of technological variant).

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dr inż. Robert Cieślak
Państwowa Wyższa Szkoła Zawodowa w Koninie
ul. Wyszyńskiego 35, 62-510 Konin, Polska
e-mail: robert.cieslak@konin.edu.pl

dr inż. Katarzyna Peta
Politechnika Poznańska
Wydział Inżynierii Mechanicznej
ul. Piotrowo 3, 60 - 965 Poznań, Polska
e-mail: katarzyna.peta@put.poznan.pl

dr inż. Marcin Suszyński
Politechnika Poznańska
Wydział Inżynierii Mechanicznej
ul. Piotrowo 3, 60 - 965 Poznań, Polska
e-mail: marcin.suszynski@put.poznan.pl

dr inż. Marcin Wiśniewski
Politechnika Poznańska
Wydział Inżynierii Mechanicznej
ul. Piotrowo 3, 60 - 965 Poznań, Polska
e-mail: marcin.wisniewski@put.poznan.pl

inż. Julia Kałużna
Absolwentka PWSZ w Koninie