Evaluation of the Reliability of the Gas Generator Starts

Dušan Nógli, Dominik Gašparovič, Plamen Kangalov, Zuzana Csillagová, Maroš Korenko

Abstract: *This paper presents the results obtained by evaluating the starts reliability of gas generators used for the propulsion of gas turbines. Evaluation of the reliability of starts, we conducted on a sample of eight gas generator, manufactured by General Electric. Collecting the necessary data from operation during the two years, we gradually acquire the information needed to calculate the starts reliability indicator. The aim of this article was to monitor and evaluate each attempt to start of the reporting period. Primarily we monitored overall percentage of starts and we show it as a percentage. Secondary we monitored a reliability of functions and failure rate of selected components of the hydraulic starting device.*

Keywords: *calendar time, gas generator, gas turbine, percent, starts reliability*

INTRODUCTION

Starting system provides a spin the gas generator to the operating speed, sufficient for its independent operation. The system is electro-hydraulic. It consists of a separate hydraulic unit, where pressure oil is guided to the gas generator. There a hydraulic motor transmits torque through claw clutch on the shaft of the gas generator (Fig. 1). When reached sufficient speed, is automatically switched off [1, 2, 4].

The aim of this paper is based on the available resources and information to assess the current state of gas generators starting reliability functions.

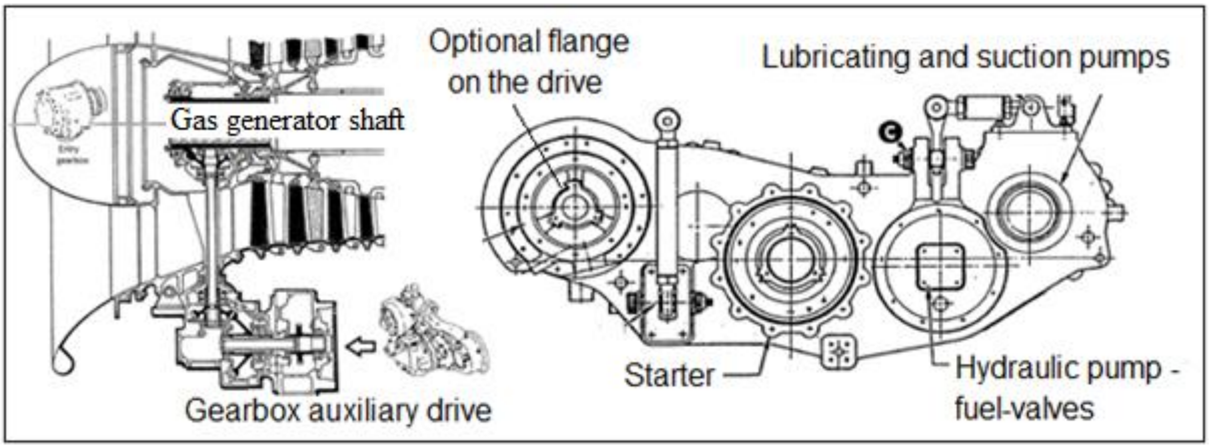

Fig. 1 Starter gas generator LM 2500

MATERIAL AND METHODS

The basic elements of the starting device of the gas generator LM 2500 are: oil tank, clutch cooling system, starting system (supplies pressure oil), system of starting process management and control of pumps, starter motors drainage, starter pumps drainage [2, 3].

Starting state: the oil tank is full, oil pipe lines, filters and valves filled with oil, the oil temperature at scale 15-70 °C, valve 33X QP-2 open and one of the valves 33X QP-1A / B open, all solenoid valves energized.

We followed these basic system functions to evaluate: launch electric motor MBX, activation valve QX QX-2AA-3A valve activation QX-2B, shutdown valves QX-2A-2B QX and QX-3A, disable electric motor MBX.

Activation of the valve QX QX-2AA-3A: After activation, the pressure in the control path changes the directional valve (which is part of the pump A4X-VG). The pressure oil from the pressure side of the booster pump gets on one side of the double-acting hydraulic cylinder, that tilts the pumps control board A4X-VG from the neutral position, thereby the pump start deliver pressurized oil to the starter motor, which starts to spin the rotor of the generator.

Activation of the valve QX-2B: After reaching the speed of the gas generator from 1200 to 1400 speed/min. leads to activation of the valve QX-2B. The channels in the valve will link and thereby increases the pressure in the path Y2, which causes a further tilt of the pump control board A4X-VG. Enlarge tilt control board means increase piston stroke of the pump starting and increase the speed of the gas generator.

Shutdown valves QX-2A-2B QX and QX-3A. After reaching the gas generator speed 4500 speed/ min. shuts down all solenoid valves. Tilt of control board pumps A4X-VG returns to the neutral position.

Shutdown of electric motor MBX: The last step is switch the starter pump *electric motor MBX*, however, cooling subsystem and drainage of motors cabinet remains in operation [3].

We monitored the reliability of temperature and pressure sensors of starting system in table (Table 1).

Table 1 Basic physical sensor

Element name		Setting	Range	Manufacturer
Number	Oil tank system			
1	The switch of high oil level in the tank		38mm	J.B:G.P. MILANO
2	The switch of low oil level in the tank		38mm	J.B:G.P. MILANO
3	Temperature switch - condition to start	15 °C	(10 - 70) °C	CELLA
4	Temperature switch - High temperature - warning	70 °C	(10 - 70) °C	CELLA
5	Indicator of starting oil temperature		(0 - 100) °C	WKA
6	Indicator of oil level in tank			HYDAC
	Cooling system and clutch lubrication of hydraulic motors system			
7	Switch high differential pressure filter	0.5 MPa	(41 - 345) kPa	ITT
8	Limit switch - Cooling Clutch			HONEYWELL
	System supplies the pressure starting oil			
9	Switch high differential pressure filter	0.5 MPa	(41 - 345) kPa	ITT
10	Limit switches - suction branch			HONEYWELL
11	Selector switch engines			
12	Pressure indicator in the pressure and suction branches		(0 - 60) MPa	WIKA
	The starting process management system and control of starter pump			
13	Switch high differential pressure filter	0.5 MPa	(41 - 345) kPa	ITT
14	Pressure indicator in the control supply route		(0 - 6) MPa	WIKA
	The drainage of starter motors system			
15	High pressure switch to the return oil filter	0.35MPa	(0.103-1.03) MPa	ITT
16	Pressure indicator in the return line to the tank oil		(0 – 0.6) MPa	WIKA

Starts reliability of the generator is an important indicator for the overall reliability of the transmission network of the international gas pipeline. Failure launches can mean failure to comply with the contracted amount or pressure at international level. It is the task number one for preventive maintenance and continuous operation workers, that figure was as high as possible.

The confidence level of turbo-compressors is monitored using indicators of reliability based on the time period, the condition of the generator and the number of characteristics associated with the operation and disorders. In this article we will discuss numerical characteristics starts reliability of the generator.

Starts reliability (SPS):

$$SPS = \frac{Us}{Ps} \cdot 100 \ [\ \%\ ] \qquad (1)$$

Where: Us - the number of successful starts TS
Ps - requirement to start TS

Indicator of the probability of a successful start is expressed by the ratio of successful starts (in the period) to the total number of start attempts.

RESULTS AND DISCUSSION

We monitored this information in the two time periods, which each was separately evaluated.

We constructed the table, we are lined tracking label of generators and organizational unit in the first column. In the second column, we recorded the requirements for operators to start. In another successful start of generators culminating in the final idling and calculated reliability starts generating the various areas in percent in the last column (Table 2).
For visual display of results we constructed a line graph with three lines. We gave him the name "Reliability starts." The first line shows the requirements for start issued by the operator, the other blue number of successful starts idling and finished last green success rate of starts for the generator (Fig. 2).

Table 2 Number of starts in the first reporting period

Label generator / Area	Number of starts in the first reporting period		
	The requirement to start **Ps**	Successful starts of **Us**	Average **%**
T1 / TKK In the first reporting period	46	45	98
T1 / TKJ In the first reporting period	27	19	70
T1 / TKZ In the first reporting period	29	29	100
T2 / TKZ In the first reporting period	24	23	96
T1 / TKI In the first reporting period	14	14	100
T2 / TKI In the first reporting period	15	15	100
T3 / TKI In the first reporting period	13	10	77
T4 / TKI In the first reporting period	16	14	88
Together	184	169	
The overall success rate in %			91.05661

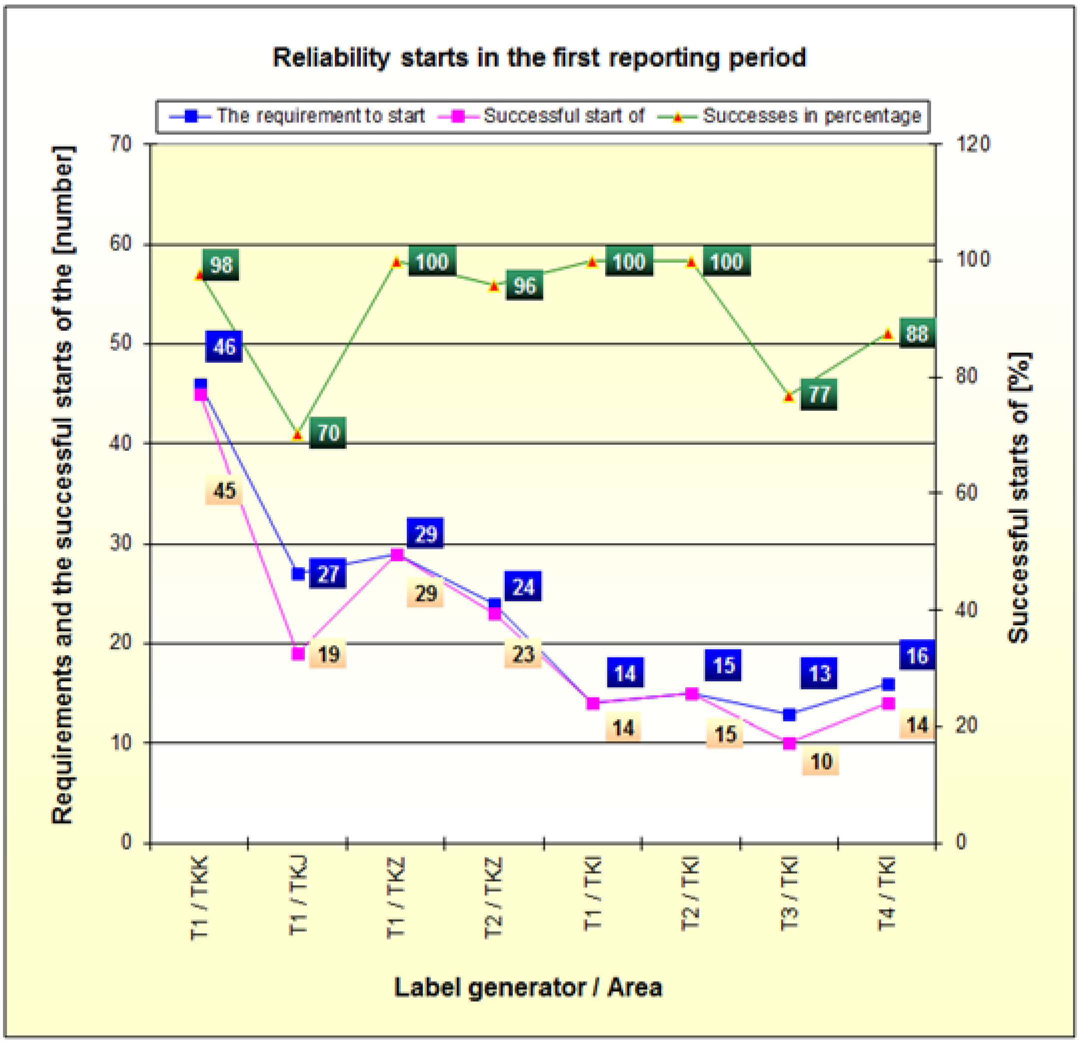

Fig. 2 Graph of starts reliability LM 2500 in the first reporting period

For the first monitored period, we evaluated the following data:

- Generator T1 and T2 / TKI together with T1 / TKZ reached the highest percentage rate of 100% of starts reliability.
- We recorded the worst results for generator T1 / TKJ where the reliability of starts reached 70%. Total number of attempts were 27 for this generator, the number of successful starts were 19.
- Generator T1 / TKK achieved very good results with a success rate of 98%. We found number of attempts 46 and the number of successful starts 45.
- The total balance of all generators achieved the value 91% of successful starts for the monitored period.

But we have to state, that the function and components of hydraulic starting device was not involved in the failure of start, which we followed and indicated in Table 1. None of these elements of measurement and regulation didn´t show significant deviation or fault of measurement. At this time the most frequent disorder was failure of flame sensor in the combustion chamber

Table 3 Number of starts in the second reporting period

Label generator / Area	Number of starts in the second reporting period.		
	The requirement to start **Ps**	Successful starts of **Us**	Average **%**
T1 / TKK In the second reporting period	30	25	83
T1 / TKJ In the second reporting period	15	14	93
T1 / TKZ In the second reporting period	20	20	100
T2 / TKZ In the second reporting period	19	19	100
T1 / TKI In the second reporting period	20	17	85
T2 / TKI In the second reporting period	14	13	93
T3 / TKI In the second reporting period	21	20	95
T4 / TKI In the second reporting period	13	12	92
Together	152	140	
The overall success rate in %			92.7587

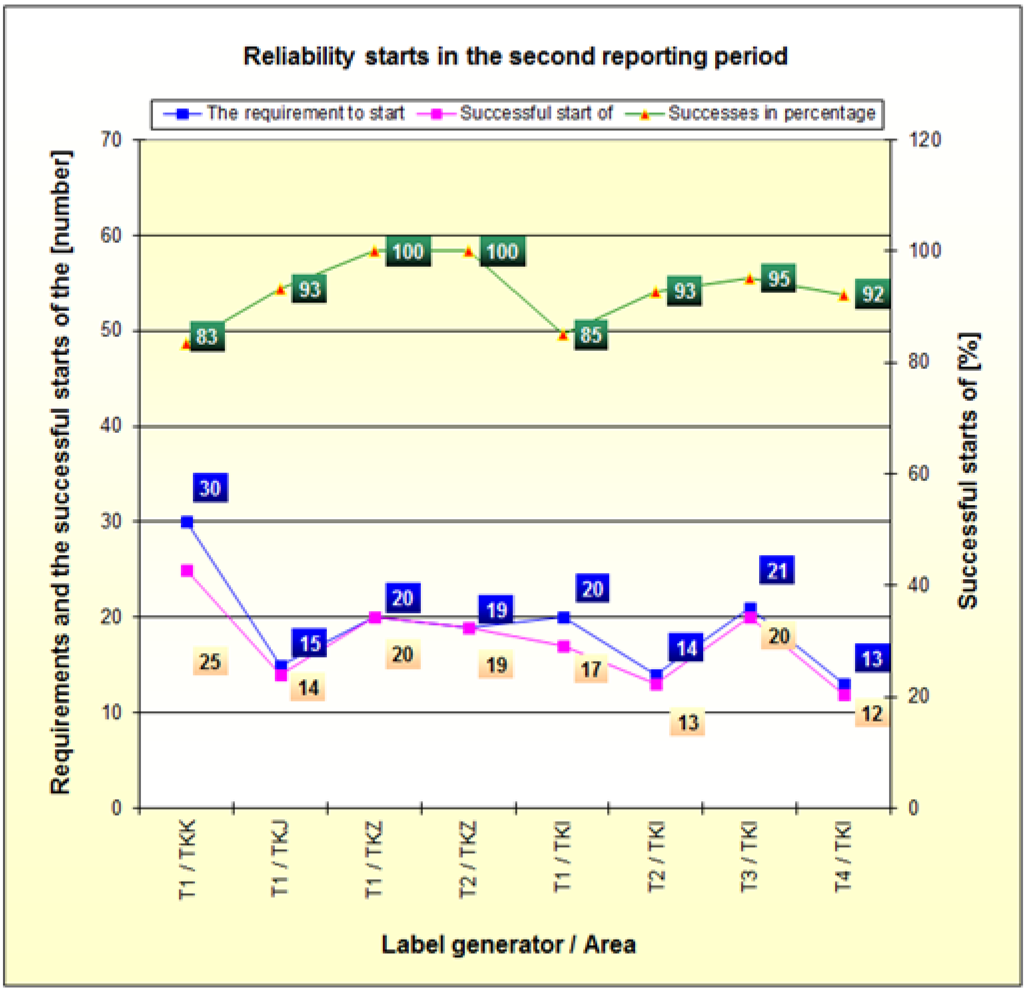

Fig. 3 Graph reliability starts LM 2500 in the second reporting period

For the second monitored period, we evaluated the following data:

The highest percentage rate of 100% of reliability starts reached the generator T1 and T2 / TKZ. Generator T1 / TKK reached the lowest percentage rate of 83%. The total balance of all generators achieved the value 92.75% of successful starts at this period. The results we recorded in Table 3 and we displayed them in the chart (Fig. 3).

Table 4 Number of starts for the whole period

Label generator / Area	The number of starts for the whole period		
	The requirement to start **Ps**	Successful starts of **Us**	Successful **%**
T1 / TKZ For the whole period	49	49	100
T2 / TKZ For the whole period	43	42	98
T2 / TKI For the whole period	29	28	97
T1 / TKK For the whole period	76	70	92
T1 / TKI For the whole period	34	31	91
T4 / TKI For the whole period	29	26	90
T3 / TKI For the whole period	34	30	88
T1 / TKJ For the whole period	42	33	79
The average starter reliability			91.875

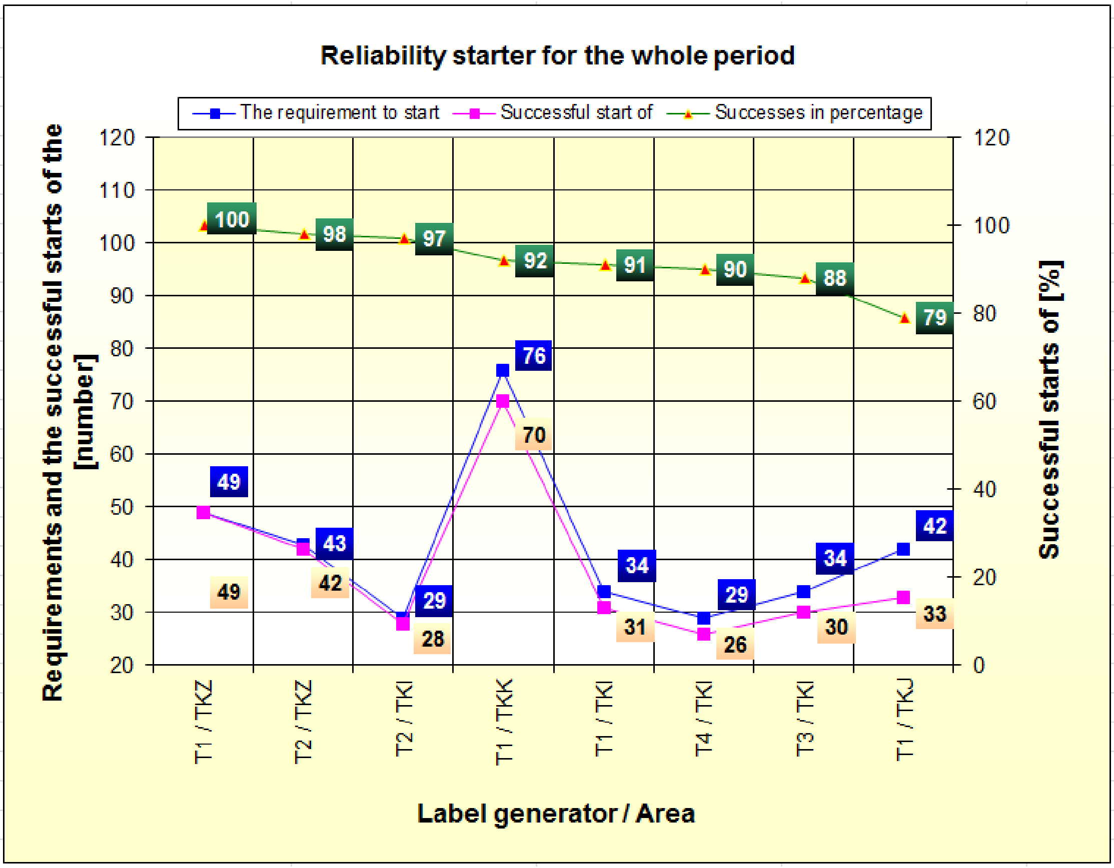

Fig. 4 Graph of starts reliability LM2500 for the whole period

For the whole monitored period we lined up machines according to the success of starts (Table 4) and we found the following results:

- The highest percentage rate of 100% achieved the machine T1/TKZ.
- The second highest percentage rate of 98% achieved the machine T2 / TKZ.
- The third highest percentage rate of 97% achieved the machine T2 / TKI (Fig. 4).

Last place and therefore the worst percentage rate of 79% reached the machine T1 / TKJ. The average value about reliability starts of all generators was 91.87%.

A major impact on the overall reliability of starts had components of measurement and regulation of sub-systems, as the previously mentioned the flame sensors. During the whole monitored period, we recorded also one electric fault at the ignition device.

CONCLUSION

Dynamic gas transport requires more frequent manipulation with transmission network technology in increased international competition for gas systems. Start of each gas generators belongs to the most frequently and also the most important starts ever, which regulate the transported volume and pressure of natural gas flowing through the transit system

In this paper, we monitored the reliability of starts during two years. We recorded total 336 commands to start on a sample of eight gas generators. Until 309 of start-up sequences were successful completed and the turbine was put into steering at idle.

During the first year of observation, we recorded total 66 faults of gas generators. Seven of these disorders are related to electronic ignition, but no with components of hydraulic starting system. In this year generators achieved a complete percentage rate of 91.05% of successful starts and we recorded 15 of unsuccessful starts. The measuring and regulations elements, which aren´t related directly to the electro-hydraulic starting device had an impact to unsuccessful starts. We found that, no-failure operation of our monitored starter functions and components was 100%.

In the second year of observation we recorded together 58 faults of gas generators. Two of these disorders are related to electronic ignition. Generators achieved a total percentage rate of 92.75% of successful starts and we recorded 12 of unsuccessful starts. The observed functions and components of the ignition device did not fail.

For the whole observed period of two years, gas generators achieved an average value 91.87% of starts reliability. It is a high success compared to the other technologies and this success is thanks to all operations entering to the start-up sequence of generators. It is mostly about reliable control systems, leading technology, professional knowledge of operators and quality maintenance. If we look at this indicator from the perspective of the various areas so the highest percentage of successful starts reached the area TKZ with generator T1 with percentage rate of 100% when the number of starts was 49. We recorded nine unsuccessful starts in the TKJ area. The most start-up sequences were launched in TKK area, total number was 76 with the percentage rate of 92%.

ACKNOWLEDGEMENT

Supported by the Ministry of Education of the Slovak Republic, project KEGA no. 035SPU- 4/2014 'Integrating innovative trends in metal machining, metrology and quality management in university studies'

REFERENCES

[1] Boyce, M. P. 2012. Gas Turbine Engineering Handbook (4th Edition). Amsterdam: Elsevier, Butterworth-Heinemann, 2012. 956 pages. ISBN 978-0-12-383842-1.
[2] Forsthoffer, W. E. 2011. Forsthoffer’s Best Practice Handbook for Rotating Machinery. Boston: Butterworth-Heinemann, 2011. 672 pages. ISBN 978-0-08-096676-2.
[3] Manual Ge. 2001. Service manual for gas turbine. B. m.: B. v., 2001. 300 pages.
[4] Soares, C. 2015. Gas Turbines - A Handbook of Air, Land and Sea Applications (2nd Ed.). Oxford: Butterworth-Heinemann, 2015. 1020 pages. ISBN 978-0-12-410461-7.
[5] Máchal, P., Beloev, H., Kročko, V. 2013 Proektnoe upravlenie, 1 vyd. -- Ruse: Izdateľskij centr na Rusenskogo universiteta im "Angela Kynčeva", 2013. 160 p. ISBN: 978-954-8467-95-7.

[6] Žitňanský, Ján - Kročko, Vladimír - Polák, Pavel. Technická spôsobilosť procesov. 1. vyd. Nitra : Slovenská poľnohospodárska univerzita, 2013. 169 s. ISBN 978-80-552-1110-7.
[7] Álló, Štefan - Kročko, Vladimír - Ibriksz, Tamás - Mareček, Jan. Detection of corrosion resistance of components in cyclic salt spray. In Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. ISSN 1211-8516, 2015, vol. 63, no. 1, s. 9-13 (2015).
[8] Bujna, Marián - Beloev, Christo Ivanov. Tools of risk management in production processes. 1st ed. Ruse : Angel Kanchev University of Ruse, 2015. 105 s. ISBN 978-954-712-654-1.
[9] Kaplík, Pavol - Prístavka, Miroslav - Bujna, Marián - Viderňan, Ján. Use of 8D method to solve problems. In Advanced Materials Research. ISSN 1022-6680, 2013, vol. 801, special iss., p. 95-101 (2013).
[10] Bujna, Marián - Prístavka, Miroslav - Kaplík, Pavol. Impact of insufficient cleaning on the quality of molybdenum layer applied by thermal spraying. In Advanced Materials Research. ISSN 1022-6680, 2013, vol. 801, special iss., p. 35-40 (2013).
[11] Kučera, Marián - Bujna, Marián - Korenková, Marcela - Haas, Peter. Possibilities of using ecological fluid in agriculture. In Advanced Materials Research. ISSN 1022-6680, 2014, vol. 1059, special iss., s. 61-66 (2014).

CONTACTS

Dušan Nógli, Department of Machine Design, Faculty of Engineering, Slovak university of agriculture in Nitra, Trieda Andreja Hlinku 2, 949 76 Nitra, Slovakia, e-mail: xnogli@is.uniag.sk

Dominik Gašparovič, Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak university of agriculture in Nitra, Trieda Andreja Hlinku 2, 949 76 Nitra, Slovakia, e-mail: xgasparovic@is.uniag.sk

Plamen Kangalov, Department of Repair and Reliability, Agrarian and Industrial Faculty, University of Ruse, 8, Studentska Str., 7017 Ruse, Bulgaria, e-mail: kangalov@uni-ruse.bg

Zuzana Csillagová, Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak university of agriculture in Nitra, Trieda Andreja Hlinku 2, 949 76 Nitra, Slovakia, e-mail: xcsillagova@is.uniag.sk

Maroš Korenko, Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak university of agriculture in Nitra, Trieda Andreja Hlinku 2, 949 76 Nitra, Slovakia, e-mail: maros.korenko@uniag.sk