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APPLICATION OF THE BIOMASS AS A CONSTRUCTION MATERIAL OF THE OIL FILTER AND ITS INFLUENCE ON THE PERFORMANCE AND EMISSION CHARACTERISTICS

Summary. Engine emissions can be reduced by performing suitable modifications to the oil filter. Biomass medium served as the replacement for the standard paper fibres, which are used in common oil filters. The experimental analysis of 4 emission elements showed a moderate increase in the case of 2 emission characteristics, whereby a 10% increase in monoxide was present, and also, an increase of 2.5% of nitrogen oxides was observed. Further, there was a significant reduction of 2 other emission elements, namely the unburned hydrocarbons decreased by 61%, and the amount of particulate matter was reduced by 18%. Measured engine power increased by 1.2% using the modified oil filter, which proves the success of this filter. There was a decrease in oil pressure as well, the value dropped by 0.5 bar during the whole period of the measuring process.
Keywords: oil filter, biomass, emissions

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1. INTRODUCTION

The main function of engine oil is lubrication, a reduction of passive resistance, which is present within moving components of the engine. Apart from the main functions, engine oil provides other functions:

- mechanism functionality or functionality of its parts,
- cylinder walls and bearings cooling,
- emissions reduction,
- corrosion protection,
- protection against sudden changes in temperature,
- dirt removal,
- noise and vibration damping.

Lubrication systems ensure the movement and displacement of engine oil to places where the oil is needed. The principle of the lubrication system is to secure the oil layer between metallic surfaces or between other surfaces and to prevent direct contact among them. The experiment used an internal combustion engine of the TDI type [1-2].

Pressure lubrication is the main method for the experimental type of the engine. It means that the oil is brought under high pressure into the needed parts of the engine, which circulate during engine operation. The oil is stored in the oil pan, which is the basic solution for nearly all commercial engines used in vehicles. The oil pump pushes the oil into the oil channels, which are present in individual parts of the engine [3-8].

The oil lubrication is as follows: When the temperature of the engine is low, the oil is located in the oil pan. The oil is distributed to the engine parts with the help of the oil pump through the oil filter, whose function is to remove excess particles possibly present in the engine oil. The oil moves from the engine oil filter into the place where the crankshaft is located. Crankshaft bearings are lubricated through the channels, which are part of the crankshaft itself. The oil continues from the main bearing to the connecting rod bearings. The next location where the oil is distributed is the pistons and cylinders. Pistons and cylinders are lubricated by nozzles, which inject oil into the cylinder wall, where the oil layer is formed [9]. Engine oil which flows to the cylinder head lubricates the valve mechanism [10].

At the top of the circumference of the piston, there are holes and grooves where the piston rings are situated. Their function, except for sealing, is to spread the engine oil through the cylinder walls, which later return to the oil pan via holes in the piston [11].

2. OIL FILTER

The main function of the oil filter is to capture all impurities of the engine oil during engine operation. Impurities can usually be small particles of metal, aluminium, silver, etc., which occur when the friction components are worn out. Then there are losses of burnt oil, fuel, and small particles of dust that were not caught by the air filter. Prolonged engine oil use causes its pollution, which means worse ability to filtrate and that means combustion of a bigger amount of pollutants, which should be carried back to the oil pan [12-13].

3. OIL FILTER MODIFICATION

Engine emissions can be reduced with the appropriate oil filter modification. The attention was centralised on natural materials without expensive manufacturing. Synthetic paper fibres have been replaced by biomass material. Moreover, obtaining biomass or sawdust itself is not a problem, as it is also generated as waste in the wood processing industry [14].

The production of biomass filter was as follows: Sawdust of different woods, mainly birch sawdust, was used as the semi-finished product. One of the main materials was an alkaline solution. Alkaline solution chemical composition was as follows: tetraethylammonium bromide, triethanolamine, lithium bromide, sodium carbonate, and distilled water. Mixture of sawdust with an approximate weight of 700 g was mixed with the alkaline solution at 50°C for 48 hours by a special machine. Distilled water was used for cleaning the sawdust until a clear filtrate was achieved. The processed material is subsequently dried out in a dryer at 80°C for 10 hours. The exact shape of the apparatus was achieved by the usage of the right technological process. Several conditions need to be fulfilled by this processed apparatus. Except for its strength and integrity, the oil filter needed to be reasonably permeable to be able to filter the engine oil while at the same time being able to capture unnecessary particles. Figure 1 shows the modified oil filter [15-16].

Fig. 1. OEM and modified engine oil filter comparison

The modified filter meets all criteria needed to perform all desired measurements. It can be expected due to the high absorbing features of biomass that the modified oil filter will be able to capture a sufficient amount of pollutants, excess substances and solid particles while leaving all the important and needed elements of oil non-degenerated.

4. ENGINE PERFORMANCE, OIL PRESSURE AND EMISSIONS MEASURING

Measuring engine performance from low to high RPM was necessary to detect the functionality of the modified oil filter. It was important to control oil filter resistance to the influence of high temperatures, flow and vibrations. According to predictions, the filter should be able to withstand slightly higher temperatures; however, these assumptions were made for ideal conditions [20].

The engine scheme with all the needed measuring instruments is shown in Figure 2.

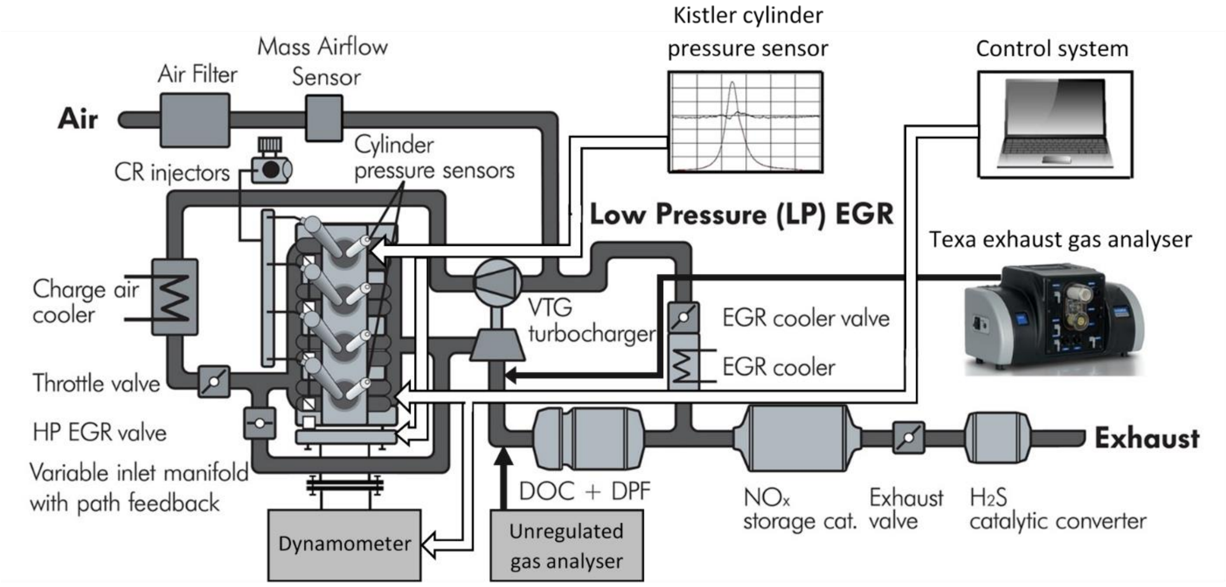

Fig. 2. Experimental engine scheme with measuring instruments

An emission measurement was done with the TEXA instrument, available with the software suitable for the evaluation of the needed data (Figure 2). Engine performance was measured by the dynamometer and for oil pressure measurement, the oil sensor was used as the part of the engine located between the oil pump and oil filter. The turbocharger and intercooler used during the experiment were OEM parts of the engine. Diesel used as the fuel meets the requirements of technical norm STN EN 590. During the whole experiment, engine oil with viscosity class of SAE 5w-30 was used in the engine. Engine oil was not brand new; the engine had run 8 000 km with this oil. Oil that is approximately in the middle of the change interval was intentionally used. The purpose of using slightly worn out engine oil was the presence of unwanted pollutants and subsequent observation of their absorption while using the modified oil filter.

5. EMISSIONS MEASUREMENT

The measured amount of carbon monoxide compounds with the OEM filter was 0,226 g/kW.h, while the modified filter reached an amount of 0,248 g/kW.h. According to measured values, the OEM filter achieved better results for a given type of compound. The modified filter showed an increase of approximately 10%.

During the measurement of unburnt hydrocarbons, the modified filter showed better results than the OEM oil filter. The average value for the OEM filter was 0,354 g/kW.h, while the modified filter’s average value was 0,138 g/kW.h. Formation of unburnt hydrocarbons with the use of the modified oil filter was decreased by approximately 61%. There was a slight increase in nitrogen oxide emissions to the detriment of the modified oil filter. The average value measured with the OEM filter was 7,723 g/kW.h, while the modified oil filter average value was 7,919 g/kW.h, which means a 2,5% increase.

The modified oil filter showed good results in the filtration of solid particles. The average value for the OEM oil filter was 0,027 g/kW.h; however, the amount of solid particles decreased with the use of the modified oil filter to 0,022 g/kW.h. However, from a percentage point of view, there was an 18% decrease.

Graphics of the results are shown in Figures 3 and 4.

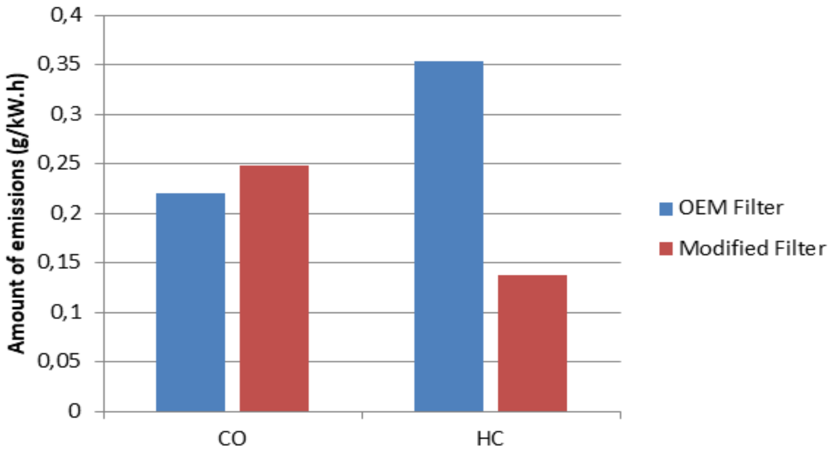

Fig. 3. CO and HC emissions production

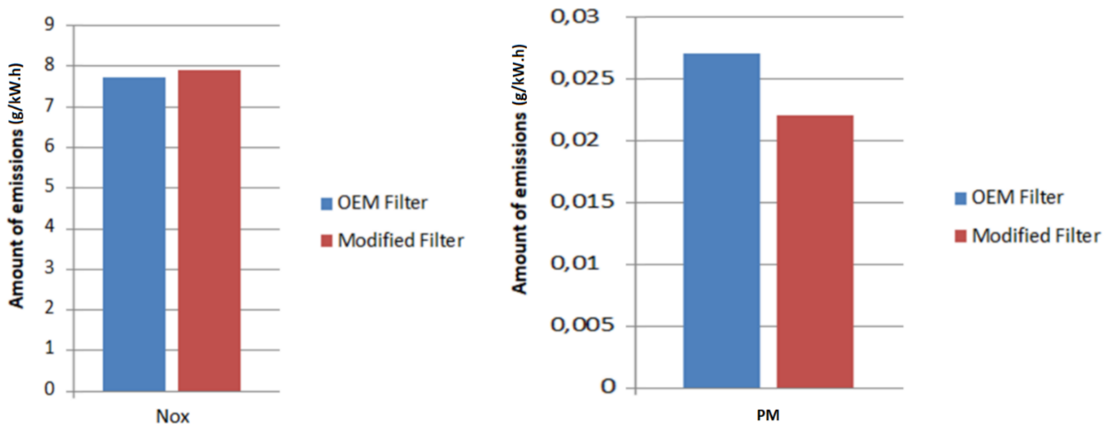

Fig. 4. NO_x and solid particles emissions production

6. MEASURING ENGINE PERFORMANCE

A dynamometer was used for the measurement of the engine performance. The manufacturer states that the highest performance of this engine is 240 kW at 3 750 RPM. However, it was assumed that the manufacturer tested the performance of the engine without wear, using new operating fluids. There is a probability that the manufacturer's stated highest power could differ from the measured power.

Engine power measurement was determined to define the preservation of the original power using a modified oil filter. The OEM filter showed a maximum engine power output of 238,5 kW at 3 580 RPM (Figure 5). The measured value is slightly different from the reference value stated by the manufacturer. Differences can be caused by a mistake during the measurement, engine wear or external factors, for example, excessive humidity or dust in the air.

The same or nearly identical values were measured using the modified oil filter. Maximum power at 3 590 RPM was 241,3 kW, which means that the engine power was raised by 2,8 kW. This value can be considered irrelevant due to a small increase in power, 1,2% in comparison to the stock engine power.

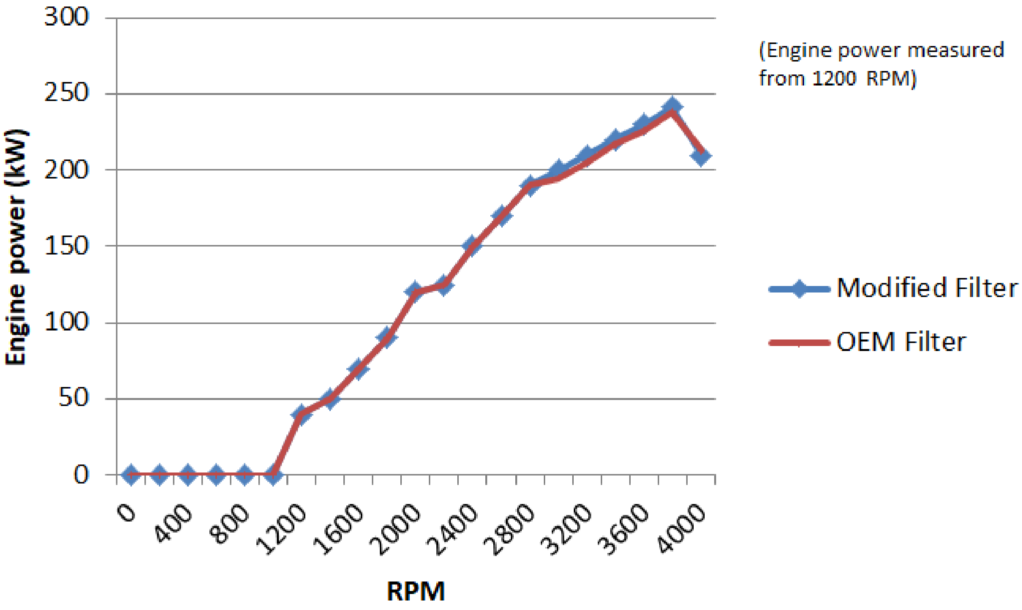

Fig. 5. Engine power

7. OIL PRESSURE MEASUREMENT

Oil pressure is an important factor for proper engine operation. Engine oil properties change from temperature to temperature, which means that the measurements were done at operating oil temperature.

At idle, the oil pressure was measured at 1,2 bar, while at 4 000 RPM, the pressure was 5,2 bar using the OEM oil filter (Figure 6). The modified oil filter showed a decreased value of oil pressure. At idle, the measured value of oil pressure was 0,75 bar, and the highest possible pressure was 4,6 bar. There was a significant difference in engine oil pressure when using the OEM oil filter and the modified one. The average value of difference is 0,5 bar. In the short term, this oil pressure decrease should not be a problem, but in the long term usage it could have a negative influence on the engine; in the worst scenario, it could malfunction or destroy some parts of the engine like the crankshaft, connecting rod bearings, piston rings, pistons, camshaft, etc.

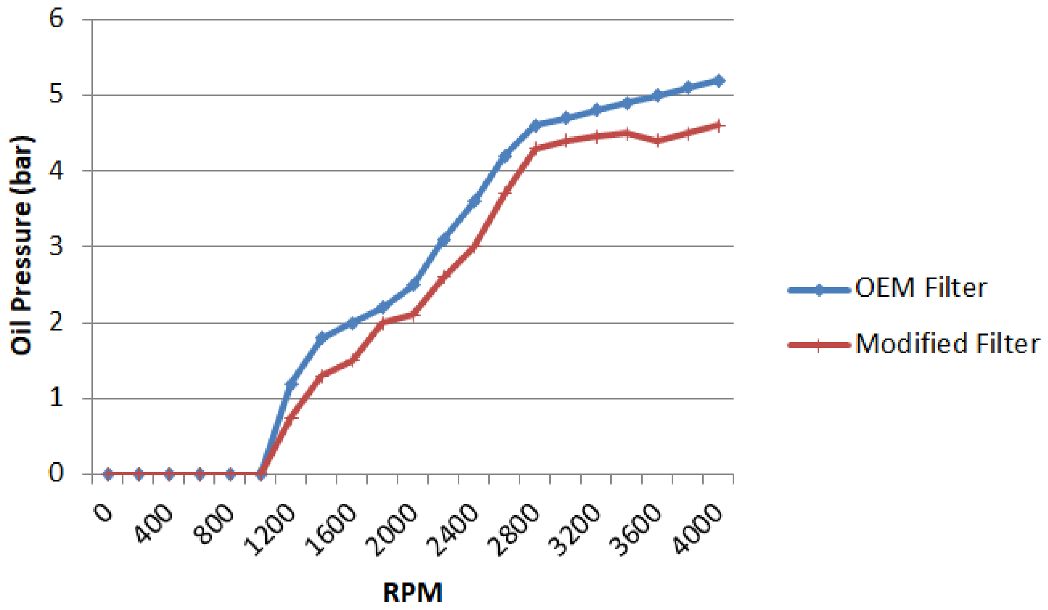

Fig. 6. Engine oil pressure

8. CONCLUSION

The measurements showed that the modified filter was functional and fulfilled emission elements reduction purposes. There were 4 measurements of emission elements done from which 2 emission elements increased, specifically a 10% increase of carbon monoxide and a 2,5% increase of nitrogen oxides. On the other hand, the other 2 emission elements showed decreases, mainly the unburnt hydrocarbons, 61%, and the amount of solid particles, 18%.

In addition, oil pressure measurements connected with engine performance were done. If a given filter recorded negative values in some of the given areas, its use would not be relevant. The 1,2% (2,8 kW) engine performance increase was achieved using the modified oil filter. The performance increase was surprising because the main purpose of these measurements was whether the modified filter would not decrease engine power.

During the oil pressure measurements, significantly lower values were achieved using the modified filter, approximately 0,5 lower on average during the whole test. The increase in engine power was probably the result of lower oil pressure.

The modified oil filter made of biomass has its functionality and advantages. The measurements have been done under laboratory conditions, which means that normal engine running conditions could change the properties of this filter, and the final results would be different. As earlier mentioned, the modified oil filter has not undergone long term tests under normal conditions, so the true efficiency is not known.

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References

1. Kučera Pavel, Václav Píštek. 2014. "Virtual prototype of a heavy duty off-road truck driveline in Simulink software". In: *Proceeding of International Conference Transport Means. Transport Means*. K. Donelaičio st. 73, LT-44029 Kaunas: Kaunas University of Technology. P. 5-8. ISSN: 1822-296X.
2. Chríbik Andrej, Marián Polóni, Matej Minárik, Radivoje Mitrovic, Zarko Miskovic. 2019. "The Effect of Inert Gas in the Mixture with Natural Gas on the Parameters of the Combustion Engine". *Computational and Experimental Approaches in Materials Science and Engineering*: 410-426. DOI: https://doi.org/10.1007/978-3-030-30853-7_24.
3. Czech Piotr. 2013. "Diagnose Car Engine Exhaust System Damage Using Bispectral Analysis and Radial Basic Function". *Advances in Intelligent Systems Research* 30: 312-315. DOI: https://doi.org/10.2991/iccnce.2013.78. Atlantis Press. ISBN: 978-90-78677-67-3. ISSN: 1951-6851. In: Zheng D., Shi J., Zhang L. (eds), *Proceedings of the International Conference on Computer, Networks and Communication Engineering (ICCNCE)*, Beijing, China, May 23-24, 2013.
4. Czech Piotr. 2013. "Diagnosing a Car Engine Fuel Injectors' Damage". *Communications in Computer and Information Science* 395: 243-250. DOI: https://doi.org/10.1007/978-3-642-41647-7_30. Springer, Berlin, Heidelberg. ISBN: 978-3-642-41646-0; 978-3-642-41647-7. ISSN: 1865-0929. In: Mikulski Jerzy (eds), *Activities of transport telematics, 13th International Conference on Transport Systems Telematics*, Katowice Ustron, Poland, October 23-26, 2013.
5. Liaposhchenko Oleksandr, Ivan Pavlenko, Vitalii Ivanov, Maryna Demianenko, Oleksandr Starynskyi, Ivan Kuric, Oleg Khukhryanskiy. 2019. "Improvement of Parameters for the Multi-Functional Oil-Gas Separator of 'Heater-Treater' Type". *IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA)*. DOI: https://doi.org/10.1109/iea.2019.8715203.
6. Czech Piotr. 2011. "An Intelligent Approach to Wear of Piston-Cylinder Assembly Diagnosis Based on Entropy of Wavelet Packet and Probabilistic Neural Networks". *Communications in Computer and Information Science* 239: 102-109. DOI: https://doi.org/10.1007/978-3-642-24660-9_12. Springer, Berlin, Heidelberg. ISBN: 978-3-642-24659-3. ISSN: 1865-0929. In: Mikulski Jerzy (eds), *Modern transport telematics, 11th International Conference on Transport Systems Telematics*, Katowice Ustron, Poland, October 19-22, 2011.
7. Pistek Vaclav, Lubomir Klimes, Tomas Mauder, Pavel Kucera. 2017. "Optimal Design of Structure in Rheological Models: An Automotive Application to Dampers with High Viscosity Silicone Fluids". *Journal of Vibroengineering* 19(6): 4459-4470. DOI: https://doi.org/10.21595/jve.2017.18348.
8. Polóni Marián, Andrej Chríbik. 2020. "Low-Energy Synthesis Gases from Waste as Energy Source for Internal Combustion Engine". *SAE International Journal of Engines* 13(5). DOI: https://doi.org/10.4271/03-13-05-0040.

9. Marcin Staniek, Piotr Czech. 2018. "Self-Correcting Neural Network in Road Pavement Diagnostics". *Automation in Construction* 96: 75-87. DOI: https://doi.org/10.1016/j.autcon.2018.09.001.
10. Puškár Michal, Peter Bigoš. 2013. "Measuring of Accoustic Wave Influences Generated at Various Configurations of Racing Engine Inlet and Exhaust System on Brake Mean Effective Pressure". *Measurement* 46,(9): 3389-3400. DOI: https://doi.org/10.1016/j.measurement.2013.05.008.
11. Murčinková Zuzana, Jozef Živčák, Jozef Zajac. 2020. "Experimental Study of Parameters Influencing the Damping of Particulate, Fibre-Reinforced, Hybrid, and Sandwich Composites". *International Journal of Materials Research* 111(8): 688-697. DOI: https://doi.org/10.3139/146.111933.
12. Puškár Michal, Andrej Jahnátek, Jaroslava Kádárová, Marieta Šoltésová, Ľudovít Kovanič, Jana Krivosudská. 2018. "Environmental Study Focused on the Suitability of Vehicle Certifications Using the New European Driving Cycle (NEDC) with Regard to the Affair 'Dieselgate' and the Risks of Nox Emissions in Urban Destinations". *Air Quality, Atmosphere & Health* 12(2): 251-257. DOI: https://doi.org/10.1007/s11869-018-0646-5.
13. Pinosová Miriama, Miriam Andrejiová, Ervin Lumnitzer. 2018. "Synergistic effect of risk factors and work environmental quality". *Qual.-Access to Success* 19: 154-159.
14. Sabol R., P. Klein, T. Ryba, L. Hvizdos, R. Varga, M. Rovnak, I. Sulla, et al. 2017. "Novel Applications of Bistable Magnetic Microwires". *Acta Physica Polonica A* 131(4): 1150-1152. DOI: https://doi.org/10.12693/aphyspola.131.1150.
15. Pavlenko Ivan, Milan Saga, Ivan Kuric, Alexey Kotliar, Yevheniia Basova, Justyna Trojanowska, Vitalii Ivanov. 2020. "Parameter Identification of Cutting Forces in Crankshaft Grinding Using Artificial Neural Networks". *Materials* 13(23): 5357. DOI: https://doi.org/10.3390/ma13235357.
16. Sága Milan, Vladimír Bulej, Nadežda Čuboňova, Ivan Kuric, Ivan Virgala, Manfred Eberth. 2020. "Case Study: Performance Analysis and Development of Robotized Screwing Application with Integrated Vision Sensing System for Automotive Industry". *International Journal of Advanced Robotic Systems* 17(3). DOI: https://doi.org/10.1177/1729881420923997

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