ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LXI 76 Number 3, 2013
http://dx.doi.org/10.11118/actaun201361030691

OIL ADDITIVE AND ITS EFFECT

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Received: March 4, 2013

Abstract

KUMBÁR VOJTĚCH, DOSTÁL PETR: *Oil additive and its effect.* Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 3, pp. 691–697

The aim of this paper are experimental approaches, selected for analysis of the engine oils and described above, are surely sufficient for the needs of presented research. The spectrometry was used for determination of presence of selected chemical elements and especially metals in oil. Particles monitoring was employed in order to describe the amount, type, and size of friction particles. The temperature dependence of dynamic viscosity was evaluated by use of rotary viscometer. In case of all three approaches it is advantageous to compare the measured values with the results received for unused engine oil of the same marking and viscosity index. If the degradation of oil is classified as low or medium, it is possible to increase its service life for several thousands of kilometers. Mathematical model (polynomial 6th degree) it was used for fitting experimental values.

oil additives, engine oil, particle monitoring, viscosity, temperature, lifetime

The engine oil should be considered as one of the constructional members and critical design factors, influencing engine's lifetime and performance. The quality of oil can directly influence some operational properties. As it is stated in Kumbár *et al.* (2011), development of the new engines should be closely connected with development and improvement of the engine oils, changes in their composition and operational properties. These changes are necessary for achieving of continuously increasing engine output, but also for extension of service intervals. Extension of the service intervals represents a relevant and considerable advantage for car users and factor decreasing the operational costs. The current costs (at given service interval) connected with oil and filter change can be reduced down to one half. Another factor, which is not negligible, is saving of time. When extending the service interval, the time losses connected with performing the service works and vehicle down-time are reduced. The change has also a positive influence on economic efficiency of the vehicle, its life-time and user's mobility. But the system of extended service intervals is strictly conditioned by oil quality. The oil evaluation must be based on extensive operational and laboratory testing, supporting the proof that oil offers high quality properties for the engines run in different and difficult conditions.

There is general practice, that large transport companies analyze the oil fillings in their vehicle fleet on regular basis. The main attention is paid to the presence of the metals in oil and its viscosity stability. Some companies perform such tests only in cases when certain signs of uncommon operation arise or in the case of doubt of fault engine run. The engines and all the friction surfaces are made of certain metal materials. These materials, generally speaking, are represented by iron alloys refined by other metals, aluminum, and copper. Some engine parts and/or members are surface treated (covered by surface layer of other metal) in order to increase the surface hardness, friction properties, and anti-corrosive resistance. Due to this fact, some other metals must be monitored, such as aluminum, copper, chrome, tin, nickel, silver etc. The friction surfaces, although they are well shaped and machined, are never absolutely smooth. Each surface has its own morphology and structure, which can be visualized as it is shown in Fig. 1. Under common operation conditions, the friction surfaces in the engine are isolated by the thin oil layer. The oils with higher value of viscosity create a thicker oil layer than oils with lower viscosity. The metal surfaces thus do not contact each other, unless there is a larger irregularity or roughness (Mang and Dresel, 2001).

1: *The metal surfaces isolated by oil layer (Kumbár et al., 2011)*

2: *The metal surfaces in close contact (Kumbár et al., 2011)*

As it is also described in Mang and Dresel (2001), the metal surfaces can be forced one against each other by means of external loads and the oil layer is pushed-out in such case and the metals get into contact. This condition is called the boundary or limiting friction and both surfaces are not lubricated by the oil layer any more but just by means of lubricating additives, which have been adhered to the metal surface. Such condition is shown in Fig. 2. If two such surfaces are in movement, there is a real risk of their reciprocal scraping and extracting of microscopic metal particles. These particles are consequently transferred to the oil. The analysis of presence of given metal particles in the oil filling can be further used for determination of engine working condition and degree of friction. The potentially dangerous conditions such as initiation of increased wear or seizing of the engine can be thus detected. This kind of diagnostics is rather effective, because it prevents large failures and/or engine damages before the other signs (noise, vibrations, overheating) can be considered.

Content of the metal particles in the oil is not the only indicator of the engine condition. The other and important one is stability of the temperature dependence of dynamic viscosity. As it is presented in Černý and Mašek (2010), the viscosity is a measure of fluidity of liquids. The oils characterized by lower viscosity are more fluid (tenuous) and have lower internal resistance against flow. The higher viscosity (thicker oil), on the other hand, is connected with higher flow resistance, slower flow and thus higher resistance against movement of lubricated surfaces.

There is a general practice that range of ± 20% of viscosity value is accepted for engine oil use. This value was set for large diesel engines. In case of gasoline engines, the higher tolerance (for lower values) is acceptable, also with regard to shearing instability of recently produced oils. Total decrease of viscosity up to 30% is thus acceptable. The viscosity value, which is too low as a result of failure in the injection system and/or water in fuel, can lead to unacceptable thinning of lubricating layer. This fact can cause fragmentation of the layer under intensive engine load and possible risk of higher wear and seizing of friction elements (Černý and Mašek, 2010).

MATERIAL AND METHODS

Material

The analyses were performed using the engine oil MOGUL FELICIA. This oil is characterised by its producer as an all-purpose, multigrade oil intended for new types of petrol and diesel engines, with special assignation to Škoda cars. Its properties are listed in Tab. I.

The oil was used in a car Škoda Felicia, 1.3MPI (50 kW), manufactured in 1999. Following liquids were monitored: unused engine oil, used engine oil after 15,000 km of operation, oil additive OIL TREATMENT, and their mixtures. The oil additive (produced in the USA) is characterized by its producer as: the agent, which prevents engine overheating, keeps the oil pressure, prevents loss of power, reduces noise of valves and pistons, and reduces production of emissions. The recommended oil-additive ratio is 1:10.

Methods

The tests were performed using three different measuring devices and approaches:

- spectrometry – the measuring device Spectroil Q100,
- particles monitoring – measuring device LaserNet Fines™-C,
- temperature dependence of dynamic viscosity – measuring device Anton Paar DV-3P.

Detection of water in oil presence was performed by external laboratory – ALS Laboratory, s. r. o.

Spectrometry

The measuring device Spectroil Q100 is a completely semiconductor spectrometer, specifically designed for oil analysis. The apparatus

I: *The properties of engine oil MOGUL FELICIA*

Signification	Viscosity Index	ACEA standard	API standard	VW standard
MOGUL FELICIA	15W40	A3/B3	SH/CF	501.01/505.00

is intended for detection of trace metal contents in mineral and/or synthetic oils. The well verified measuring technique of rotational disc electrode is used. The device meets the requirements for standardized methods ASTM D6595 for detection of abrasive metals and contaminants in lubricating oils and/or hydraulic fluids.

Particles monitoring

The particle analyzer LaserNet Fines™-C is used for detection and characterization of friction particles. The particles are in most cases of metal origin. Since there are several types of friction elements loading, several types of mechanical wear can occur (fatigue wear, pitting, scuffing, abrasive wear etc.). The particles created in different mechanical conditions are of different shape and size. The size of particles connected with common wear usually ranges in micrometers with upper limit of 5 micrometers. The engine wear increases with increasing size of friction particles (tens up to more than hundred of micrometers) and their number (Mang and Dresel, 2001).

Temperature dependence of dynamic viscosity

Measuring of temperature dependence of dynamic viscosity of given engine oil was performed using rotational viscometer Anton Paar DV–3P. This experimental device measures the torque of rotating spindle placed into the sample. The viscometer detects the resistance against rotation of cylinder or disc surrounded by measured fluid. The rotating cylinder or disc is connected with electric motor shaft via defined springs. The shaft is rotating by set speed (expressed in rotations per minute). The angle of swing is electronically monitored and offers the precise information on shaft (spindle) position. The measured data are used for calculation of dynamic viscosity expressed in *mPa.s*. In case of fluids with constant viscosity is the resistance against movement increased with spindle size. The range of measuring and rheological properties determination can be customized according to specific measuring and experimental conditions by selection of spindle and its rotation velocity. Relevant evaluation of the results is conditioned by detailed knowledge of tested material. It is necessary to classify the material in a correct way (Kumbár *et al.*, 2012).

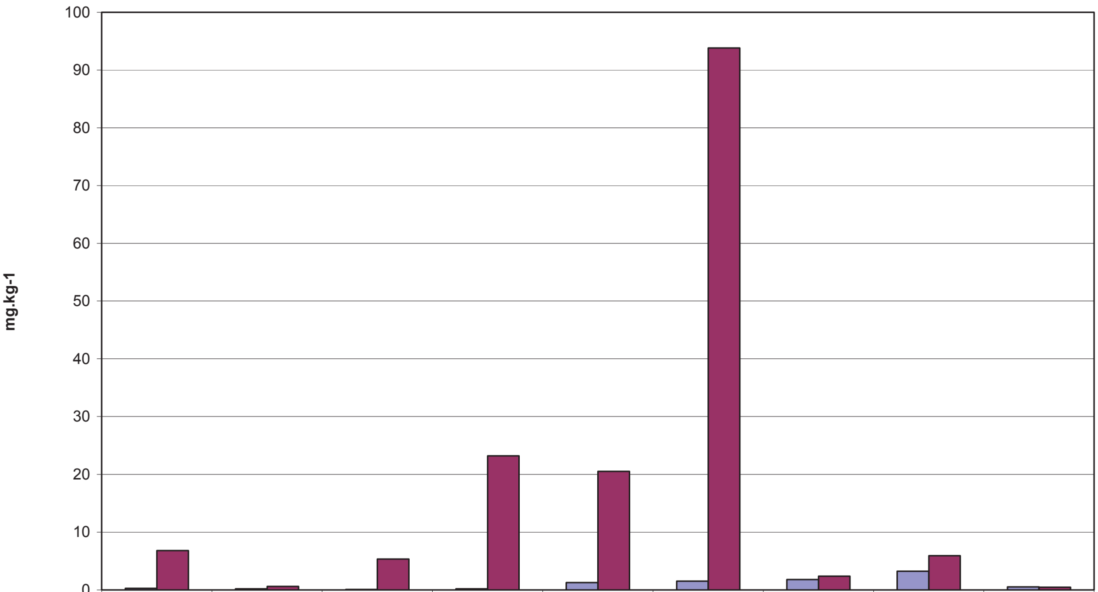
The sample oil was measured with use of standard spindle of R3 type, which is the most suitable spindle for this kind of test specification. The spindle speed (revolutions per minute) was selected to 30 rpm. The temperature dependence was modeled using polynomial of 6th degree and software Microsoft® Excel 2002 (10.6871.6870) SP3.

RESULTS AND DISCUSSIONE

The research was focused on evaluation of possibilities of enriching the engine oil by additives in order to increase its service life. Three different experimental approaches were used (see the chapter Methods). As a first series of experiments, the new (unused) oil was compared with used one in order to determine, if the used oil can be treated by additives. Consequently, the temperature dependence of dynamic viscosity of unused oil, used oil, and mixture of used oil and additive was measured.

Spectrometry

Comparison of amount of friction particles present in new and used engine oil is graphically



	Al	B	Cr	Cu	Fe	Na	Pb	Si	Sn
new oil	0,25	0,21	0,07	0,19	1,25	1,51	1,77	3,23	0,53
used oil	6,80	0,63	5,35	23,21	20,54	93,82	2,37	5,91	0,46

3: *Presence of friction particles in engine oil* presented in Fig. 3. The presence of water in oil was tested in ALS Laboratory, s.r.o.

According to the results of spectrometric analysis, it is possible to state that used engine oil exhibits lower or medium degree of degradation. Increased presence of aluminum, chromium, copper, and iron is acceptable for given type of engine. Increased amount of sodium and positive result of water in oil presence test can show on leakage of cooling fluid into the oil filling.

As it results from spectrometry experiments, the used engine oil is suitable for conditioning by additives in order to extend its service life, because the amount of friction particles does not exceed the orientation limit proposed in literature (Mang and Dresel, 2001).

Particles monitoring

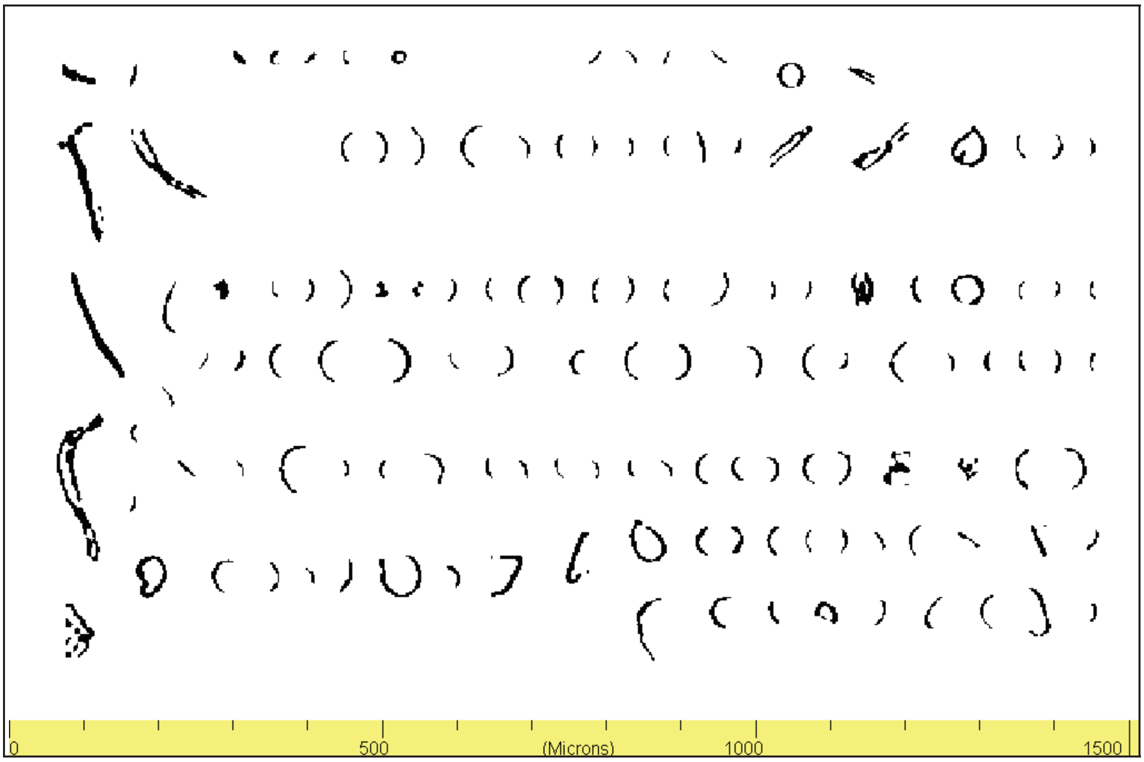
Due to existence of several types of friction components, there are several types of friction wear. The particles produced during different wear types are characterized by different size and shape. As it is presented in Kumbár *et al.* (2011), the particles produced during common wear do not exceed 5 micrometers in size. Increasing size of friction particles (tens up to more than hundred of micrometers) and their number indicate the engine wear.

The total amount of 39,500 particles was detected in one *ml* of unused oil. In case of the new oils these particles represent rather lubricating particles than friction metal particles. In case of used oil, the total amount of 98,600 particles was detected in 1 ml of the sample. The most frequent particles and their mean and maximum sizes are listed in Tab. II. Selection of detected particles is shown in Fig. 4.

As it results from this experiment, the oil does not contain excessive amount of large metal particles, and it is thus suitable for adding the additives in order to increase its service life.

II: *The most frequent particles present in used engine oil*

	Num/ml	Mean (microns)	Max (microns)
Cutting	87.4	30.6	65.0
Severe sliding	10.8	52.0	158.2
Fatigue	1.9	26.7	26.7
NonMetallic	39.3	44.5	68.8
Unclassified	21.2	25.6	29.6
Fibers	80.0		

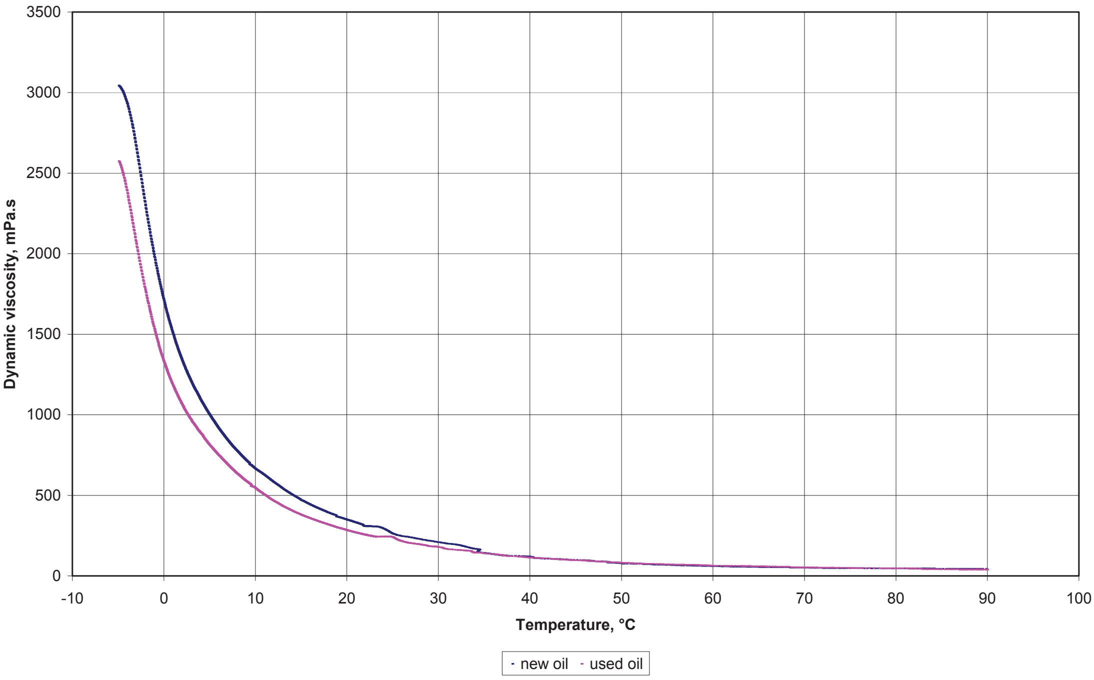


4: *The particles detected in used engine oil*

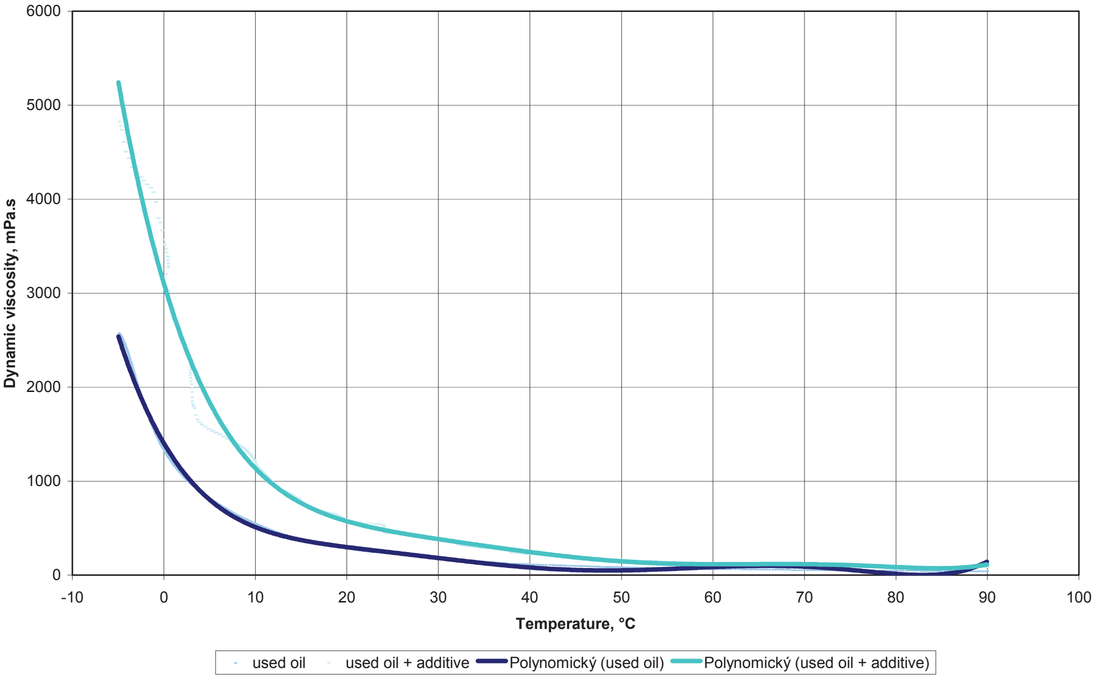
Temperature dependence of dynamic viscosity

Temperature dependence of the engine oils dynamic viscosity was evaluated in broad temperature range: −5 °C to +90 °C. As a first step, the dependence of used and unused oil was compared. As can be seen in Fig. 5, the temperature dependence decrease in case of used oil is just slightly smaller than in case of unused one, especially in temperatures below +30 °C. Similar results were presented in literature – see e.g. (Kumbár *et al.*, 2013).

The results of quantifying the temperature dependence of the oil viscosity revealed that used oil was not critically degradated and it is thus suitable for treatment by additives in order to increase its service life.



5: *Dynamic viscosity of used and unused engine oil*



6: *Dynamic viscosity of used engine oil treated by additives*

Treatment of the used engine oil by additives

Since no performed experimental method eliminated the possibility of treatment the used oil by additives, the oil was enriched by additives in ratio 1:10. Consequently, the influence of additive on temperature dependence of dynamic viscosity of created mixture was evaluated.

As it is obvious from Fig. 6, the additive addition had a significant influence on flow properties of tested oil. In case of oil treated by additives, the dynamic viscosity at −5 °C increased from approx. 2,500 mPa.s to approx. 5,200 mPa.s. The viscosity differences were negligible at the temperatures exceeding +50 °C.

The temperature dependence of dynamic viscosity of both, used oil and used oil added by additive was modeled by polynomial fit of 6th degree. Following general formula was used:

$$y(x) = a_6 \times x^6 + a_5 \times x^5 + a_4 \times x^4 + a_3 \times x^3 + \\ + a_2 \times x^2 + a_1 \times x + a. \quad (1)$$

The coefficient of determination R^2 in both cases reached the satisfying value of 0.98.

CONCLUSIONS

The role of engine oil in the engine operation is of multipurpose character. None of the oil characteristics or physical properties can be preferred and/or increased to the exclusion of other. Another factor playing the important role in the oil management is meeting the emission limits. Ensuring demanded properties is always a sort of a compromise, which must consider and accept all technical requirements. The primary goal of the oil manufacturers is to produce such oil, which would extend the engine service life and fulfill all technical requests.

Three experimental approaches, selected for analysis of the engine oils and described above, are surely sufficient for the needs of presented research. Similar results were presented in literature – see e.g. (Kumbár *et al.*, 2012) and (Guo *et al.*, 2007). The spectrometry was used for determination of presence of selected chemical elements and especially metals in oil. Particles monitoring was employed in order to describe the amount, type, and size of friction particles. The temperature dependence of dynamic viscosity was evaluated by use of rotary viscometer. In case of all three approaches it is advantageous to compare the measured values with the results received for unused engine oil of the same marking and viscosity index. If the degradation of oil is classified as low or medium, it is possible to increase its service life for several thousands of kilometers. But it is necessary to monitor the condition of the oil in appropriately selected period – e.g. each 3,000 km. If the degradation of oil is found as higher or high, it is necessary to change the oil immediately. The change should obviously include the oil filter.

SUMMARY

The objective of this paper is find changes of the flow behaviour of the raw engine oil and engine oil with special additive. The experimental approaches, selected for analysis of the engine oils and described above, are surely sufficient for the needs of presented research. The spectrometry was used for determination of presence of selected chemical elements and especially metals in oil. Particles monitoring was employed in order to describe the amount, type, and size of friction particles. The temperature dependence of dynamic viscosity was evaluated by use of rotary viscometer. In case of all three approaches it is advantageous to compare the measured values with the results received for unused engine oil of the same marking and viscosity index. If the degradation of oil is classified as low or medium, it is possible to increase its service life for several thousands of kilometers. The temperature dependence of the dynamic viscosity has been modelled by the exponential mathematical model. The values of the determination coefficient R^2 was 0.98. The knowledge of the dynamic viscosity behaviour of engine oils as a function of its temperature is great important, especially when considering running efficiency and performance of combustion engines. Proposed models can be used for description and prediction of flow behaviour engine oils (raw and with special additive).

Acknowledgement

The research has been supported by the project TP 5/2013 "Application of non-destructive methods of technical diagnostics in agricultural technology" financed by IGA AF MENDELU.

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