non-traditional methods of construction. A similar situation occurred in the 'Do Bazin' forest unit. The use of brick rubble and local materials was applied here. Bark and slash (brushwood) as a protective course of the road body appear to be a non-traditional material here. Based on the results of our study it is possible to conclude that bark has favourable properties and if sufficient quantity of bark is available it is suitable to use it. In order to preserve the required properties of bark it is necessary to prevent access of air or to situate bark below the groundwater table. As for the service life of bark it will be necessary to monitor and evaluate it. Under natural conditions of the area it is possible to use also mobile methods of reinforcement such as tube mats or plate grids.

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THE SERVICE LIFE OF BIODEGRADABLE OILS IN GEARBOXES

1. Introduction

The use of methods of tribotechnical diagnostics in the field of estimating the reliability (expressed by service life) of biodegradable oils appearing to be a suitable replacement for mineral oils in gearboxes of forest and wood-processing machines is important part of the study of problems relating to the requirement of environmentally-friendly forest management. After adopting a forest law, conditions for the operation of machines in forests have been made stricter (Forest Act No. 289/95, § 13, subsection 3 and § 32, subsection 8). The Law places a duty to introduce biodegradable oils into forest practices. The reason of the requirement is a fact that mineral oils used in forest practice have negative ecological properties and one of the possibilities of increasing environmental safety is transition to environmentally more suitable fluids. It applies both to hydrostatic circuits (systems) and gearboxes. However, also these fluids have to meet criteria necessary for the evaluation of their suitability for gearboxes. The paper is a continuation of the methodology of testing published by the author in (1) and proves that present possibilities of biodegradable oils cannot be overestimated.

Based on the failure rate, it is necessary to distinguish between products with sudden and gradual failures according to the course of parameter changes. Changes in gearbox fillings can be characterized by the gradual change (degradation) in some parameters. It follows that applications of methods of traditional reliability suitable for products with sudden failures can be completed using methods of technical diagnostics.

2. Material and methods

The series of ALB OX ALFA gearboxes consists of 6 sizes of single-speed gearboxes of the following gearing axle distances: 63, 80, 100, 125,160 and 200 mm.

From the viewpoint of construction, the gearboxes are designed in such a way that the body of the gearbox consists of two identical halves of aluminium alloy interconnected in a vertical dividing plane by screws. In the box, pinions and shafts with gear wheels are placed on single-row ball bearings. The gearing is nitrided and dimensioned for the service life of 25 000 service hours. Relatively small weight of the gearboxes, the size of transmitted power per kg weight, range of power from 0.37 to 30 kW and modular construction predetermine the gearboxes to the broad use and replacement of old types and, therefore, the gearboxes were chosen for testing the service life of biodegradable oils. Filling of OA PP 13, OA PP 80 and OA PP 90 mineral gear oils according to the power transmitted by the gearbox is recommended as original.

For the tests, oils were selected according to the following considerations. All oils were manufactured on the basis of rape triglycerols and there is an endeavour to choose that oil as a basic type which is subject to refinement, neutralization, bleaching and deodorization. BIOMIL PR 46 and ECOVIS PR 46 products appear to be suitable fulfilling given conditions. They differ in the use of antioxidants which do not affect the value of initial acidity in the former oil (toluene butylhydroxide or better the mixture of antioxidants with sodium thiocarbamate). The second product is additivated by antioxidants of acid character increasing many times the initial acidity of oils. Another type of oil is BIHOL 43, a crude oil heat-extracted after pressing out and still containing considerable amounts of phospholipides and lecithins after cleaning, completed with antioxidants and other additives. Tests should prove an argument on the low service life of the oil. These types of oils show viscosity values corresponding to the filling of hydraulic circuits and for the purpose of comparison, tests of PRIMOL EKO 150 and 220 and BAB DEGOL 220 oils for gearboxes were carried out.

The ALBOX series of gearboxes is of a modular character making possible to design two-and three-speed combinations from six basic single-speed gearboxes. A two-speed combination, viz. construction size 63/100 driven by a 4 AP 90L-8 electric motor attached by mans of a distance piece, power 0.55 kW, 28 r.p.m. and T.M. 190 Nm was chosen for the tests.

For the purpose of testing, a test bench has been designed and constructed consisting of a frame on which two ALBOX ALFA 63/100 gearboxes driven by an electric motor are attached by screws. Output shafts of both gearboxes are fitted with pulleys and interconnected by three V-belts. In the electric connection, an adjustment has been carried out ensuring the state when both gearboxes are mutually loaded. Both gearboxes are so loaded to their full power and can be used for testing oil fillings.

The gearboxes were filled with oils which appeared to be superior in the course of previous applications in hydraulic circuits. It is, therefore, supposed that the oils can be used also in gearboxes. According to a working hypothesis, properties of each of the oils tested will be very good for a period of min. 2000 service hours. It means that changes in basic selected parameters will range within allowable limits. After 500 service hours, sampling was carried out and parameters under study were determined. It is very important oil temperature to be kept below a limit of 70°C. The limit was regularly checked being exceeded in no case. The measurement of parameters was carried out according to standards given below.

Acid value	CSN 588756	corresponds to ISO 660-1983	
Peroxide value	CSN 588765	corresponds to ISO CSN 3960-1994	
Water content	CSN 650330	Viscosity	DIN 53015

3. Results

For better illustration, data from records of tests given in tables were converted into diagrams prepared as a continuous diagram of data of particular parameters with the exception of density which is constant.

4. Discussion

According to recommendations of the standards it is possible to state that viscosity is the main parameter under investigation changes of which must not exceed 10%. The requirement has been observed and the oils can be used as much as 2500 hours.

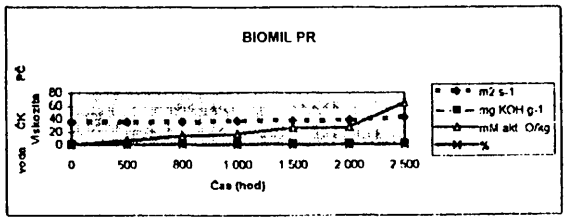
Results of tests of BIOMIL PR 46 oil are summarized in tables and diagrams. The oil ranks among the most high-quality oils of Czech production. Under given conditions, its service life amounts to more than 3500 hours having classical pattern of parameter changes and being fully comparable with ECOVIS 46 oil (SUNOCO product).

According to our expectations, water content in ECOVIS PR 46 tests (Fig. 2) was not increased because the development of peroxide number showed that the oil was in the state of a certain increase of induction period, polymer formation increased as was shown by the development of viscosity but ester bond hydrolysis did not occur yet. Acid value which could inform on the change through its increase cannot be used in the oil because substances of acid character are obviously used as antioxidants and the method is not able to distinguish between the increase of acidity caused by the release of fatty acids and the decrease of acid value given by the exhaustion of the content of acid antioxidants. The effect was also observed in the course of tests of oils in hydraulic circuits and it is possible to say that it has no negative influences on the condition of sealing rubber for the period of tests. An increase in peroxide number after 2500 hours of testing shows that oil degradation has occurred.

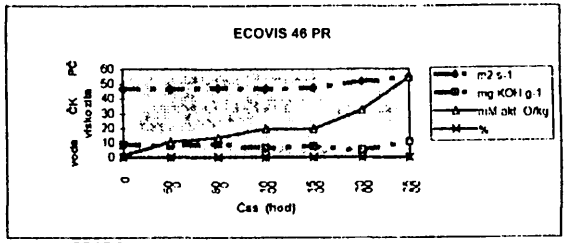
Data from records on the tests of BIHOL oil show that the main parameter under investigation, i.e. viscosity the changes of which must not exceed 10% is observed up to the value of 1500 service hours and the oil is able to be used for other 500 hours. According to our expectations, water content was not increased during the tests. The development of a peroxide number shows that the oil is in the state of a certain increase of induction period, polymer formation increases as shown by the development of viscosity but ester bond hydrolysis has not yet occurred. After the lapse of the time. Fig. 3 shows that oil degradation occurred. Acid value which could provide information on the change through its increase indicates that the course of changes is sufficiently slow and in spite of higher values due to higher initial values of oil acidity is comparable with changes occurring in corresponding refined products. Increased content of free fatty acids is not desirable for the operation of gearboxes, however, effects on the loss of the function of sealing have not been proved. The peroxide number increases steeply and its decline has not occur so far. Increase in viscosity is directly proportional to the operation time, however, its value unfortunately exceeded allowable limits. Further tests are not necessary because present experiments show that accelerated degradation of oils would occur. In conclusion, it is possible to state that the technical service life of the oil tested under our conditions is 2000 service hours. The oil can be classified as a relatively quality oil.

Other oils tested in the same gearbox were PRIMOL EKO L 150 and PRIMOL EKO L 220. The tests were conducted in 1996, i.e. in time when the test methodology was not specified yet. Results of the analyses of oil chemical parameters after 3000 service hours show that the oil is totally degraded. Acid value is considerably high from

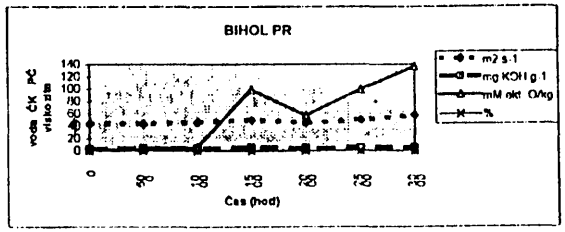
the beginning of the tests being increased by a value comparable with quality oils during the tests, peroxide number being in the range of decline, relatively high water content decreased paradoxically during the test and also olfactory tests indicated total degradation of the oil. Unfortunately, oil viscosity was not measured. Technical service life of the oil can be estimated to be max. 1500 service hours. With respect to the possibility of negative effects of the oil on rubber sealing a test of swelling capacity of various sealing materials was carried out. Results of the test, however, showed that swelling properties do not change markedly. Thus, a higher acid value has only limited effects on the service life of the sealing. The course of changes observed in BAB DEGOL 220 oil for the period of 1000 hours corresponds to properties of refined products (Fig. 4).



GRAF 1



GRAF 2



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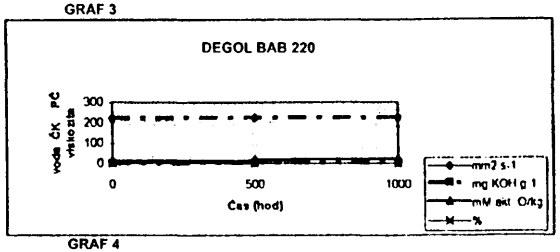

GRAF 4

5. Conclusions

Service life tests proved comparable properties of refined oils with measurable differences in service life and good conditions of BIHOL 43 oil for the period of 2000 service hours so that it is possible to recommend the oil as a filling into gearboxes. Comparisons with usually recommended oils show that BIHOL oil ranks among relatively quality types of rape oils in spite of the different method of production. It is recommended to give annual terms of replacement in these types of oils for the operation of gearboxes.

The paper provides information on the possibility of using methods of tribotechnical diagnostics for the estimation of service life as a parameter of reliability of biodegradable oils in gearboxes of forest machines. The analysis is aimed at three types of HETG oils characterized by various differences in the production, refinement and additivation. Changes were monitored of selected diagnostic parameters in the interval of 500 service hours up to the moment of the loss of function, i.e. limiting state of some of the parameters. Information is given on the suitability of using particular oils for particular operation conditions.