EFFECTIVENESS AND USES OF BIODEGRADABLE HYDRAULIC LIQUIDS

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Biodegradable hydraulic liquid of vegetable origin decreases the contamination of life environment. This paper shows the scope of the diagnostic following the alterations of influencing these liquids during the operation and the design methodology of optimal administration for their recovery.

biodegradable hydraulic liquid; content of contaminants; viscosity; regime of wear out; diagnostic signal

INTRODUCTION

The replacement of crude oil products by other materials is currently motivated above all by the search to acquire materials with better ecological character and utilize a part of The Agricultural Fund for non-agricultural objects. One of the obstacles to wide usage and application of biodegradable hydraulic liquids are currently the undefined and unclarified questions concerning its utility and effectiveness.

The use of hydraulic equipment in tractors, mobile technology, agricultural and construction machines, etc. presents a serious threat to the environment because of oil losses in the fields which lead to the contamination of water and soil (Pošta, 1995; Chrást et al., 1995). In the same way thousands of tons of fossil oil products enter the soil and water annually. This leads, together with construction solutions, to look for an alternative method of reduction of harmful effect, acceptable biodegradable hydraulic liquid that does not, in case of leakage, cause large damage and protects the environment.

Along with the use of a biodegradable hydraulic liquid in the hydraulic system of a machine together with the presently used classical mineral oil as a complex it is possible to predict (Zewdie, 1997; Hartweg, Keilen, 1989):

1. the different acquisition costs
2. different technical life of both types of hydraulic oils

3. possibly different life range of hydraulic elements in hydraulic systems
4. different degrees of contamination of the environment
5. the use of surplus agricultural land for technical aspects, ecology, employment, etc.

The objective of this contribution is to adapt the theoretical and methodical analysis of a given problem concerning total techno-economical effectivity.

MATERIAL AND METHOD

To reach the established objective of the work it is necessary to:

1. elaborate and compile the theoretical part of the problem
2. elaborate all methodologies including essential method for realization of the experiment
3. execute the verifying experiment
4. apply the result of the experiment to the methods required to analyze the effectivity of Biodegradable Hydraulic Oil.

The renewal (replacement) of liquids in a hydraulic system could be understood as an optimization normative for a renewal, extension or a reduction of the interval in which the exploited liquid has an impact on the total effectiveness. The contribution analyzes this problem from techno-economical point of view which includes all influences connected with the discharged liquids, due to different wear out intensity of elements of hydraulic aggregates and with respect to ecological requirements.

THEORETICAL PRINCIPLES OF SOLUTION

Professional literature substantiated that the effectivity of technical object is determined by the sum of acquisition (production) and operational costs to its lifetime per unit (number of km, work done, production etc.). It means, we are talking about the so called average unit price of a given technical object (Pošta, 1993; Havlíček et al., 1989).

If the condition of technical object is evaluated by the change of a selected diagnostically signal S, as the indicator of the effectivity of the object the renewal time is determined by a hidden value S_o of a given signal, then the ratio of the sum of acquisition and operational cost to its lifetime is minimal.

The operational costs are supposed to increase with the increasing volume of the work performed (i.e. with increasing time of operation), due to failure mechanisms. If the result in form of the average unit costs of renewal and operation of the equipment can be identified with sufficient accuracy with the similar value of the selection set, then the selected diagnostic signal can be stated (Havlíček et al., 1989):

$$u(S) = \frac{\sum_{i=1}^{n} N_{oi} + \sum_{i=1}^{n} N_{pi}(S)}{\sum_{i=1}^{n} t_i(S)} \qquad (1)$$

where: $u(S)$ – mean value of the average unit costs of the renewal and the operation of the equipment when reaching the technical state S

n – range of the selection set (number of investigated elements)

N_{oi} – costs of the renewal of the i-th element

$N_{pi}(S)$ – costs of the operation of the i-th element from the beginning to reaching the S state or till the necessary putting out of the operation before reaching the S state

$t_i(S)$ – operational time of the i-th element from the beginning up to the S state or physical life of the i-th element, which did not survive up to the S state

As every discrete value S_i of the diagnostic signal has the corresponding variable operational times for the respective element $t_i(S_i)$, from which it is possible to calculate the mean value $t(S_i)$, to determine the function $t(S)$, Fig. 1, and after a statistical evaluation, the equation (1) can be transformed to a general form of the effective function of renewal

$$u(t) = \frac{N_o + N_p(t)}{t} = \frac{N_o + \int_0^{t(S)} v_p(x)\,.\,dx}{t} \qquad (2)$$

where: $u(t)$ – mean value of the average unit costs of the renewal and the operation of the equipment when reaching the S technical state, or $t(S) = t$

N_o – mean costs of the renewal of the equipment

$t(S) = t$ – mean operational time of elements up to the S state

$N_p(t)$ – mean cumulative operational cost up to the S state, or $t(S) = t$

$v_p(t)$ – mean instantaneous costs of the operation till the S state, or $t(S)$

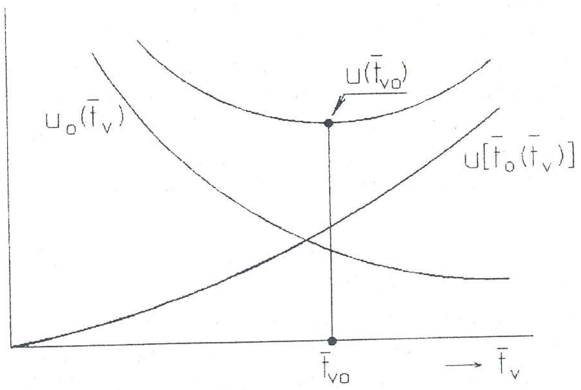
As the unit renewal costs $u_o(t) = N_o\, t^{-1}$ are a permanently decreasing function of the mean operational time and the unit operational costs are an increasing function, the summary function $u(t)$ has a local minimum $u(t_O)$, whose coordinates are dependent on the items, that form the function (1) or (2), and obtaining them is the general purpose of the whole optimization solution.

The methods of the determination of the standard for the liquid renewal in a hydraulic system should therefore be as follows:

1. A perspective diagnostic signal Q is chosen for the evaluation of the state of the considered liquid and a real range of this signal is estimated, where the experiment will be held. It is obvious, that the experiment and the

whole optimization solution can be carried out for several different signals and then the signal with the most obvious results can be recommended for practical application.

2. For every chosen discrete value Q_i of the Q signal, for which the experiment is carried out, the selection set of hydraulic systems is monitored during operation, for which the liquid replacement occurs at Q_i value. The number of these sets is the same as the number of the selected discrete values of Q_i.
3. For every replacement of the liquid at the technical state of Q_i the individual operational time – the individual replacement interval $t_{vi}(Q_i)$ – is recorded and for the same state Q_i also the mean replacement interval $t_{vi}(Q_i)$ is calculated; it can be expected, that with increasing values of Q_i also the values of $t_v(Q_i)$ will increase and that there is a possibility to describe this fact by the $t_{vi}(Q)$ relation.
4. Each discrete value of Q_i has a corresponding level of the technical state of the observed liquid and of the observed hydraulic system. It can be expected, that with increasing values of Q_i the physical and technical characteristics of the liquid will deteriorate, so each subsequent value of Q_i will correspond higher instantaneous operational costs.
5. These experimental data are transformed into the form of the functional relations of the technical life of the investigated element of the system. And the average unit costs of the mean interval of the operational time up to the liquid replacement, t_v, which enables to determine the optimal mean interval of replacement of the filling of the hydraulic liquid t_v, and also the optimal value of the diagnostic signal S_o for the renewal of the liquid charge belonging to this interval. This principle is illustrated in Fig. 1.



1. The principle of the assignation of the optimal value of the diagnostic signal of preventive replacement

EXPERIMENTAL VERIFICATION

To obtain the necessary source materials for the verification of the possibility of the application of the above mentioned theoretical constructions, the laboratory test of the hydraulic system was carried out with biodegradable liquid of Czech production. Observed were the changes of selected parameters characteristic for the technical state of the hydraulic system as well as for the liquid:

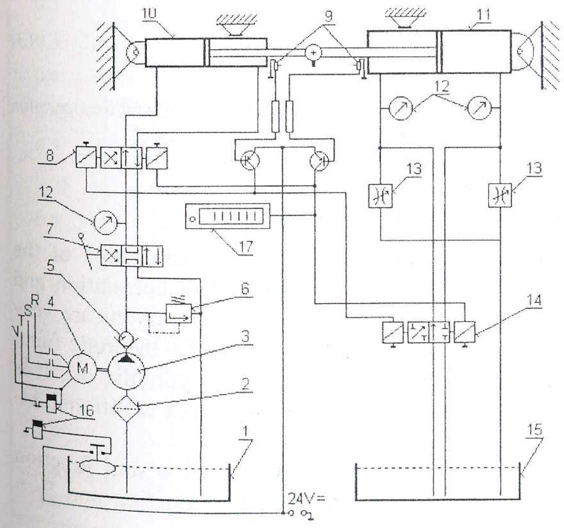
- total content of contaminants
- viscosity
- water content
- regime of wear out
- changes in acidity number.

The analyses were carried out repeatedly, the gained results were statistically evaluated.

The testing equipment consisted of two basic units, that were formed by a high-pressure hydraulic aggregate and a loading equipment. The scheme is given in Fig. 2.

The testing equipment was adjusted for automatic operation. Operational times, the pressures at measurement points, the number of cycles, and the temperature of hydraulic liquid were continuously monitored.

The first stage of the experiment was carried out for 400 hours (120 000 loading cycles). The control samples of the liquids were extracted every



2. Scheme of laboratory apparatus

1, 15 – basin, 2 – filter, 3 – hydraulic pump, 4 – electric motor, 5 – clack-valve, 6 – insurable (pressure) outlet, 7, 8, 14 – conveyance, 9 – alteration switch, 10, 11 – hydraulic motor, 12 – barometer, 13 – adjustable outlet, 16 relay

50 hours of operation. During the experiment the temperature in the primary circuit was maintained on 54 ± 3 °C. The loading pressure was set on 14 Mpa.

RESULTS

A number of particular data were obtained during the experiment. An example can be given by the data relating to the parameter "total content of contaminants", see Tab. I.

I. Experimental ascertained and rated values

t	h	0	50	100	150	200	250	300	350	400
$S = CN$	%	0.015	0.046	0.106	0.140	0.154	0.197	0.240	0.266	0.292
$No/t(S)$	Kc/h		90.04	45.02	30.01	22.51	18.01	15.01	12.86	11.25
$Np[t(S)]/t(S)$	Kc/h	0	0.007	0.051	0.075	0.115	0.135	0.183	0.251	0.268
$u[t(S)]$	Kc/h		90.047	45.071	30.085	22.625	18.145	15.193	13.111	11.518

It is apparent during this experiment that the minimum sum function was not accomplished. Behalf the chance attestation applicability of a designed methodology have been accordingly experimental data replaced by a theoretic function. The sum function has been expressed in common conformation

$$u(S) = \frac{(N_o + a_1 S^{b_1})}{a_2 S^{b_2}} \tag{3}$$

where: $u(S)$ – mean value of the average unit costs of the renewal and the operation of the equipment when reaching the technical state S

N_o – mean costs of the renewal of the equipment

S – diagnostic signal

a_1, b_1, a_2, b_2 – parameters of a theoretic sum function

For the assignation of arguments and indexes of the correlation of the theoretic sum function was applied the standard method of correlation and regression analyses. It is apparent, that designed theoretic functions are very well described by experimental data. By the extrapolation of a theoretic function these were assigned optimal values for recovery of hydraulic oil. It is once again an exigency to admonish, that those values need additional experimental acknowledgment.

Under equation (3) there were rated theoretic values of a sum function behalf diagnostic signal S_1 = content of aggregate contamination and S_2 =

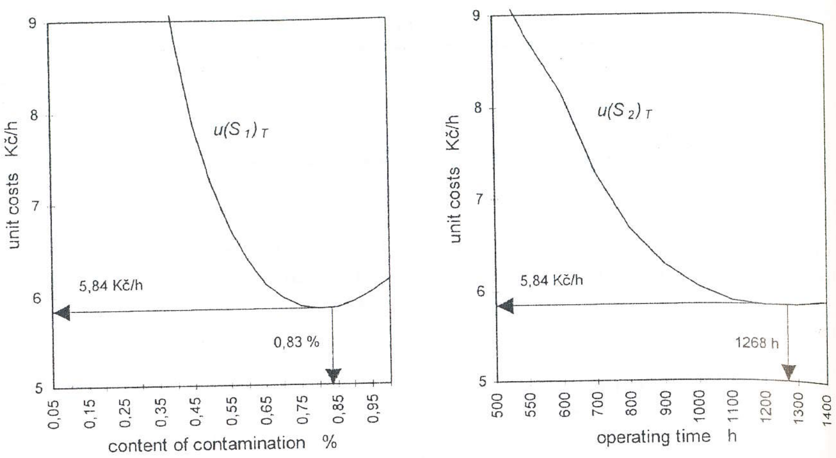
II. Parameters and correlation indexes of theoretic functions

$a_1 = 5205.8321$	$a_2 = 1575.9358$
$b_1 = 3.0931$	$b_2 = 1.1512$
$r_1 = 0.9966$	$r_2 = 0.9915$

operating time. Values of $u(S)_T$ of theoretic and values $u(S)_E$ of experimental function are in Tab. III and Fig. 3. Appropriate values of diagnostics signals ($\cong S_1$) and ($\cong S_2$) are assigned by a linear interpolation.

III. The values of the function $u(S_1)$, $u(S_2)$

$u(S_1)$				$u(S_2)$			
S_1	$u(S_1)_E$	$u(S_1)_T$	$\cong S_2$	S_2	$u(S_2)_E$	$u(S_2)_T$	$\cong S_1$
%	Kc/h	Kc/h	h	h	Kc/h	Kc/h	%
0.05	89.86	89.99	50.1	50	90.05	91.70	0.05
0.1	40.21	40.50	111.3	100	45.07	45.05	0.09
0.15	25.43	25.45	177.4	150	30.09	30.08	0.13
0.2	18.32	18.36	247.1	200	22.63	22.61	0.17
0.25	14.27	14.32	319.5	250	18.15	18.16	0.20
0.3	11.64	11.74	394.1	300	15.19	15.21	0.24
0.35	–	10.00	470.6	350	13.11	13.12	0.27
0.4	–	8.76	548.8	400	11.52	11.58	0.30
0.45	–	7.86	628.5	450	–	10.40	0.34
0.5	–	7.21	709.6	500	–	9.48	0.37
0.55	–	6.72	791.9	550	–	8.75	0.40
0.6	–	6.37	875.3	600	–	8.15	0.43
0.65	–	6.12	959.8	700	–	7.27	0.49
0.7	–	5.96	1045.2	800	–	6.68	0.55
0.75	–	5.87	1131.6	900	–	6.29	0.61
0.8	–	5.84	1218.9	1000	–	6.04	0.67
0.85	–	5.85	1307.0	1100	–	5.89	0.73
0.9	–	5.92	1395.3	1200	–	5.84	0.79
0.95	–	6.02	1485.6	1300	–	5.85	0.85
1.0	–	6.16	1575.9	1400	–	5.92	0.90



3. Determining of optimum time of replacement from the theoretic sum function

CONCLUSIONS

Besides the characteristics of the biodegradable liquids at the moment of their production, there is very important there are also changes of these characteristics during the operation. The knowledge of these relations is necessary for the control of the optimal replacement of liquids.

The performed experiments have proved the possibility of the monitoring and the usage of the selected parameters of the technical states of the hydraulic system with a biologically degradable liquid. The selected parameters and the method of their determination are therefore suitable for this purpose.

We can recommend the following procedure to the users who want to achieve an optimal control of renewal of biodegradable hydraulic liquids:

- continuous monitoring and recording of the operational time for the liquid
- with drawing of control liquid samples and performing analyses for the total content of impurities, viscosity and acidity number at determined intervals of operational times
- determining whether the optimal time for renewal has been reached by substituting the obtained values into the theoretical equations. If yes, carrying out the replacement of the liquid.

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Náhrada ropných produktů jinými vhodnými materiály je motivována především snahou získat materiály s lepšími ekologickými vlastnostmi, snížit závislost na producentech ropy a využít zemědělskou půdu pro nepotravinářské účely.

Použití hydraulických zařízení u mobilní techniky, především u traktorů, užitkových vozidel, zemědělských a stavebních strojů atd. v sobě skrývá mimořádné riziko znečištění vody a půdy při ztrátách hydraulických kapalin v terénu.

Při použití biologicky odbouratelných kapalin v hydraulických soustavách strojů lze při komplexním pohledu, ve srovnání s dosud užívanými minerálními kapalinami, očekávat (Zewdie, 1997; Hartweg, Keilen, 1989):

- rozdílné pořizovací náklady na hydraulické kapaliny,
- rozdílný technický život biologicky odbouratelných a minerálních kapalin,
- možné rozdíly v životnosti strojních prvků hydraulických systémů,
- rozdíly ve stupni poškozování životního prostředí,
- možnost nepotravinářského využívání zemědělské půdy se všemi doprovodnými jevy, tj. uchování kulturní krajiny, pracovní příležitosti aj., a současně také úsporu a uchování zásob ropy, včetně vedlejších efektů z toho plynoucích.

Teoretické a metodické zpracování problému celkové technicko-ekonomické efektivity užití biologicky odbouratelných hydraulických kapalin bylo cílem práce. Pro jeho dosažení bylo nutné:

- provést teoretický rozbor vlivů působících na celkovou efektivnosti zařízení, používajícího biologicky odbouratelnou hydraulickou kapalinu,
- navrhnout metodiku stanovení celkové efektivnosti užití těchto kapalin,
- experimentálně ověřit správnost a reálnost návrhu a způsobu zjišťování vstupních údajů, potřebných pro navrženou metodiku.

V odborných publikacích je dostatečně zdůvodněno, že vhodným integrálním ukazatelem efektivnosti užití technického objektu je suma pořizovacích (výrobních) a provozních nákladů, připadajících po vyčerpání technického života objektu na jednotku jeho doby provozu. Jedná se ukazatel „průměrné jednotkové náklady" (P o š t a, 1993; H a v l í č e k et al., 1989). Toto kritérium bylo použito i v této práci.

Pro stanovení normativu pro výměnu (obnovu) biologicky odbouratelné kapaliny v hydraulické soustavě byl navržen tento postup:

- Vybere se nadějný diagnostický signál pro hodnocení technického stavu kapaliny a odhadne se rozsah reálných hodnot tohoto signálu.
- Sleduje se závislost hodnoty vybraného signálu na době provozu kapaliny pro každý prvek výběrového souboru.
- Pro každou výměnu kapaliny se zaznamená individuální hodnota diagnostického signálu a jí odpovídající hodnota doby provozu.
- Takto experimentálně získaná data se statisticky zpracují a nahradí se teoretickými závislostmi, které umožní snadné získání optimálních hodnot diagnostických signálů i odpovídající doby provozu.

Bylo navrženo a vyrobeno laboratorní zkušební zařízení, které umožnilo sledování a registraci všech potřebných údajů. Zařízení je schematicky znázorněno na obr. 2.

Při tomto experimentálním ověřování byly sledovány tyto diagnostické signály:

- celkový obsah nečistot,
- změna viskozity,
- obsah vody,
- režim opotřebení,
- změna kyselosti kapaliny.

Byla získána experimentální data, která byla zpracována podle navržené metodiky. Výsledky, vztahující se k nejvhodnějšímu diagnostickému signálu jsou uvedeny v tab. I až III a graficky znázorněny na obr. 3.

Jako nejvhodnější a nejpřesnější diagnostický signál se v podmínkách experimentu ukázal „celkový obsah nečistot". Pro tento signál byly zpracovány všechny zjištěné údaje, stanovena teoretická závislost na době provozu a určen normativ pro výměnu kapaliny. Byla potvrzena vhodnost a reálnost použití navržené metodiky pro optimální výměnu hydraulické kapaliny a pro hodnocení celkové efektivity užití biologicky odbouratelných hydraulických kapalin.

Uživatelům hydraulických zařízení s biologicky odbouratelnou hydraulickou kapalinou lze doporučit následující postup optimálního řízení výměny kapaliny:

1. Průběžně sledovat a evidovat dobu provozu kapaliny (zařízení).
2. V intervalu 100 provozních hodin odebírat vzorky kapaliny a stanovit celkový obsah nečistot, viskozitu a číslo kyselosti.
3. Dosazením zjištěných hodnot do vztahů odvozených v této práci zjišťovat, zda bylo dosaženo optimálního okamžiku pro výměnu kapaliny. Pokud ano, provést výměnu.
4. Uvedený postup aplikovat na všechny uvedené diagnostické signály a po nějaké době dodržování uvedeného postupu vybrat ten signál, který bude pro dané konkrétní podmínky nejvýhodnější. Obnovu kapaliny nadále řídit podle tohoto signálu.

biodegradovatelná hydraulická kapalina; viskozita; obsah nečistot; režim opotřebení; diagnostický signál

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