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TECHNICAL AND COMMERCIAL CONDITIONS FOR DIESEL ENGINE ALTERNATIVE SUPPLY WITH VEGETABLE OILS

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ABSTRACT: The partial substitution with vegetable oils of Diesel fuel used to power Diesel engines is a possible behavior and benefits bringer. Under ecological aspect, this practice presents the general advantages of the fossil fuels replacement with biofuels obtained from renewable resources. From strategic point of view, this leads to an increase of energy independence of the practitioners. Finally, in certain sectors such as the agriculture, the use of vegetable oils as Diesel fuels can be bringers of immediate economic benefits. The technologies for the adoption of this behavior are relatively simple and available but, for its promotion, it is necessary to be ensured some technical and commercial conditions. This paper aims to present a summary of these conditions as they resulted from the researches performed during the last years within the National Institute of Research and Development for Machines and Installations Designed to Agriculture and Food Industry - INMA

KEYWORDS: conditions of alternative supply, Diesel engine, vegetable oils

INTRODUCTION

The use of raw vegetable oil for the supply of Diesel engines is not a new practice. Thus, the history records that at the Universal Exhibition from Paris of 1900, Rudolf Diesel himself made demonstrations with a model of the engine invented by him operating with peanut oil. Also, is known the widespread use of rapeseed oil for supplying of some Diesel engines in the first decades of the last century. More recently, the preoccupation for the alternative of using of raw vegetable oils for the supply of motor vehicles engines reappeared after the petroleum crisis of the beginning of decade 8 of the last century. Thus, in that period, major automotive manufacturing companies (General Motors in USA, Audi and Daimler – Benz in Europe) made testings with motor vehicles whose engines have been equipped with injection equipment specifically designed for the use of oils. The results of these tests were satisfactory, the only problems observed keeping of the appearance of gum deposits in the injection installations and inside of cylinders. „Unfortunately", the relatively rapid exit from the mentioned petroleum crisis, followed by an unprecedented availability of oil resources, led to abandonment of "visible" researches in this direction.

The effects of oil crisis episodes from the postwar period always consisted of a rearrangement of the oil price at higher levels, with adverse consequences on the world economic balances and industrial growth rates of all states. On the background of these consequences, in the family of industrialized countries was born the energetic security concept, under the banner of which were made and initialed arrangements on planned rhythms of oil extraction and the predictable evolutions of the trading prices of this. At the same time, with the status of part in the energetic security, began to be examined and was developed the concept of energetic independence. Under general energetic aspect, this concept has generated, at the level of each state or of some groups of states, development and promotion strategies of some intensive technologies for obtaining the energy - such as the nuclear reactors with fission - or of some sustainable technologies for obtaining the energy - such as the hydroenergetical stations. Under the particularly aspect but very important as share of fuels for the thermal engines, the concept of energetical independence enabled concerns in obtaining of alternative fuels. At the same time, the perspective of a relatively close depletion of world oil reserves directed the searches towards the finding of alternative fuels obtained from renewable resources. Under these conditions, the attention has been focused on biofuels, and the specialists have remembered that the use of vegetable oils as fuels is recorded in the "genetics" of Diesel engines.

Obtaining the vegetable oils appeal to limited resources as rhythm of use but periodically renewable through the life cycles of oleaginous plants. Also, the technologies involved are mature and relatively simple. Furthermore, current researches seems to indicate substantial growth possibilities of vegetable oils productions by the exploitation of algal cultures, and such an accomplishment would

allow and a reduction of the objections that the biofuels field has to face in the dispute "biofuels versus food".

The use of vegetable oils for the supply the Diesel engines presents nowadays a common form, but "indirect". Subjecting of vegetable oils to a process of transesterification leads to obtaining the bioDiesel, fuel with "engine properties" similar to those presented by Diesel fuel and therefore able to be used as a substitute for the latter. However, this biofuel has the disadvantage of relatively complicated processing, which is profitable only on a large scale and uses ingredients with a high environmental risk (methanol and sodium hydroxide). At the same time, the preparation of the bioDiesel and the use of vegetable oils in this form means to introduce between relatively simple operations for obtaining the crude vegetable oils and their use in engines a set of activities with the complexity of an integrated chemical industry. Obviously, this behavior complicates the way of oils "from furrow to the engine". The direct use of raw vegetable oils as fuel for Diesel engines simplify this way because only obtaining of vegetable oils is obviously much easier than getting the bioDiesel. Concretely, for obtaining of vegetable oils should be covered, outside the steps for obtaining the crops, only the stages of extraction of oil from oilseeds and its purification by processes of degumming and filtration. In addition, the profitability of these operations is not dependent on the size of production and the maintenance of a continuous flow of it. Therefore, the production of vegetable oils intended to be used as motor fuels can be organized without sensitive affecting of the profitability, in local sectors, located near the users and sized according to their needs.

MATERIALS AND METHODS - GENERAL CONDITIONS FOR THE ALTERNATIVE SUPPLY

Promoting the use of vegetable oils for the Diesel engines supply means primarily that they are available in sufficient quantity and quality and at prices competitive with the price of Diesel oil. We specify that the quality requirements imply that the vegetable oils to be released by the components producing deposits in the engine („gums and waxes") ie to have a phosphorus content less than 12 ppm (EN 14107) and to undergo a process of filtration with fineness of at least 5 μm. Assuming that these conditions are met, the following requirement refers to preservation of freedom of choice of the potential users.

The vegetable oils have to be proposed as alternative fuels for Diesel engines built for the supply with Diesel fuel. Under these conditions, so that the alternative supply to be accepted and attractive, must that it be possible with the intact preservation of the construction and adjustments of the Diesel engines used. May be allowed, at most, the necessity of using of some additional devices with reasonable prices, easy to install in the vicinity of engine and passive to its functioning with original supply. These conditions define the regime of poly-carburizing where the user can decide at will the use of of Diesel fuel or of vegetable oil without any intervention to the engine. In absence of this regime, the engines operating with vegetable oils are engines dedicated to some operating niches.

COMPARATIVE CHARACTERIZATION OF VEGETABLE OILS

The difficulties occuring in the practice of Diesel engines alternative supply with vegetal oils have their origin in differences between some properties of oils and the similar properties of Diesel fuel. Such differences are easy to see in Table 1 in which are presented the main characteristics of Diesel fuel and vegetable oils.

Table 1. The main characteristics of Diesel fuel and vegetable oils

PROPERTY	DIESEL FUEL	VEGETABLE OIL
PHASE HOMOGENEITY	homogeneous liquid	homogeneous liquid
COMPOZITION HOMOGENEITY	hydrocarbon molecules	triglicerydes molecules
DENSITY (at 20°C)	840	920
CETAN NUMBER	50	40
LOW CALORIFIC POWER [MJ/kg] ; [MJ/l]	41.8; 35.1	37.6; 34.6
VISCOSITY (at 20°C) [mm^2/s]	4 ... 6	40 ... 60
CONTAINING OF SUBSTANCES WHICH FORMS DEPOSITS TO BURN	low	high

The two fuels are homogeneous liquids as regards the aspects of phase and composition. Also, their lower caloric power are very close if it refers to the unit of volume and must made the observation that, for most of the Diesel engines, dosing is volumetrically done. Substantial differences appear relating to cetane number, viscosity and content of substances which form deposits at combustion. All these differences cause problems at the supply of engines with vegetal oils and, for this practice to be possible, must be taken adaptation measures.

SOLUTIONS FOR THE ADAPTATION TO SUPPLY WITH VEGETABLE OILS

The cetane number of vegetable oils, lower than that of Diesel fuel, makes that these do not self-ignite in the unheated cylinders of the engines, which prevents their starting "at cold". At the same time, the cetane number is enough for in the heated cylinders of the engines brought to operating temperature the vegetable oils to ignite under similar conditions for the case of Diesel fuel.

Therefore, the Diesel engines can not start "at cold" in the conditions of supplying with vegetable oils but, after reaching the thermal regime, they can function normally with this variant of fuel. The solution for the adaptation to this situation is organizing the sequential alternative supply. Thus, at the beginning of a stage of exploitation, the engine "cold" is started under the conditions of supplying with Diesel fuel and this supplying type is kept until reaching the temperature of regime. After warming up of the engine, is passed at the supply with vegetable oil and this is maintained almost the entire duration of the exploitation stage. Finally, near the end of the working stage, it returns to the Diesel fuel supply for an enough time that the supplying and injection installations of engine (the supply pump, the fuel filters, the injection pump, the injection pipes and the injectors) to be "washed" of vegetable oil and filled with Diesel fuel. This latest sequence is intended to allow the supply with Diesel fuel of the engine to the next working stage when, again must be started the engine "cold". In the conditions of practicing of sequential alternative supply, proportion in which the vegetable oil used replaces the Diesel fuel is obviously dependent on the duration of the working stages. For the Diesel engines exploited in working processes (agricultural works, cogeneration of electricity and heat, transports etc.) under the conditions of sequential alternative supply with vegetable oils we can speak practically of an almost total substitution of Diesel fuel, its share in total fuel consumption having a marginal proportion.

The viscosity of vegetable oils is about 10 times higher than that of Diesel fuel. At the supply of Diesel engines designed to run on Diesel fuel, the high viscosity of vegetable oils raises problems at passing through filters and, in the case of the engines with mechanical injection, at the level of injection pump elements. Thus, the pressure drop across the filters increases with the oil viscosity and, depending on the type and construction, the supply pump of the engine may be unable to deliver the necessary fuel or it may even damage. Also, at the level of the injection pump the size of mechanical stress increases because the transfer in cylinders of some doses of more viscous liquid requires amounts of energy corresponding increased. Finally, in the case of the engines with injection with "common rail", the raised viscosity of vegetable oils is likely to lead to the lowering of fuel injected dose, because in this case, the dosage depends on the injectors opening time. Removal or diminishing of the undesirable effects of vegetable oils viscosity is done by acting in the sense to reduce of it. Concretely, the vegetable oil used to the supply of an engine constructed to be fueled with Diesel fuel is delivered to the supplying installation heated to temperatures high enough that the viscosity to be lowered to "bearable" values.

To ensure the poly-carburizing regime, the oil heating is done in a additional device which, in a concentrated or distributed shape, contains one or more heaters placed on the fuel supply route and the directing distribution organs, as appropriate, the Diesel fuel or the oil to the supplying installation. The device is assisted by sensors that measure the temperatures achieved and by automation circuits which, depending on the levels of these temperatures, command the access of of Diesel fuel or of oil and functioning of heaters. Regarding the availability of a Diesel engine equipped with such a device, an essential condition is that the "normal" positions (without actuation) of the fuel distribution bodies must permit the fueling with Diesel fuel. Ensuring of this condition - with technical and commercial value - will allow the engine to be operated, being fueled with Diesel fuel, in the cases of failure of the additional device. Also, a condition with high commercial impact is that the installation of the device on the engine to claim only simple interventions, requiring intermediate skills and the use of common tools.

For high content of substances which form deposits at combustion does not exist a solution that can be associated with the engine exploitation. Therefore, the vegetable oils which are going to be used at supplying the Diesel engines must be treated in order to remove these substances. The main category of substances which cause deposits consists of phosphorus compounds ("phosphatides"). The release of the oil of these components requires organized development of chemical reactions inside the oil mass within a process generically called "degumming". The efficiency of degumming process is illustrated by the phosphorus content from the processed oil, which must be below 12 ppm (EN 14107) or even 10 ppm (ASTM D 6751-07). Another category of substances which cause deposits consists of so-called "waxes" present in the raw vegetable oils. In essence, it is about agglomerations of complex molecules, forming microscopic particles with gel consistency. These microparticles have the density very close to that of the oil and dimensions exceeding 5 μm; therefore it can not be removed by centrifugation actions, but may be retained within a filtration with the fineness of 5 μm or better. In conclusion, the vegetable oils intended to be used as fuels for diesel engines must be conditioned by degumming and filtration at the specified levels.

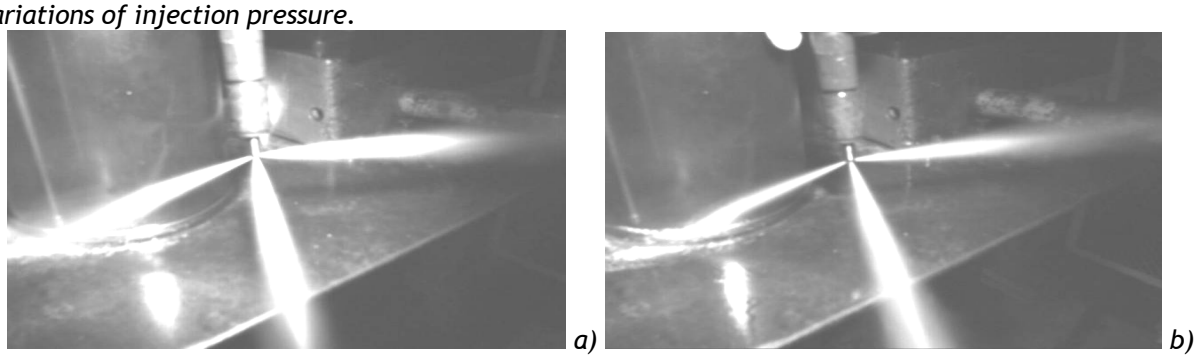
RESULTS

Experimental researches developed at INMA laboratories, under our management, therefore financially limited, have aimed to find certain practical solutions which should allow Diesel engines alternative feeding with crude vegetable oils, degummed and filtered.

The first test was designed to examine Diesel engines behaviour when feeding with mixtures of Diesel-oil and crude vegetable oil. Results obtained, confirmed after repeated and throughly processed tests, have allowed to state the fact that when feeding Diesel engines with mixtures of Diesel-oil-crude vegetable oil, which contains up to 30% oil, their behavoiur is identical with that when feeding with Diesel-oil. The aspects analyzed concerned the engines „cold" starting, at temperatures appropriate to cold season, energetic performances and specific fuel consumption. The oils used were obtained through commercial ways, so they were produced through usual technologies from seeds of rape, sunflower and soya. The possible effect of these results is extremely important as it confirms the existance of possibility of relatively rapidly replacing up to 30% out of Diesel-oil consumption of Diesel engines in operation by crude vegetable oils which are conditioned (degummed and filtered), by adopting the feeding with Diesel-oil-vegetable oil mixtures. We can deduct that, in this variant, the difficulties encountered are related to availability of necessary quantity of vegetable oils conditioned up to the required quality.

The second direction analyzed aimed to define the procedures necessary to quasi-totally replace the Diesel-oil by vegetable oils, within the alternative sequential feeding.

Therefore, the first objective aimed was to determine the temperatures up to which the vegetable oil has to be pre-heated so that the injection process should be qualitatively satisfactory, in order to assure suitable coditions for self-ignition and combustion processes in engines cyliders. The comparative tests, performed on an injection stand and appreciated by visually surveying the fuel jets, filmed with 1000 images per second frequency have shown that injecting rapeseed oil heated in the range of 80...100ºC presents aspects comparable to those when injecting Diesel-oil at ambient temperature (figure 1), and viscuosity differences between the two situations above do not conduct to variations of injection pressure.



a) *b)*

Figure 1. Aspects of the injection jets on the test bed
a – diesel fuel (22 ºC; 190 bar); b – rapeseed oil (90 ºC; 190 bar)

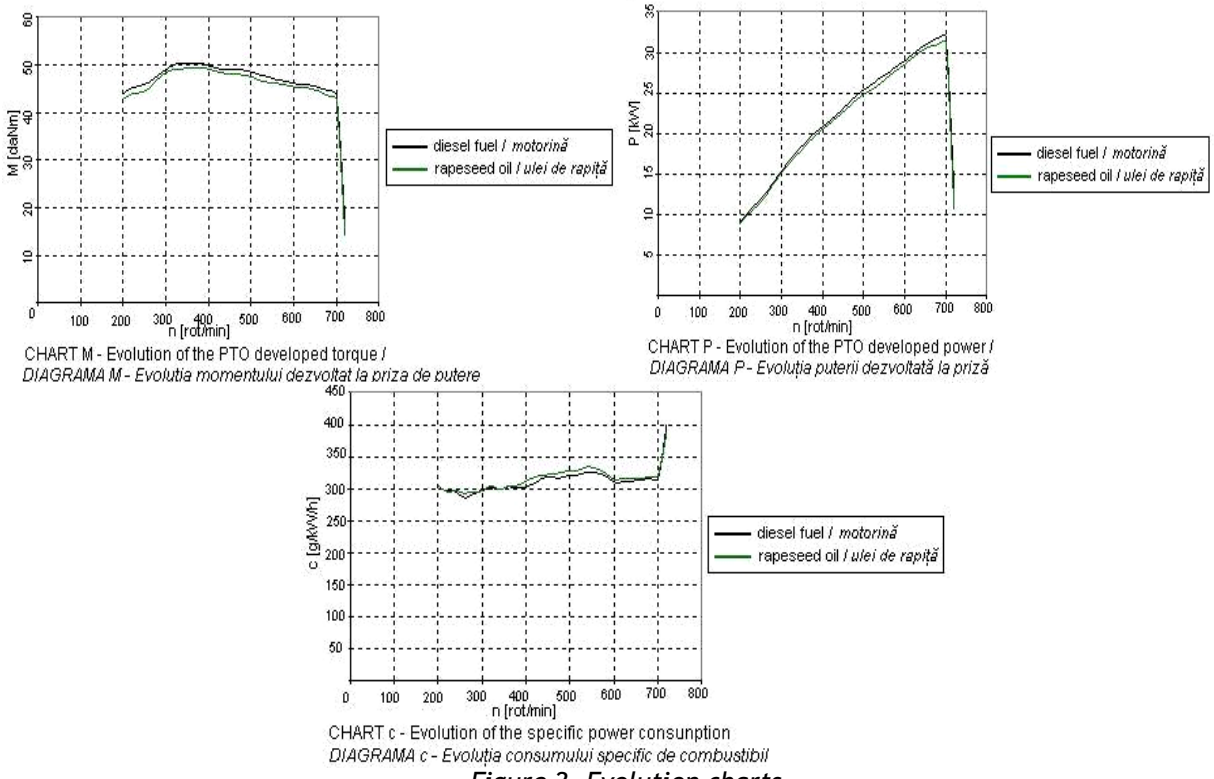


Figure 2. Evolution charts

In order to assess the engine behaviour when feeding with pre-heated rapeseed oil, an experimental device designed to heat the oil in two stages was built. In the first stage, the heat coming from the engine cooling system is used and the oil is warmed up to 60ºC, before entering the filter battery. The second stage resorts to an electric resistance placed in the supplying circuit, at the injection pump inlet, being fed by the electric installation which assists the engine. The fuel distribution was controlled by electrovalves. The experimental device described was mounted on an engine of 33 kW power, D115 model, with direct injection and combustion chamber of Meurer type, set on an agricultural tractor.. Evaluation of performances was made by raising the rotative speed characteristic to the PTO, under total load regime. When feeding with gas-oil and warmed rape oil, characteristics were raised, and the homologous results were compared. Graphical aspects of compared values evolution are shown in diagrams M, P, and c below.

After examining the diagrams it has resulted that the testing engine feeding with warmed rapeseed oil determines light decrease of torque and power developed, as well as an easy increment of fuel specific consumption. These variations are rather natural, because the calorific power is about 2% smaller than that of Diesel oil, and the oil heating before the injection could lead to a little reduction of mass of fuel dose injected.

CONCLUSIONS

Results obtained and presented are able to validate the possibility of Diesel engine alternative feeding with crude vegetable oils. The partial substitution of Diesel oil by preparing mixtures of Diesel oil-vegetable oil is the most simple, as it does not require to intervene to engine area. When the aim is to quasi-totally replace the Diesel oil by vegetable oil, by alternative and sequential feeding and heating the oil before supplying it, an additional device assuring the processes above is necessry. In all the variants, we must underline the fact that the vegetable oil used has to be previously conditioned by degumming and filtering at the levels mentioned before.

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