A FUZZY BASED APPROACH FOR CONDITION MONITORING OF ENGINE OIL

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Introduction

Engine oil is an important requirement for protecting engines from excessive friction and overheating. Several problems may be caused by using bad quality oil. Since the introduction of engine oil, the engine oil users have the problem of managing the quality of engine oil. Researchers have been analysing the characteristics and possible contents of engine oil to find out the factors that can affect on the condition of engine oil in order to provide a better solution. Some of the important factors that decide the quality of the engine oil are listed below. (Macian *et al.*, 2006).

Oil characteristics: Viscosity, Total Base Number, Total Acid Number, Oxidation, Nitration

Oil contaminants: Fuel dilution, soot, ingested dust (silicon), water, glycol

Metallic elements: Wear metals, Contaminant metals, Multi-source metals, Additive metals

This research proposes an effective and accurate solution for condition monitoring of engine oil by considering the most important factors from the above. Each of the above parameters have been analysed to choose the most influential parameters for the proposed system in order to provide an accurate real-time solution. Most appropriate in this case are the parameters that have a greater impact on oil condition and also the ability to be measured at any time.

This system can be improved further with the existing technology. For example an automatic alarm can be easily added to the system, so that it triggers for bad quality oil.

Methodology

The proposed system uses a Mamdani type Fuzzy controller which uses centroid of area as the defuzzification method. The selected three input variables lead to a rule base of 27 rules with three outputs. The output may be one of the followings.

Good - The condition of engine oil is good

Ready to change - Does not require an immediate change. But need frequent checking

Change - Engine oil should be changed immediately

Most of the existing systems check one parameter at a time in order to check the condition of engine oil and they do not provide a real-time solution.

This system considers each SAE viscosity grade of engine oil separately. Therefore it checks whether the used engine oil deviates from the variation of the new engine oil of that particular SAE viscosity grade.

Data Collection and Pre-Processing

By considering the influence of the above parameters on the oil quality, three parameters have been selected for this research. Higher and lower viscosities and higher particle count of engine oil were recognized as very unfavourable conditions for the engine. (Farlex, 2010) Acidity of oil was also recognized as a crucial factor. Therefore TBN was taken as a measure of acidity of oil.

The variation of viscosity against temperature for engine oil is linear. The variation of SAE viscosity grade can be plotted using the standard values. (Fig. 1). (Fitch, J., 2006).

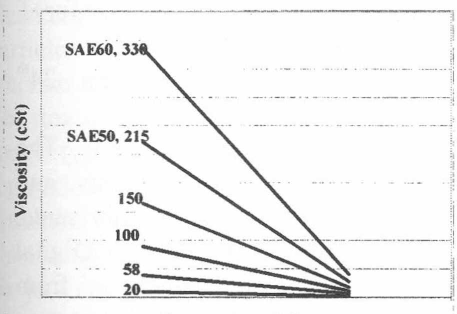

Fig. 1. Viscosity variations of SAE grades against temperature

The gradient of the plotted line was considered as Standard Gradient (SG). Viscosity of used engine oil may deviate from the above standard values. Since the Viscosity vs. Temperature variation is linear another line can be superimposed in the above plot indicating the variation of the viscosity of used engine oil with temperature. (Fig. 2). The gradient of this was taken as Calculated Gradient (CG). The ratio between the difference of these two gradients and SG was taken as Viscosity Difference (VD) as follows:

VD= (CG-SG)/SG

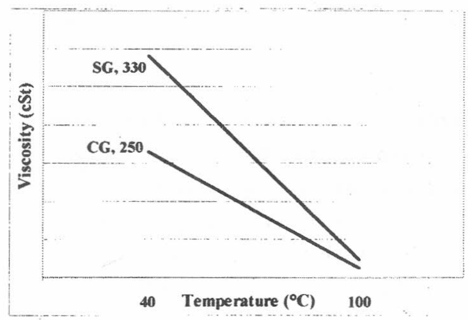

Fig. 2. Viscosity variations of new oil and used oil against temperature

The standard method of representing the particle count is known as ISO 4406 code. (Horizon, 2010). It counts the particles of three different ranges of particle sizes as described below. The volume of particles was calculated using the following equation.

Volume of particles = $4\pi \{(2.5)^3 * x + (5.0)^3 * y + (7.5)^3 * z\} (\mu m)^3 /3$

Where x is the number of particles of diameter between 4μm and 6μm, y is the number of particles of diameter between 6μm and 14μm and z is the number of particles of diameter greater than 14μm

Results

The system works well for temperatures greater than 25°C. (Table. 1). But the accuracy is low for very low and very high viscosities. (Table. 2). Accuracy is measured as follows:

Accuracy = the number of test cases with the expected result * 100% / the total number of cases tested

Table 1. Accuracy of the results according to temperature

For viscosities of normal range	
For temperatures less than 25°C	For temperatures greater than 25°C
66%	94%

Table 2. Accuracy of the results according to viscosity

For temperatures greater than 25°C	
For very low viscosities	For very high viscosities
58%	76%

Discussion

Each SAE grade has a significant difference in viscosity variations (20cSt for SAE10 and 330cSt for SAE60 at 40°C). (Horizon, 2010). Therefore instead of considering viscosity as a direct input, proposed system considers SAE viscosity grades separately. Additive metals can be used to change the viscosity of oil, but adding larger amounts leads to higher particle count. Input temperature (temperature at which the viscosity is measured) should not be equal to 100°C. Taking two different viscosity readings at two different temperatures may lead to a more accurate result, but this leads to a practical problem of providing a real-time solution.

This application works well with temperatures greater than 25°C. The temperature inside a running engine is usually high. Therefore this application is applicable in most of the cases. But in some countries the temperature may fall down below this value in winter. In such cases there is another viscosity grading. It is introduced as SAE Winter grades.

Taking the average volume of particles is more accurate than taking the direct particle count as input to the system. But there can be various types of particles. Some may be wear particles, and some may be dirt or additives. It is better if we can distinguish these particles. A higher count of wear particles may attribute to wear therefore has a great influence on the oil quality. On the other hand a higher number of additives may not cause a significant problem.

Since the system is very simple and the processing time is very low, it can be installed in to a vehicle to indicate the engine oil condition.

References

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