INVESTIGATION INTO THE USE OF WATER BASED BRAKE FLUID FOR LIGHT LOADS

W. A. AKPAN[1], E. G. IKRANG[2], I. E. MARKSON[3], P.ASANGUSUNG[4]
[1,3]Department of Mechanical Engineering, Faculty of Engineering, University of Uyo, P. M. B. 1017, Uyo, Akwa Ibom State, Nigeria; akpanasuk@yahoo.com
[2]Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, P. M. B. 1017, Uyo, Akwa Ibom State, Nigeria; elijahikrang@yahoo.com
[4]Department of Chemical and Petroleum Engineering, Faculty of Engineering, University of Uyo, P. M. B. 1017, Uyo, Akwa Ibom State, Nigeria; peterasangausung@yahoo.com

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ABSTRACT

This paper addresses the possibility of using water based fluid as a brake fluid for light loads. Characterization of both standard and water based braked fluids formulated was carried out. The properties of the latter were compared with that of a standard commercial brake fluid. The actual test of the formulated brake fluid was carried out with a Nissan Sunny vehicle model 1.5 within the speed range of 20km/hr to 80km/hr at the permanent campus of University of Uyo and the braking efficiency obtained attest to its suitability for light loads.

Key words: Water-based, Brake fluid properties, Light loads, Efficiency

1. INTRODUCTION

Fluids are substances that may flow and its constituent particles may continuously change their positions relative to one another Massey (2001). It also offers no lasting resistance to displacement. Fluids may be divided into liquid and gases. Under ordinary conditions liquids are so difficult to compress and for most purposes may be regarded as incompressible, however gases may be more easily compressed. Raijput (2008), Douglas and Gasiorek (1985). Fluids have unique and distinct properties that enable its application in Engineering. Brake fluid is a very important component of the braking system. It assists the braking system to bring a moving mass to rest. Most of the brake fluids that are in use are glycol-ether based, though mineral oil and silicon-based fluids also exist. These brake fluid must meet the standard spelt out by various organizations. Brake fluids are classified according to their physical properties. The standards in the US come from the Department of Transportation (DOT, 1971). Thus we have DOT 3, DOT 4, DOT 5 and DOT 5.1. The society of Automotive Engineers SAE has similar standards of SAE J1703, J1704 and J1705. The international organization for standardization (ISO) 4925 specifications exist for non-petroleum based fluids for hydraulic system (SAE, 1998).

The two commonly available types of brake fluids are- Glycol-ester blends and ester based (Performance, 2010).The glycol-based fluids normally have low compressibility but are hygroscopic in nature. The dry boiling point of glycol based fluid seldom exceeds 304°C . The second classification which is ester-based has higher dry and wet boiling points. It is not hygroscopic but it is more expensive than the glycol-based fluids.

There are several properties which a fluid must posses for it to be considered as a brake fluid. These properties are: Dry and wet equilibrium boiling points, viscosity, pH value, fluid stability corrosion resistant, fluidity and appearance at low temperature, water tolerance, resistant to oxidation, swell test, compressibility test, and compatibility. The brake fluid must possess a high boiling point to

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avoid it vaporizing.It must not boil after accepting a certain amount of moisture-wet boiling point. The brake fluid must also possess high viscosity and should not change under a wide range of temperatures. The pH value should not be less than 7.0 and not more than 11.5. Brake fluids should not be corrosive. Brake fluid must maintain low compression despite variance in temperature and must be non-compressible and should have high bulk modulus value (Techni/Tips,1996). The braking efficiency is said to be 100% when the braking force is equal to the weight of the vehicle, or when deceleration is $9.81 m/s^2$ (Dolan. 1991). An efficiency of 100% is not desirable because of the rapid wear to the brake linings and tyres, discomfort to passengers and the risk of losing control of the vehicle. It is generally accepted that brake efficiency of 80% to 85% should be aimed at. The main objective of this paper is to determine the suitability of water based fluid as an alternative brake fluid **for light vehicles.**

2. MODELS AND THEORIES

The foundation of the hydraulic system is from the Pascal's law. The breaking force is derived from the applied pressure in a confined fluid and if the fluid is incompressible that pressure is transmitted equally in all directions throughout the fluid. Work is done by the applied force which pushes a friction plate onto the rotating brake drum. When a rotting members of a machine are caused to stop by means of a brake, the kinetic energy must be absorbed (Shigley, 1977). The energy absorbed by the brake depend son the type of motion, such motion could be translational, pure rotational or both (Khurmi, *et al.* 2005).

For pure translational Maslow, the energy absorbed is given as:

$$E_1 = \tfrac{1}{2} m (v_1^2 - v_2^2) \qquad (1)$$

E_1 is the energy absorbed, m the mass and v_1 and v_2 are the initial and final velocities respectively of the body, respectively.

Similarly, when the moving body is brought to rest after the braking, then v_2 is zero.

Thus:

$$E_1 = \tfrac{1}{2} m (v_1^2) \qquad (2)$$

In pure rotational motion the kinetic energy of the rotation is given as:

$$E_2 = \tfrac{1}{2} m ({}_1^2 - {}_2^2) \qquad (3)$$

Where $_1$ and $_2$ are the initial and final angular velocities of the body.

If the moving body is stopped after the brake $_2$ is equal to zero.

$$E_2 = \tfrac{1}{2} m ({}_1^2) \qquad (4)$$

In both cases, the total kinetic energy involved is:

$$E = E_1 + E_2 \qquad (5)$$

Work done by the breaking force in time t seconds is given by:

$$W = F_t \, dNt \qquad (6)$$

Where F_t is the breaking or frictional force, d the diameter of the brake drum, N, mean speed of the brake drum and (pie) a constant (relating to the circumference of the brake drum)

From the law of conservation of energy, since the total energy to be absorbed by the brake must be equal to the work done by the frictional force, therefore:

$$E_T = W. \qquad (7)$$

The heat generated during the braking process is dissipated into the surrounding air, in other to avoid excessive temperature rise of the brake lining, the wheel and the tyres this heat generated is expressed as:

$$H_g = \mu R_N V = \rho A V \qquad (8)$$

Where H_g is the heat generated, R_N normal force acting act the contact surface (N), p is the normal pressures between the braking surfaces $(\frac{N}{m^2})$ A, the area m^2 and v the peripheral velocity m/s

The heat dissipated can be estimated from:

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$$H_d = C_h (t_1 - t_2) A_1 \qquad (9)$$

where H_d is the heat dissipated. C_h is the dissipation coefficient of heat transfer *($W/m^2/^0C$, t_1, t_2)* are the temperature difference between the exposed radiating surface and the surrounding air and A, area of radiating surface *(m^2)*.

The rise in the temperature of the brake drum is expressed as:

$$\Delta t \qquad (10)$$

C is the specific heat capacity of the material of the brake *drum ($J/Kg^0 C$)*

3. METHODOLOGY

The water based fluid was formulated using distilled water, sugar, hydrazine and potassium nitrate. The materials are intended to, increase its viscosity, inhibit corrosion, and increase the boiling point of water. The viscosity of the distilled water with and without the additives was measured at room temperature. The dry and wet boiling points, pH value, fluid stability, corrosion test of the formulated brake fluid were all conducted and the values compared with the standard commercial DOT 3 brake fluid used. The brake fluid line was emptied and flushed before the introduction of the formulated water based fluid into the system. After this, the fluid line was also bled to remove any entrapped air. The test was conducted using in a Nissan Sunny 1.5 model car of about 3000kg. Before conducting the test, the brake system and the tyres were checked to be in good conditions. A point was chosen and marked on a tarred road for an experienced driver to start to apply the brake. When the car finally comes to rest that point was also noted and mark. The distance between when the brake was applied and when the car stops was measured. The time interval of each activity was also measured. For each speed limit six values were obtained and the mean data recorded. The **speed** range used was between 20km/hr to 80km/hr.

4 RESULTS AND DISCUSSION

The measured physical properties of the a DOT 3 standard brake fluid and the formulated water based fluid are presented in table 1 .The boiling point of the formulated water based fluid is higher than the boiling point of water and just 15°C less than DOT 3 standard brake fluid used in this research study.

Table 1: Laboratory Measured Physical Properties of Standard Dot 3 and Formulated Brake Fluid

S/NO	Properties	Standard Brake	Formulated Water Based Fluid
1	Equilibrium reflux boiling point(ERB)	230 °C	215°C
2	Wet equilibrium reflux boiling point(WERBP)	160°C	210°C
3	Viscosity m^2/s	35.4×10^{6}	37×10^{-6}
4	Fluid stability	stable	Stable
5	Fluidity and appearance at low temperature	Amber	colourless
6	pH value	9.5	8.9
7	Water tolerance	tolerant	tolerant

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The water based fluid has a lower change of 5°c in wet equilibrium reflux boiling point compared to 70°c by the standard by the standard brake fluid used in the study. This high value is due to the hygroscopic nature of the brake fluid and therefore should not be exposed to the atmosphere for too long. An appreciable change in the WERBP) affects the fluid stability and will affect the efficiency of the brake fluid. The addition of ionized sugar significantly increased the viscosity of the formulated water based brake fluid. The fluid is also odourless and stable within the operating temperature not exceeding 215°C. The performance data of the standard and the formulated water brake fluids are presented in Table 2.

Table 2: Performance Test of Standard Brake Fluid

S/NO.	Speed (m/s)	Braking Distance (m)	Braking Time(s) (SBF)	Deceleration (m/s^2) (WBF)	Braking Time(s) (SBF)	Deceleration (m/s^2) (WBF)	Applied Force (N) (SBF)	Applied Force (N) (WBF)	Energy Absorbed (J)
1	5.56	2.00	0.71	7.83	0.71	7.83	23,490	19,170	46,370.40
2	11.11	7.00	1.20	9.26	1.30	8.55	27,780	25,650	185,148.15
3	16.67	15.00	1.80	9.26	1.90	8.77	27,780	26,310	416,833.35
4	22.22	25.50	2.30	9.66	2.40	9.26	28,980	27,780	740,593.60

*SBF – Standard Brake Fluid * WBF – Water-based Brake fluid

Table 3 shows the effective braking efficiency of the two fluids. The formulated water based fluid gives an average braking efficiency of 88% which is more than the minimum required Doland, 1991).

Table 3: Braking Efficiency of the Two Brake fluids.

S/NO.	Speed (m/s)	Standard Brake Fluid	Formulated Water Based Brake Fluid (%)
1	5.56	80	80
2	11.11	94	87
3	16.67	94	89
4	22.22	98	88
5	Average (%)	92	88

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5. CONCLUSION AND RECOMMENDATIONS

From the laboratory analysis and performance testing results, the formulated water based brake fluid was suitable for use as a brake fluid for light loads. It is also evident that the physical properties of water can be modified to meet brake fluid requirements. The formulated brake fluid is limited to low load values because of its dry boiling point temperature. Further studies should be conducted on how to increase the dry boiling point of this fluid to provide for its use for loads greater than 3000 kg. Since the permissible allowable safety use of hydrazine is 10 parts per million (ppm). Other friendly anti -corrosive agents that can function with this formulated brake fluid should be investigated and adopted for use. Additives that can absorb water vapour at high operating temperatures should be investigated to enhance the fluid performance at high operating temperatures.

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