Ultrasonic Studies on High Pressure Transmitting Fluids used for Hydrostatic Pressure Measurements up to 1.0 GPa

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In the present investigation, an attempt was made to study the ultrasonic propagation parameters viz. ultrasonic velocity (V), attenuation (A), acoustic impedance (Z), bulk modulus (k_0), adiabatic compressibility, (β) and relaxation time (τ) of some of the high pressure transmitting fluids (PTFs) used for hydrostatic pressure measurement up to 1.0 GPa, using an ultrasonic pulse echo transmission technique at 2.5 MHz. All the ultrasonic measurements are performed at room temperature of (21 ± 1.5)°C within the measurement uncertainty of $\pm 0.5\%$. Efforts are made to correlate the results with the suitability of these fluids (obtained from the characterization of a controlled clearance piston gauge (CCPG)) to generate pressure up to 300 MPa using J-13, 680 MPa using di(2-ethylhexyl) sebacate (commercially known as BIS), and 1000 MPa using a mixture of 5% white gasoline (G), 10% J-13 and 85% BIS (GJBIS). Although, we have not studied the ultrasonic parameters as a function of applied pressure, yet interestingly, the adiabatic compressibility (β) is found to decrease with an increase in suitability of pressure range except for 'G', which has minimum viscosity as 0.6897 mm^2/s in comparison to other fluids, which have viscosity in the order of 10.0 mm^2/s or more. Ultrasonic measurements were also performed to investigate the effect of temperature on ultrasonic velocity in BIS, the most common pressure transmitting fluid (PTF) used all over the world and also in the newly developed mixture of GJBIS. The studies would open new lines to measure the ultrasonic velocity as a function of applied pressure and temperature in the future.

1. INTRODUCTION

The industrial PTFs are used in a variety of applications and industries, which include aerospace, automotive, marine, or military applications. Others are used with pressure measuring instruments, combustion engines, processing equipment, compressors, piston pumps, gears, and final drives. Passivators, or deactivators, are applied to internal or machined surfaces. Fluids with extra pressure additives form a film to prevent sticking or seizing under heavy loads. They are used to transmit pressure in hydraulic pressure measuring instruments and other pressure transmission applications. The PTFs transmit pressure generated by a pump through hydraulic lines to a cylinder or actuator. Transmission fluids lubricate gearbox assemblies where pressure is transmitted from an engine to a driving axle. Most industrial PTFs consist of petroleum or mineral oils, oil-water emulsions, synthetic lubricants, or water-glycol mixtures. High water-content fluids and high water-base fluids are used in applications where the leakage of a flammable fluid is likely to cause ignition. Wax, paraffin, and stearate compounds are well-suited for anti-corrosive and anti-static applications. Some natural oils pose fewer risks to workers and have a reduced environmental impact.

The oil operated piston gauge is nowadays the ultimate primary instrument for the hydrostatic pressure measurements over a wide pressure range.[1–6] The PTF used in a piston gauge should be such that it could provide the optimum fall rate of the piston, adequate pressure transmission time and is compatible to the components of the system. The rheological properties, mainly, density, compressibility, kinematic viscosity, operating temperature, pour point, boiling point, and flash point of the PTFs are of primary importance and contribute significantly. They have attracted the attention of the researchers to investigate the details. Unfortunately, it is hardly possible to get any fluid of which, compressibility, viscosity, and density do not change, and such changes are much more complex to understand at high pressure. In this paper, we are reporting the results obtained on adiabatic compressibility, bulk modulus, and viscosity of some of the PTFs used in our laboratory for hydrostatic pressure measurements up to 1.0 GPa, using ultrasonic pulse echo through transmission technique.

2. MATERIAL AND METHODS

2.1. Materials Used

The details of various PTFs studies in the present investigation and their procurement are shown in Table 1. The J13 mineral oil, commercially known as UNIVIS J13[7] (specific gravity 0.845, boiling point 96.5°C pour point -66°C, flash point 102°C) was procured from USA under INDO–US project. The ATF[8] (specific gravity 0.810, boiling point 300°C, pour point -59°C, flash point 38°C, freezing point -47°C) was procured directly from Air Sahara and Pawanhans Helicopters, Delhi Airport, Delhi. The JATF, a mixture of 1 part J13 and 2 parts ATF, was prepared in the laboratory. The BIS,[9] also known as sebacate oil, sebacic acid, dioctyl sebacate (DOS) or di ethyl hexyl sebacate ($C_{26}H_{50}O_4$) (specific gravity 0.912, boiling point 232°C – 249°C, pour point -59°C, flash point 222°C, freezing point -47°C) was procured from M/s Sigma Aldrich, USA. The straight run unleaded white gasoline (G) (specific gravity 0.72, boiling point 32°C, flash point 46°C, freezing point -57°C) was directly procured from Indian Oil Corporation Refinery, Panipat, India. The GJBIS(A),[4,5,10,11] the mix-