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Tribological Performance of Ionized Vegetable Oils as Lubricity and Fatty Oiliness Additives in Lubricants and Fuels

Lubricity and oiliness additives, also known as friction modifiers, are steadily gaining acceptance from lubrication engineers and lubricant formulators. This paper describes how describes how such additives function in various tribosystems and which parameters control lubricity of finished formulations. Extensive experimental data are presented to demonstrate the outstanding tribological performance of bio-based lubricity and fatty oiliness additives produced by Elektrionization™ of vegetable feedstocks. Featuring a unique combination of viscosity and polarity, ionized vegetable oils form sufficiently thick and resilient protective layers by adsorption to rubbing surfaces. It is shown that, unlike extreme pressure additives, which act when a direct asperity-asperity contact occurs in the boundary lubrication regime, ionized vegetable oils function by postponing the onset of the boundary lubrication regime.

Introduction

The terms "lubricity" and "oiliness" refer to slipperiness of lubricant films formed in boundary lubrication, a condition which lies between unlubricated sliding and fluid-film lubrication, and which is also defined as that condition of lubrication in which the friction between the surface is determined by the properties of the surfaces and properties of the lubricant other than viscosity. Boundary lubrication encompasses a significant portion of lubrication phenomena and commonly occurs during the starting and stopping of machines.

The function of lubricants in tribological systems is to reduce friction and wear. The reduction of friction results from the formation of a lubricant film separating the rubbing surfaces. As a rule of thumb, lubricant films are anisotropic and reveal fairly complex non-Newtonian rheology. As a result, the coefficient of friction is not constant - it depends on the applied load, film deformation (elastic effects), sliding speed (viscous effects), as well as on their time-derivatives.

The thickness of the lubricant film depends upon constituent chemistry (base oil and additives), as well as upon the operating conditions, specifically the applied load and the sliding velocity. At a sufficiently high load or low sliding speed - the condition encountered e.g. for rod journals near the top dead center - lubricant may be expelled from the friction zone, leaving the rubbing surface unlubricated. In this case, severe friction and intense wear result.

Previously, in the field of fuels and lubricants, lubricity had always been taken for granted. However, the situation has started to change in the past two decades. Lubricity - or rather the lack thereof - has become a "hot topic" in the beginning of the 90s, following the introduction of ultra-low sulfur diesel (ULSD).[1,2] The major benefit of the change to ULSD is that the environmental impact of emissions of sulfur dioxide is greatly reduced. However, soon it has been realized that a reduction in the sulfur content also causes a reduction in the fuel lubricity, blamed for premature fuel pump and injector wear. To address this new challenge, ASTM has developed the lubricity standard ASTM D975 which went into effect on January 1, 2005.

At the same time, in the lubricant branch, ever-growing quality demands and stringent environmental regulations have led to broad commercialiazation of hydrocracking, catalytic dewaxing and hydrofinishing technologies creating an abundant supply of API Group II and III base oils. The soaring crude oil price also drives development of other competing technologies, such as gas-to-liquid (GTL) conversion using the Fischer-Tropsch process. However, despite many undisputed advantages over their Group I predecessors, new base oils produced using the all-hydrogen route or the GTL conversion have one major drawback - they lack solvency and lubricity.

To alleviate the dramatic effect of "dry" friction, extreme pressure (EP) additives are deployed. Those additives - normally containing sulfur, phosphorus or chlorine - are capable of reacting with the material of rubbing surfaces to form a thin surface layer of sulfide, phosphate or chloride, which acts as a solid lubricant when the rubbing surfaces come into a direct contact with each other. When unlubricated sliding is encountered, friction and material deformation generate enough