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Lecture 34: Grease: preparation, description and application

Hello and welcome to lecture number 34 of Petroleum Technology. In this lecture, we will learn about grease, its preparation, description, and application. Now, coming to the greases. Greases are having various consistencies ranging from the semi-liquid to solid. ASTM defines lubricating grease as a solid to semi-fluid product of dispersion of a thickening agent in liquid lubricant. Other ingredients imparting special properties may be included.

That means, the grease mainly consists of a liquid lubricant base in which a semi-fluid product, called the thickening agent, is dispersed uniformly. Besides the thickening agent, various other components may be added to improve the properties and impart special characteristics to the grease. Greases are created by processing lubricating oils along with additional components in a grease plant, resulting in a gel-like material.

The most crucial application of greases is for the lubrication of rolling element bearings. Rolling element bearings, or roller bearings, involve two surfaces moving relative to each other with rollers or balls in between that rotate, and greases are applied at these points. Grease offers the advantage of staying in place where applied, forming an effective seal against moisture and contaminants. These properties are essential for effective lubrication.

It should not drip down and can form an effective seal against moisture and contaminants; these are also the required properties for any lubricating component. Its major practical requirement is that it retains its properties under shear forces at all temperatures it experiences during use. Therefore, grease prepared for a specific use and temperature range should withstand shear forces, encompassing both pressure and temperature, while retaining its properties.

Grease components include a lubricating fluid or base oil, where the lubricating oil serves as the base oil for grease, and a thickening agent dispersed in it to create a stable semi-solid product. Additives may also be included to give the grease special qualities or improve existing properties. A typical grease composition consists of about 80 to 85 percent base oil, around 10 to 15 percent thickener, and 5 to 10 percent additives. This means that the major part of grease is the base oil, comprising 80 to 85 percent, along with a portion of thickener and additives. The selection of base oil for a particular grease significantly influences its lubricating properties and is determined by the required grease characteristics.

So, the choice of lubricating oil for a particular grease is the determinant of the grease's properties, and it is based on the application in which the grease will be used. The viscosity of the base oil is a major key factor in determining grease properties, along with the low-temperature characteristics of the base oil. Greases made with mineral oils are suitable for the majority of applications and, due to their cost-effectiveness, constitute 95 percent or more for industrial use. In most industrial applications, greases are formulated using mineral oils, which are petroleum-based lubricating oil base stocks.

Their cost is lower, and their application is versatile. However, when grease needs to be applied at very low or high temperatures, requiring a wider temperature range application, synthetic oils or a blend of synthetic oil and mineral oil may be used to meet the application conditions. The thickening agent is crucial for grease. The amount and type of thickening agent used in making grease significantly affect its consistency, determining its softness and stiffness. The required extent of softness or stiffness for grease is determined based on the amount and type of thickening agent used.

The principal thickeners in greases are called metallic soaps. Soaps are salts obtained by reacting metal hydroxides with fatty acids. Metallic soaps are the primary thickeners used in greases. In the early days, greases were made with calcium and sodium soaps, and although these soaps are still in use today, lithium soap greases have become more popular. Lithium soap greases offer higher stability compared to calcium and sodium soaps and can be applied over a broader temperature range.

Some metal soap greases are made with a mixture of soaps, not limited to a single soap. These are known as mixed-base greases. Others, called complex greases, are created using a metallic soap and a complexing agent. A complexing agent, usually a simple organic or inorganic acid, is used alongside the metallic soap to form a complex molecule within the grease. Several non-soap greases are available, primarily used for high-temperature applications. One popular non-soap grease is polyuria grease, based on inorganic polymers. Thickeners in these greases include bentonite (a clay), silica (silicon dioxide SiO_2), powdered graphite (a carbon form), and various these are also popular thickeners used in grease. Now, coming to additives, most greases contain additives that improve existing properties or confer special properties to the grease. Among the additives most often used are the following:

Detergent or Dispersants: These additives ensure that the base oil and thickener form a stable mixture with a uniform and consistent structure throughout. Detergents or dispersants mainly disperse the thickeners within the base oil matrix, forming a uniform and consistent mixture.

Antioxidants: These substances resist the oxidation of grease, similar to how antioxidants resist the oxidation of lubricating oil.

Corrosion Inhibitors: These additives ensure that the grease effectively protects the metal surfaces it lubricates, providing corrosion inhibition similar to lubricating oil.

Anti-Wear and EP Additives (Extreme Pressure): In applications where greases are used, such as those related to the wearing of metal surfaces and working under high pressure or extreme pressure, anti-wear and EP additives are incorporated into the grease. These additives help reduce wear and improve the load-carrying capacity of the grease. The load-carrying capacity of grease is also influenced by the type of base oil used in the grease organic polymers.

Solid lubricants, such as molybdenum disulfide (MoS_2) and graphite powders, are also used for specialized applications at high temperatures and heavy loads. Grease exhibits unique properties, and one of the key characteristics is its flow behavior. Unlike normal liquids, when pressure is applied to grease, it does not start to flow until a specific critical pressure, known as the yield point, is reached. Grease is classified as a non-Newtonian fluid, requiring a threshold pressure, the yield point, to initiate flow.

As additional pressure is applied, the flow rate increases disproportionately, and the viscosity of the grease decreases. In non-Newtonian fluids like grease, the relationship between pressure and flow is not directly proportional. When grease flows through a pipe, it forms a concentric core or plug-like structure, exhibiting a unique flow pattern. This flow rate against pressure shows that as pressure increases, the flow rate increases, but the two are not directly proportional. The observed viscosity of grease, known as apparent viscosity, varies with both temperature and flow rate. Apparent viscosity, when plotted against flow rate, exhibits a specific nature that reflects the non-Newtonian behavior of grease.

The apparent viscosity of grease is primarily determined by the viscosity of the base oil. The viscosity of the base oil plays a crucial role in controlling the apparent viscosity of grease. Understanding this value at a specific temperature and flow rate provides insights into the handling properties of the grease. It helps gauge how the grease behaves within a particular temperature and flow rate range, indicating its handling characteristics. Moving on to consistency, the consistency of grease varies with temperature and is mainly influenced by the quantity and type of thickener used. The type of thickener employed determines whether the grease will be too hard or too soft.

Additionally, the consistency is affected by the type of base oil and the working conditions of the grease. It is crucial that grease retains its consistency after being subjected to operational conditions over time. Greases can range from very soft, semi-liquid forms with a consistency akin to thick cream, too hard, wax-like solids. Different types of greases are prepared based on their intended applications, ranging from very soft and semi-liquid to hard, wax-like forms.

Greases are commonly classified according to the NLGI grading system, which stands for the American National Lubricating Grease Institute. This system establishes a scale for consistency, specifying 9 grades ranging from 000 (the softest) to 6 (the stiffest). These grades are directly related to the penetration index of the grease, determined by the 60-stroke worked grease, with units measured in tenths of a millimeter.

Now, let's discuss mechanical stability. Mechanical working, commonly occurring in bearings or gearboxes where greases are applied, has the potential to break down the grease structure and alter its consistency. Continuous mechanical work on a grease can lead to structural breakdown or changes in consistency. The ability of a grease to resist such changes in consistency during working is referred to as mechanical stability.

It is evident that grease should resist structural breakdown, maintaining its mechanical stability over an extended working period. Unstable greases that excessively soften may leak from the bearing houses, making them unsuitable for specific applications as they may drip from the housing. Oil separation is another phenomenon where, under certain conditions, the base oil in grease may separate from the thickener. Some degree of separation is essential for effective lubrication.

The effects of temperature on grease, especially when thickened with a metallic soap, involve gradual softening until, at a critical temperature, its structure breaks down, and the grease liquefies. Increasing the temperature of grease eventually leads to a point where continuous softening causes structural breakdown, transforming the grease into a liquid state. This temperature at which liquefaction occurs is known as the dropping point, a crucial property measured to determine the performance of grease.

The maximum operating temperature of grease is considerably below its dropping point. It's crucial to note that the dropping point does not represent the maximum temperature at which grease can effectively function. The maximum operating temperature is significantly lower than the dropping point. If grease is allowed to cool after being heated above its dropping point, it may not regain its original consistency. Once the dropping point is reached, the structure is destroyed, preventing the grease from regaining its original consistency.

When cooled, grease gradually hardens, and there comes a point where it becomes too rigid to function effectively as a lubricant. Therefore, the low-temperature properties of grease are crucial for applications in extremely cold environments. The low-temperature performance of grease is highly dependent on the low-temperature properties of the lubricating base oil used in its manufacturing. Regarding oxidation stability, the base oil in grease is susceptible to oxidation, similar to a lubricating oil, considering that most of the grease's components are based on oil.

So, obviously, the base oil in grease is susceptible to oxidation in exactly the same way as lubricating oil. Just as lubricating oil is prone to oxidation, the grease's base oil faces a similar susceptibility to oxidation. Thickeners can also undergo oxidation, although they are usually less susceptible to oxidation than base oil. Thickeners are generally less vulnerable to oxidation than base oil. High temperatures promote oxidation, as does active mechanical working, which increases the exposure of the grease to oxygen and generates heat. Both high temperatures and prolonged mechanical working create conditions suitable for the oxidation of grease.

Water-resistant greases are necessary for lubricating mechanisms exposed to sprays or splashes of water. In situations where there's a risk of water coming into contact with the grease, water-resistant greases are essential. Similar to other lubricants, greases are expected to offer protection against corrosion while providing lubrication. All lubricating substances should possess corrosion protection properties. Now, let's discuss the thickening agents and the mechanism of action of greases. When soap-based grease is examined under high magnification, a three-dimensional mesh of microscopic soap fibers becomes visible.

Look at this picture; it's a scanning electron micrograph image of lithium grease. Here, you can observe the three-dimensional mesh structure of the soap dispersed within the lubricating oil base. Both the base oil and thickener fibers pass through the contact zone in the lubricated bearing, enhancing the film thickness. For effective lubrication on metal surfaces, there needs to be a thin film of lubricating substance; thus, both the base oil and thickener fibers enhance the film thickness in the contact zone of lubricated bearings, preventing direct contact between the two metal surfaces and avoiding wear or friction.

There are various types of greases, and let's discuss various soap greases. Lithium soap greases, in particular, have a characteristic smooth, bottle-like texture and are commonly manufactured. Lithium soap greases are more stable and have the ability to withstand high-temperature conditions. They boast a dropping point of over 170 degrees Celsius, excellent mechanical stability, and good water resistance. Although the dropping point is more than 170 degrees Celsius, the maximum allowable temperature range for working is 120 degrees Celsius.

Calcium soap greases, also known as lime soap greases, represent the oldest type of industrial grease. Manufactured since ancient times, these greases have a smooth texture, are easy to apply, and exhibit very good water resistance along with fair mechanical stability. However, a notable drawback of calcium soap grease is its limited usability at temperatures exceeding approximately 60 degrees Celsius. This limitation poses challenges for applications requiring higher temperature tolerance.

Sodium soap greases, alternatively termed soda greases, were among the first high melting point greases and boast a broader temperature range compared to calcium greases. A distinctive feature of sodium soap greases is their ability to absorb water, providing them with effective rust-inhibiting properties. While these greases can absorb water in the application area, they are not suitable for use in high-moisture conditions.

These are the references which you can go through. Thank you for your attention.