

# Handling Shear Sensitive and Abrasive liquids by **LOBE** Pumps

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## 1) Introduction

Today, many of the industrial products are moved in a liquid state from one place to another. We use pumps to move these liquids throughout the process industry. During processing, liquids may behave in unexpected ways. Thus, Rheology, or the study of fluids in motion, is key to an efficient production process. It is also critical to understand the various pumping principles available to determine the effects of pumping action on the fluid properties.

In choosing a pumping solution, one should aim for the best balance between product integrity and pump efficiency. The purpose of this article is to study how positive displacement rotary lobe pumps can provide pumping solutions for some of the typical industrial liquids which are shear sensitive and/ or abrasive in nature.

It is very difficult to list down all the liquids in the industry which require deep insights in handling them due to their shear sensitive and abrasive nature. Though, some of the common liquids are: Paints, adhesives, soap solutions, printing inks, pigments, clay slurries, paper coating emulsions, latex emulsions, glues, waxes, polymers, resins, dyes, detergents, surfactants, glycerine, acids, starch and many more.

## 2) Positive Displacement Rotary Lobe Pumps

Pumps can broadly be classified as

kinetic pumps and positive displacement pumps, depending on the type of principle it uses to transfer the liquid. Kinetic pumps operate on the principle of converting energy of a prime mover (an electric motor or turbine) first into velocity or kinetic energy and then into pressure energy of a fluid that is being pumped. The energy changes occur by virtue of two main parts of the pump, the impeller and the volute or diffuser. The impeller is the rotating part that converts driver energy into the kinetic energy. The volute or diffuser is the stationary part that converts the kinetic energy into pressure energy.

By definition, positive-displacement (PD) pumps displace a known quantity of liquid with each revolution of the pumping elements. This is done by trapping liquid between the pumping elements and a stationary casing. PD Pumps are further classified into PD Rotary and PD reciprocating pumps.

### 2.1) Principle of operation of PD Rotary Lobe Pumps

The pumping action of Rotary Lobe

pump principle is generated by the contra-rotation of two pumping elements (rotors) within a chamber (rotor-case). The rotors are located on shafts supported by bearings which are isolated from the pumping media. The shafts are fitted with gears which transfer the drive from the driven shaft to the lay shaft, synchronizing the rotors such that they rotate without contact with each other or rotor-case. As the rotors pass the suction port, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the lobes as they rotate. Liquid travels around the interior of the casing in the pockets between the lobes and the casing. The fluid does not pass between the lobes. Finally, the meshing of the lobes forces liquid through the outlet port under pressure.

### 2.2) Advantages & Disadvantages of using PD Rotary Lobe Pumps

Each pump offers certain advantages and disadvantages due to its

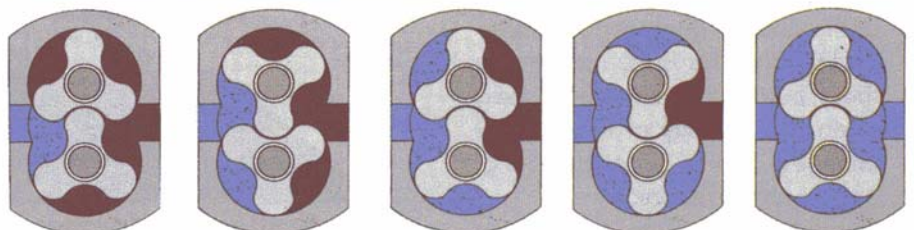


Figure 1: Principle of Operation of Lobe Pumps

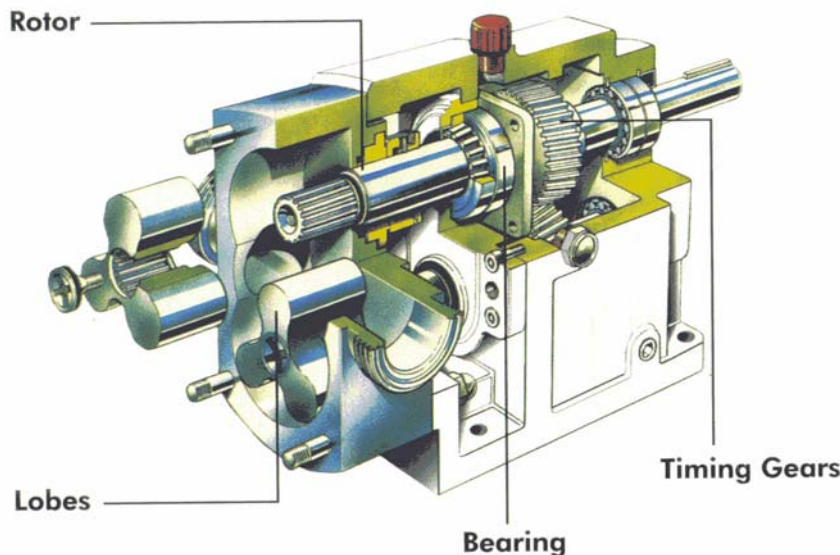


Figure 2: Cut away picture of a lobe pump

particular design and pumping action. When comparing with the other pumping technologies, it will be a trade-off between their features and limitations. Here, we will describe the advantages and disadvantages of lobe pumps without going into specific details of the liquid nature which we will cover in the later part of this article.

### Advantages

- Since the lobe pumps are based on the positive displacement principle, they transfer fixed amount of liquid per revolution. So, you can use PO pumps for metering applications.
- The lobe pumps give more or less constant flow regardless of the discharge pressure as against the centrifugal pumps where flow will vary significantly upon a change in the discharge pressure.
- The lobe pumps gives higher flow as the viscosity goes up due to drop in slippage. This is the reason why these pumps are extensively used when the viscosity of the product changes during processing e.g. polymerization process.
- The lobe pumps are self-priming pumps. Also, the Net Positive Suction Head requirements

(NPSHr) are considerably lower.

- The lobe pumps are best known for its superior Cleaning-in-place (CIP) and Sterilizing-in-place (SIP) capabilities. They are generally 3-A rated and can even be used for sanitary applications.
- The lobe pump gives non-pulsating flow as against the PO reciprocating pumps.
- There is no metal to metal contact and hence the mechanical wear and tear of the parts will be less, thereby longer pump life
- The tolerances between the parts are not very tight. Also, the lobe design allows passing medium solids with liquids.

- The lobe pumps generally operate at slow speed and have a gentle pumping action and there will be very little damage to the product.

### Disadvantages

- There are two shafts in the lobe pumps, hence requires two seals.
- The shafts are synchronized by timing gears which requires skill labour to assemble the pump.
- Since the tolerances are not very tight, it has got reduced flow with thin liquids due to slippage.

### 3) Processing Shear Sensitive liquids by Lobe Pumps

Viscosity is an important physical property of a fluid. It is defined as the measure of resistant to flow. The viscosity of some fluids can change while processing them, depending on the degree of shearing they undergo. This change in viscosity may dramatically affect the behaviour of the fluid. Shear occurs when one molecular layer moves against another, causing internal friction within the fluid. Hence, it is important to study the nature of fluid to understand the challenges it poses to process them.

All fluids can be classified as either Newtonian or non-Newtonian. The difference lies in the relationship between the fluid's tangential stress (friction force between the layers per unit surface) and the shear rate or

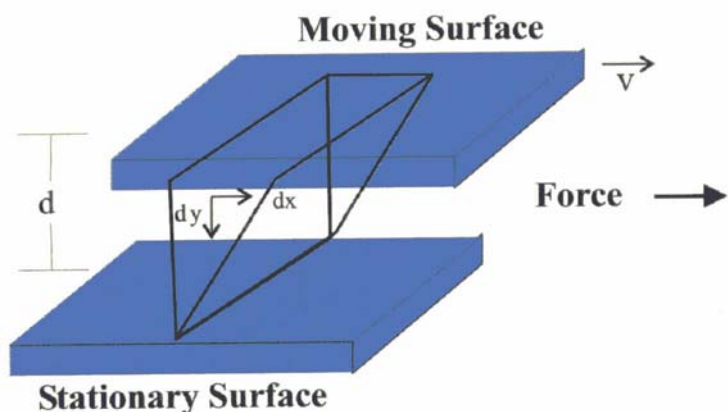


Figure 3: Shear Force due to moving surfaces

gradient (difference in speed between the layers divided by the distance between them) (See Figure 3).

$$\zeta = \frac{F}{A} = \mu \frac{dv}{dy} \quad [1]$$

Where  $\zeta$  is shear stress defined as the mechanical force per unit area.  $\mu$  is the viscosity of the liquid and  $\frac{dv}{dy}$  is the velocity gradient.

If the relationship is linear and the fluid has zero stress at zero velocity gradient then it is Newtonian. If not, it is non-Newtonian, and is further classified into one of various subdivisions based on the curve of their stress vs. their velocity gradient (See Figure 4). For non-Newtonian fluids, the velocity gradient is dependent on the viscosity; that is, the fluid has a higher or lower stress depending on its velocity. Based on these qualities, the fluid can be given its sub-classification.

**Pseudo-plastic fluids** will thin with shear but will return to their previous viscosity when the product is again at

rest. It includes sewage sludge, paper pulp, grease, soap, paint, Printer's ink, starch, latex, most emulsion solutions and many more.

**Dilatant fluids** may thicken during pumping and then return to a stable state. Some candy compounds may thicken and cause problems in a pump, e.g. Feldspar, Mica, Clay, Beachsand, Quicksand, starch in water etc.

**Thixotropic fluids** decrease in viscosity with shear over time and may take three seconds or three days to recover, according to the media. On the other hand, fluids which shear thin with time and never return to their original state are known as Rheomalactic fluids. Some of the fluids are inks, most paints, carboxymethyl cellulose, silica gel, greases, asphalt, starch, bentonite, gypsum solutions in water etc.

### Typical Applications:

One of the important liquids used in the paint industry is latex emulsion, a colloidal dispersion of a polymer in

water. The most important property involved in handling latex is the degree of shear sensitivity- tendency to change state when placed between closely fitted surfaces having relative motion. When the latex emulsions are subjected to enough mechanical shear, some of the colloidal shells may break and thereby allowing the polymer to coalesce into larger particle. If this shearing continues far enough, a film may build up which can actually cause a pump to bind. The raw material for soap and detergent industry is surfactant, an abbreviation for surface active agents. These embrace any compound that affects surface tension when dissolved in water solutions, or which similarly affects interfacial tension between two liquids. Each molecule of the cleaning solution may be considered a long chain; one end of the chain is hydrophilic (water loving) and the other is hydrophobic (water hating or soil loving). The soil loving ends are attracted to soil particle and surround it and water loving ends pull the molecules and soil particles away from the fabric and into the wash water. While transferring the surfactants, the close tolerances between the pumping parts can produce enough mechanical shear to destroy the long polymer chains of surfactants.

### How and why Lobe Pumps?

Kinetic pumps generally operate at very high speed as they develop pressure by increasing the velocity of the fluid. It is very evident from the above discussion that the higher the pump speed, the higher would be the shearing of the liquid. Secondly, kinetic pumps are not efficient when handling viscous liquids and many of the liquids have high viscosity. Thus, we are left with only positive displacement pumps for pumping shear sensitive fluids.

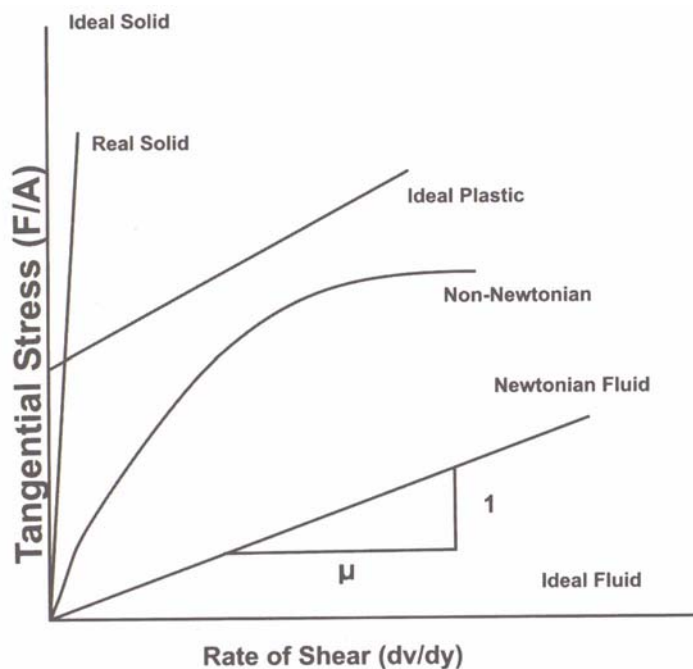


Figure 4: Classification of liquids based on degree of shear sensitivity

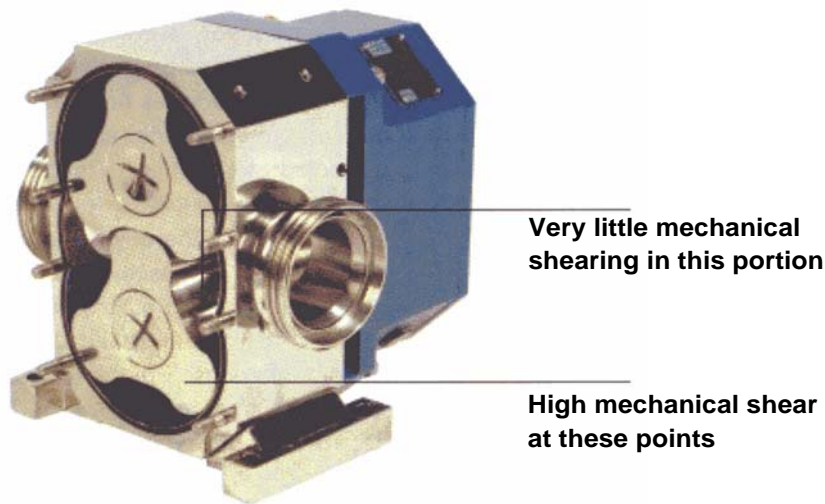


Figure 5: Little Liquid exposed to mechanical shearing

The other consideration for these kinds of applications could be air operated double diaphragm pumps. These pumps transfer liquid by using compressed air and have a gentle pumping action. However, they have very poor mechanical efficiency. They can't handle high pressure applications and have very limited temperature range.

Lobe pumps generally operate at low speed and have a very gentle pumping action: hence doing very little damage to the product integrity. The other feature of the lobe pump is

that it does not allow any entrapment of foreign particle during its pumping action.

The other important factor that affects shear rate is the amount of liquid exposed to the shear force in the pump. From the equation 1, it is obvious that the shear rate would be high when the two relatively moving surfaces are very close to each other. In a pump, the liquid which is trapped in the close tolerances between pumping parts will be subjected to high shear force. Lobe pumps don't have any metal to metal contact inside the liquid chamber.

Incidentally, the non-contacting nature of lobes is also the reason why they are used for food applications, and lobe pumps are often FDA and 3-A-Approved.

Now consider other rotary pumps, almost all the fluid contained in the cavities are exposed to the shear forces. On the contrary, in the lobe pump, only little amount of fluid is under shear rate. (See Figure#5)

Multi-lobe pumps offer relatively lower shear than the normal lobe pump. Liquid will try to go back to suction side through end clearances due as the pressure on the discharge side is higher than that of suction side. The phenomenon is known as "slip." If the slippage of the fluid pumped is high, more liquid is going back to suction. It can be very critical in case of shear sensitive liquids as this liquid will again exposed to high shearing forces. Multi-lobe pumps will have lesser slippage and hence they can even handle high shear sensitive liquids. (See Figure#6)

#### 4) How Abrasive Applications can be handled by Lobe Pumps

Fluids containing solid or foreign particles are known as abrasive liquids. These particles can beat away against the material while processing the fluid and can significantly deteriorate the pump parts. Corrosive liquids are different from abrasive liquids as a corrosive liquid interacts chemically with the materials of construction and wears away some of the materials of construction in a uniform pattern.

Abrasive wear is uneven and is often noted by grooves which follow the mechanics of the flow. To test abrasiveness, place a small drop of the liquid between two glass slides. An abrasive liquid will cause a scratchy, grinding sound. Although this test is

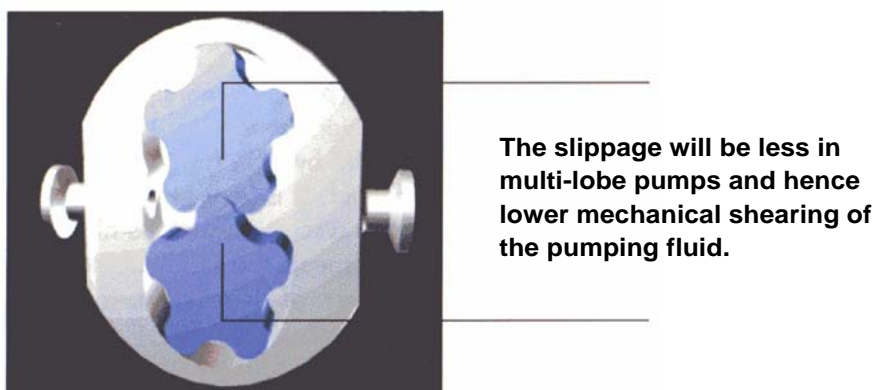


Figure 6: Multi-lobe pumps offers lower shear

subjective, with practice it can be related to the potential for pump wear.

The performance of the pump will change significantly due to removal of the some material. If the liquid is very abrasive and the pump is not selected properly, one has to change parts more frequently. The pumps has a high maintenance cost, leave alone the loss of production due to downtime.

### Typical Applications:

Liquids- like paints, inks and slurries containing particles are called abrasive liquids and are very common in process industry. These particles will beat away some of the material of pumping parts and the performance of the pump can significantly deteriorate.

### Why and How Lobe pumps?

It can be easily established that the higher the speed at which pump is being operated, the higher would be the mechanical wear and tear of the materials of pumping parts. As a rule of thumb, the wear rate reduces at a

slower speed, and is a function of approximately RPM<sup>3</sup>. So if you double the speed of the pump, the wear rate would be increased to eight times than the wear rate at the original speed.

Lobe pumps don't have very tight tolerances in the liquid chamber and small solid particles can get away without doing any damage to the pump material.

In the Lobe pumps, the shafts and bearings are not running in the pumping media (See Figure 2). Compare this with other PD rotary pumps, where the shafts and bushings are running in the pumping liquid. These parts are, therefore, subjected to heavy wear. By providing hardened materials, we can slow down the rate of wear and tear in these pumps, but we can not prevent it. Contrary to this, in lobe pumps, there is no need to worry about shaft wear due to pumping abrasive liquids.

At any moment, the shallow dwells are created because of the lobe design. The dwell design of the lobes allows even the large solid particles to get away without affecting the material of

the pumping elements (See Figure 7). Pump manufacturers are coming up with new design of the lobes to improve the pump life while handling typical liquids. Consider bi-wing type design, (See Figure 7), and a normal lobe pump. Bi-wing pumps have a larger surface facing the abrasive particles and there are no tips that may be damaged by the solid particles. This would ensure that there will be very little effect on the top section of the wings.

In other rotary PD pumps, the rotating elements are used for two purposes: to pump the fluid (transfer it from inlet to discharge ports), as well as to transmit torque. Lobe pumps don't have any metal to metal contact in the liquid chamber, and torque transmission is done by another set of gears, called timing gears, which are positioned outside the liquid chamber, on the other side of the seals. Thus, the job of the lobes is only to transfer fluid. Since the lobes do not touch each other they last longer. As a result of this, the maintenance cost of a lobe pump would be quite low.

### Conclusion

The life cycle cost of any equipment is the total lifetime cost to purchase, install, operate, maintain and dispose of that equipment; instead of just considering the initial purchase and installation cost of a system. Lobe pumps not only offer the benefits of the positive displacement technology but also provide efficient pumping solutions for shear sensitive and abrasive liquids without damaging the product integrity. Obviously, it is in the interest of the plant manager to evaluate the Life Cycle Cost of different solutions before installing major new equipment.

### About the Author

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Dwells allows larger solid to pass through the pump

Wider surface allows better solid handling capabilities

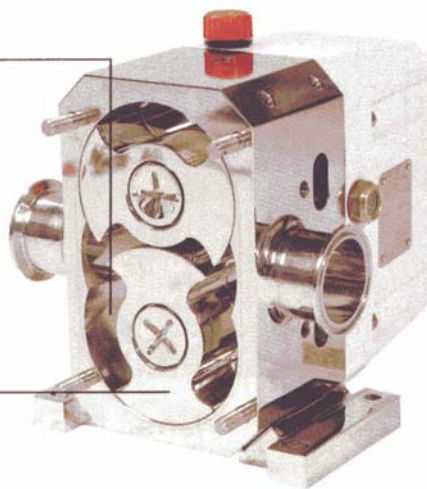


Figure 7: Handling abrasive liquids by Bi-wing pumps