Diesel Engine Lubrication And Lube Oil Contamination Control

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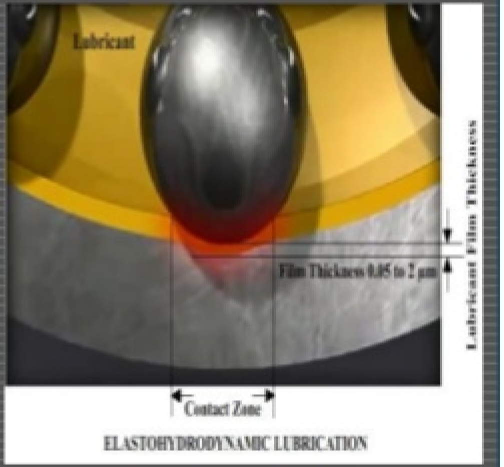
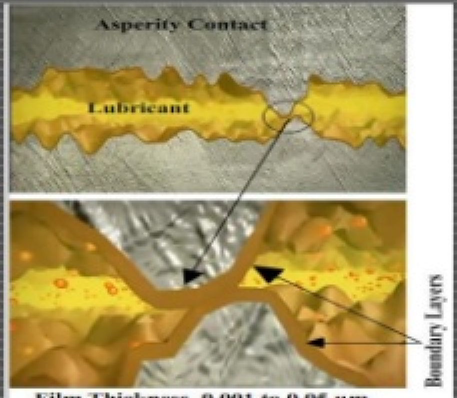
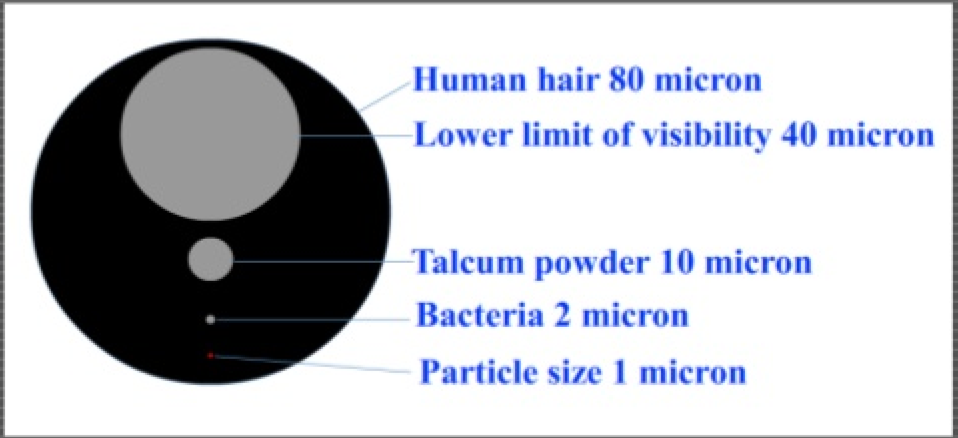


ELASTOHYDRODYNAMIC LUBRICATION



BOUNDARY LUBRICATION



A downloadable "pdf " version is available on author's website

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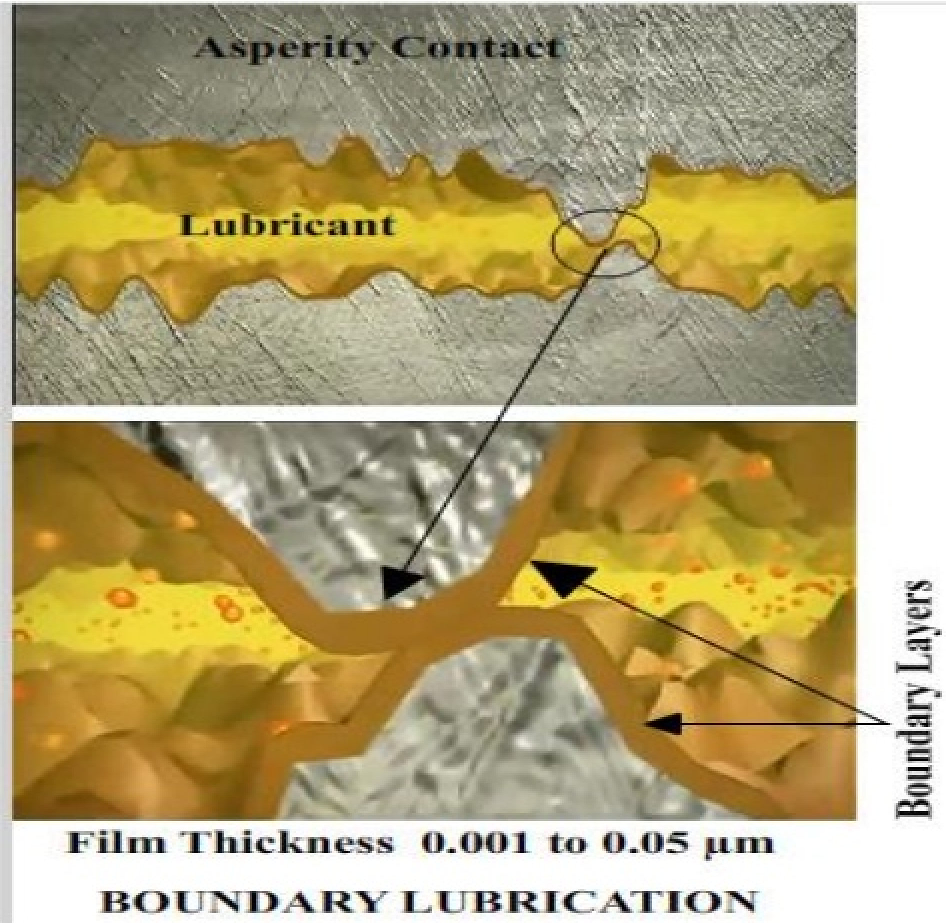
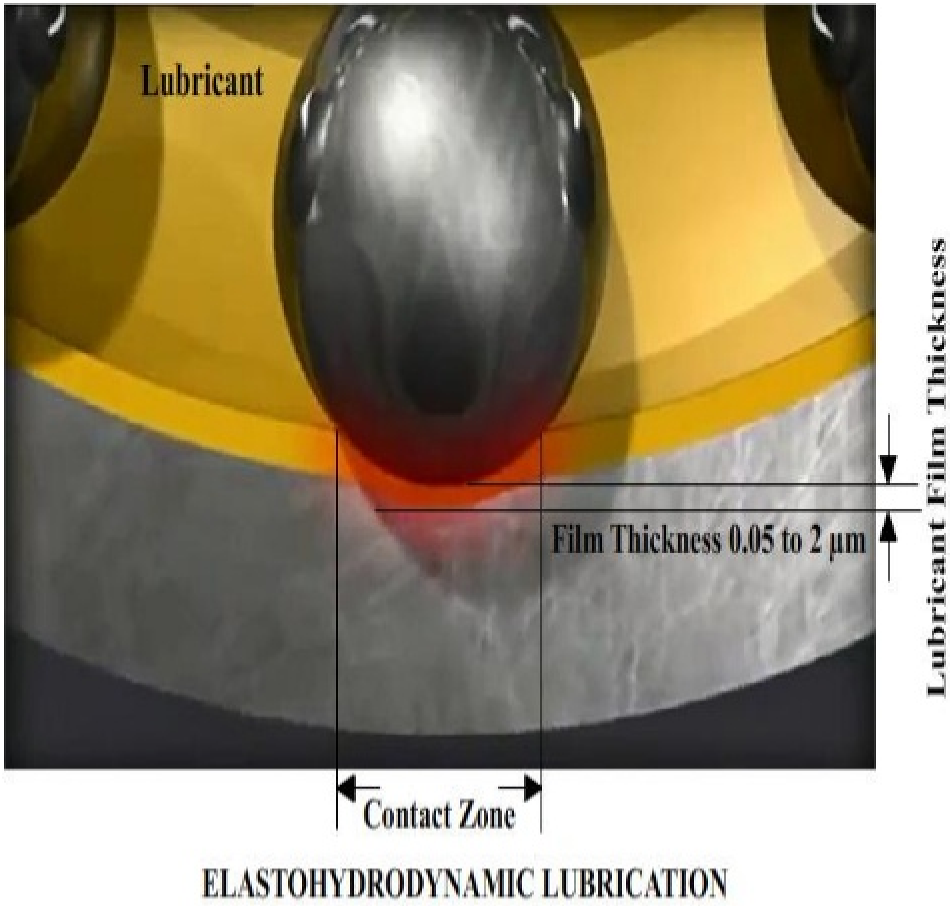
Diesel Engine Lubrication And Lube Oil Contamination Control

Identify contamination
Identify wear and its possible sources
Deploy appropriate contamination control guards
Move your maintenance practices toward a more condition-based-approach





Introduction

Lubricating oil is imperative for the correct function of an engine. It forms a separating oil film between adjacent moving parts to prevent their direct contact, decrease friction-induced heat and reduce wear. Therefore it protects the engine.

One of the most important characteristics of lubricating oil is its **viscosity**. This has to be high enough to maintain the lubricating oil film and low enough to enable the flow of oil around the engine.

During engine operation the characteristics of the oil change. Soot particles generated in the combustion process, contaminate the oil along with small metallic particles caused by mechanical abrasion. These contaminants increase the viscosity of the oil and as a result the oil can no longer completely carry out its protective function. This leads to increased fuel consumption, a loss of engine performance and increased wear or damage to engine components.

In order to exclude these risks, the lubricating oil has to be effectively treated. **The focus of the treatment is the maintenance of the oil quality and protection of the engine which are two equally important requirements.**

Friction and Purpose of Lubrication

To understand lubrication you have to understand friction and also about following things.

- how friction causes damage
- How operating conditions can increase damage
- How lubricants help to prevent damage

Reducing friction between moving parts is critical to increasing vehicle/equipment life.

Purpose of Lubrication:

- Protect critical components
- Provide reliable operation
- Lower maintenance costs
- Decrease downtime
- Increase equipment life

Main Functions of Lubricants:

- Reduces friction in engines
- Controls friction in transmissions
- Acts as a heat transfer agent
- Inhibits corrosion and oxidation
- Removes contaminants
- Lessens the effect of temperature extremes on viscosity
- Noise Reduction

Engine Parts Lubrication and Engine Oils

Engine Parts Lubricated by Engine Oils

- Piston Motion in Cylinder
- Crankshaft Rotation in Engine Bearings (Main Bearings and Big End Bearings)
- Piston Pin Rotation in the Bush of Small End of the Connecting Rod
- Camshaft Rotation in Camshaft Bearings
- Cams Sliding Over the Valves Rods
- Intermediate Gears
- Turbocharger Bearings
- Pedestal Bearing
- Reciprocating Motion of Valve Stems

Functions of Engine Oils

- Provision of stable oil film between moving surfaces
- Provision of reliable engine operation in a wide temperature range
- Rust / Corrosion protection in engine components
- Cleaning the engine components from sludge
- Sealing Piston Ring- Cylinder Gap
- Prevention of Foaming
- Cooling the Engine Parts

Functions of Engine Oil

Provision of stable oil film between moving surfaces

It prevents direct metal to metal contact by creating a continuous oil film (hydrodynamic lubrication regime functions as a hydraulic lifters) between two moving surfaces like rotation of crank shaft and engine bearings, reciprocating motion of piston rings over cylinder liner inner wall, various gears arrangements, etc. It reduces the coefficient of friction as the oil film keeps moving surfaces away from each other and that ease the movements of moving parts producing less heat. It helps to evenly distribute load applied bearing over its surface, cools down the sliding parts. It takes foreign particles away from the friction region

Provision of reliable engine operation in a wide temperature range

Viscosity of oils strongly depends on its temperature. Again the oil film thickness depends on oil viscosity. When an engine starts at low temperature the oil is viscous (Thick). If the viscosity is too high the oil will not be able to flow to the sliding parts and the non-lubricated engine will not run.

On the other hand oil viscosity in an heated engine is low. The oil flows easily, however the oil film thickness of hot oil is low, and it may become less than the roughness of the sliding surfaces. In this case hydrodynamic lubrication regime is broken and direct metal to metal contact between the surfaces occurs. Metal to metal contact causes excessive wear, overheating and even fatigue of the sliding surfaces. Hence, lubrication is formulated considering the requirement in both cases.

Functions of Engine Oil

>> Rust / Corrosion protection in engine components

Combustion gases containing water vapors and other chemically active gases partially penetrate to the crankcase and may cause corrosion. In addition to this some constituents of combustion gases dissolve in the oil and increase acidity. Such oil may become aggressive to the metal parts contacting with it. Corrosion inhibitors are added to engine oils in order to provide protection of metallic (both ferrous and non-ferrous) parts.

>> Cleaning the engine components from sludge

Combustion gases past through the piston rings to the crankcase contain some amount of not burnt carbon which may deposit on the rings, valves and cylinders, forming sludge. The sludge clogs oil passages and clearances decreasing lubrication of the engine parts. In order to remove the sludge from the surface, detergents are added to the engine oils. Dispersants, which are also added to the engine oils, help to maintain maintained removed sludge and other contaminants (both ferrous and non-ferrous) in form of fine suspension permitting engine functioning between the oil changes.

>> Sealing Piston Ring- Cylinder Gap

Imperfection on the surfaces of the piston rings and cylinders walls result in penetration of combustion gases in to the crankcase, which decreases the engine efficiency and cause contamination of the oil. Engine oil fills these microscopic passages and seal the ingression of combustion gases.

Functions of Engine Oil

>> Prevention of Foaming

Engine oil circulating in an engine may entrap air and form foams. Foamed oils are less effective in their important functions (oil film formation, heat removal, cleaning). In order to diminish foam formation special additives anti-foaming agents are added to the engine oils.

>> Cooling the Engine Parts

Combustion heat and friction energy must be removed from the engine in order to prevent its overheating. Most of heat energy is taken by the engine oil. Clean oil passages, proper viscosity and low contamination provide sufficient flow rate of the engine oil and effective cooling.

Surface Roughness, Friction and Lubrication

To understand the working principle of lubricants, first of all you have to be familiar with the nature of the two surfaces to be lubricated.

Whenever a surface is machined (no matter how sophisticated tools are being used) there will be tiny microscopic irregularities in the machined surface. The nature of these irregularities will vary depending upon the materials, machining process (i.e. rolling, turning, grinding, milling or plateau honing, lapping, but the net effect is the same. Under microscopic examination, the surface is anything but smooth. When two such surfaces are forced to slide over each other, opposing high spots (known as asperities) will contact, resisting any sliding motion. The contact invariably alters the surface of the mating parts due to distortion, scuffing, micro-welding and subsequent tearing. An engine or any machine operated under such conditions would not last long without corrective maintenance

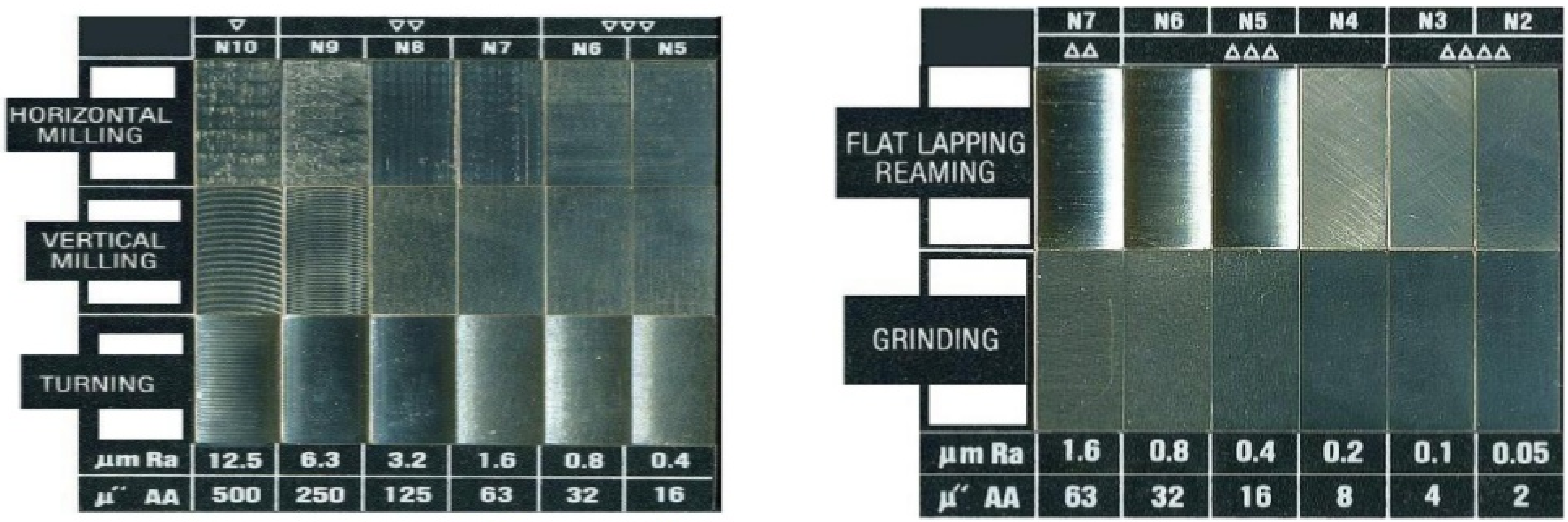


***Figure**: Surface roughness in different machining operation*

Surface Roughness, Friction and Lubrication

Visual Appearance of cylinder liner surface

Microscopic Appearance of cylinder liner surface

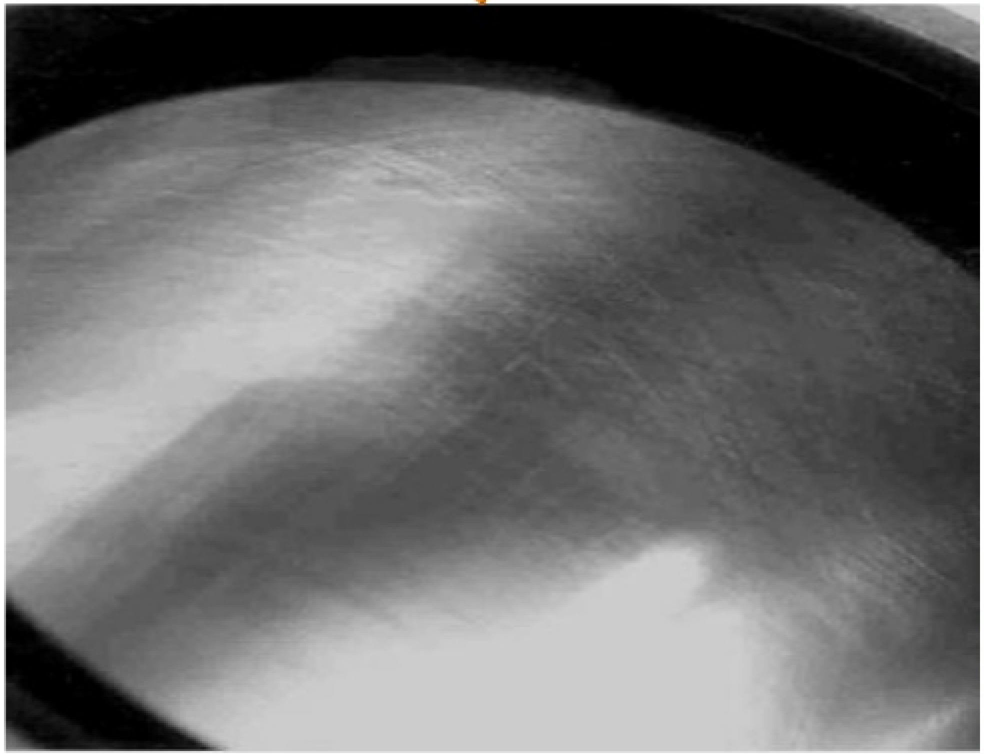


Figure: Polished (by honing) liner surface

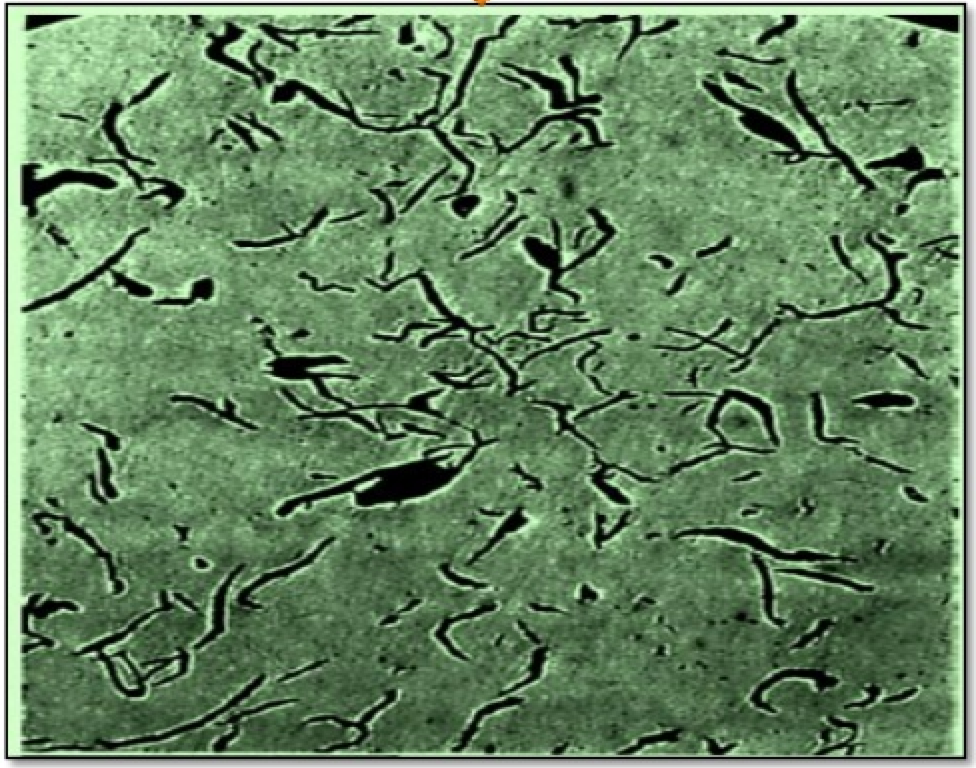
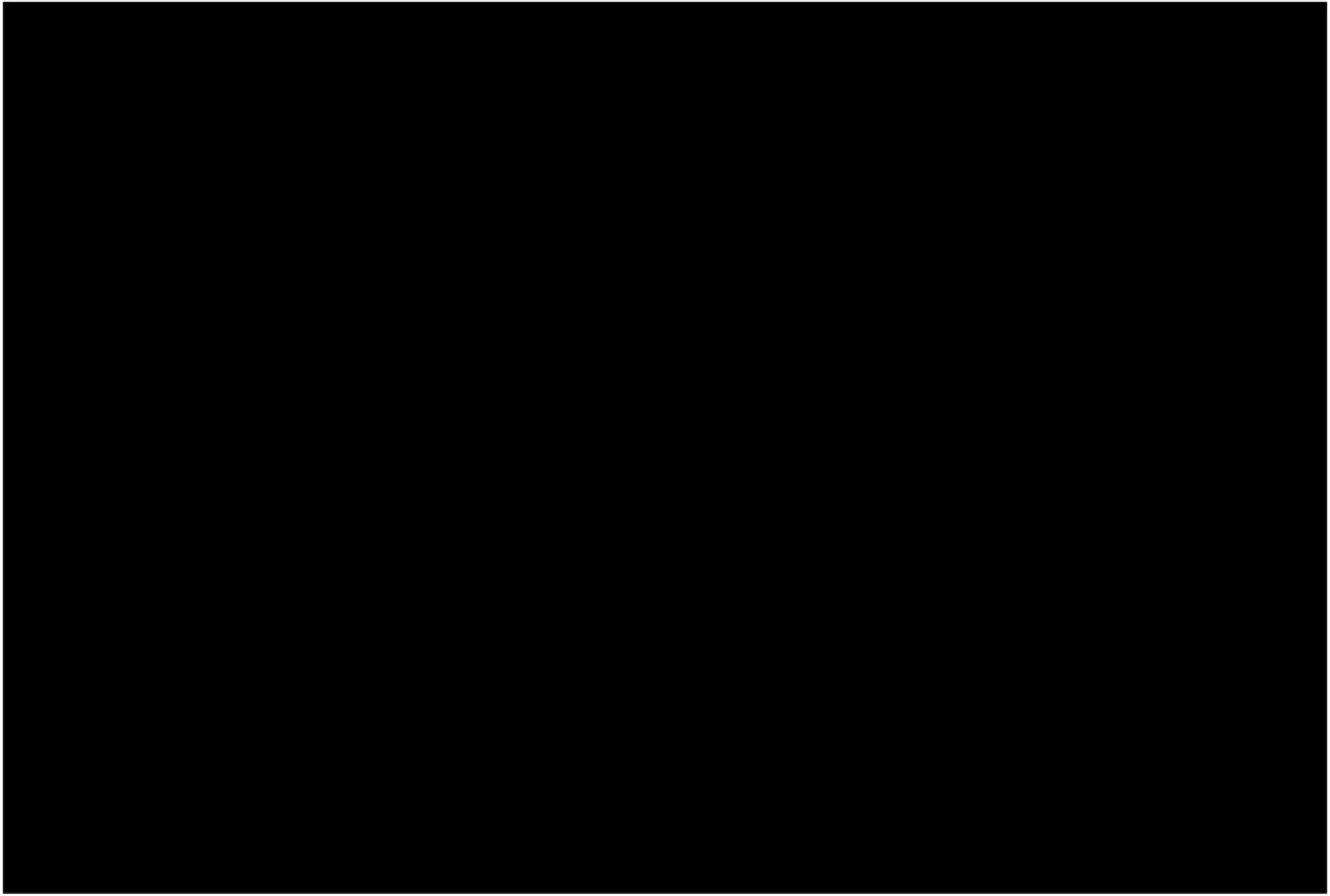


Figure: Microstructure of polished liner surface

Surface Roughness, Friction and Lubrication



Video Clip To Illustrate Friction and Lubrication

Types of Metal Contacts

There are three types of relative motion which can take place between diesel engine component surfaces.

>> **Rolling Contact**
>> **Sliding Contact**
>> **Squeeze Contact**

Rolling contact takes place in ball and roller bearings and in gear drives. As shown in figure , large compressive forces act between the component surfaces. The lubricant is swept into the contact zone by the rolling motion.

Particles larger than the thickness of the lubricant film separating the opposing surfaces indent and pit the surfaces.

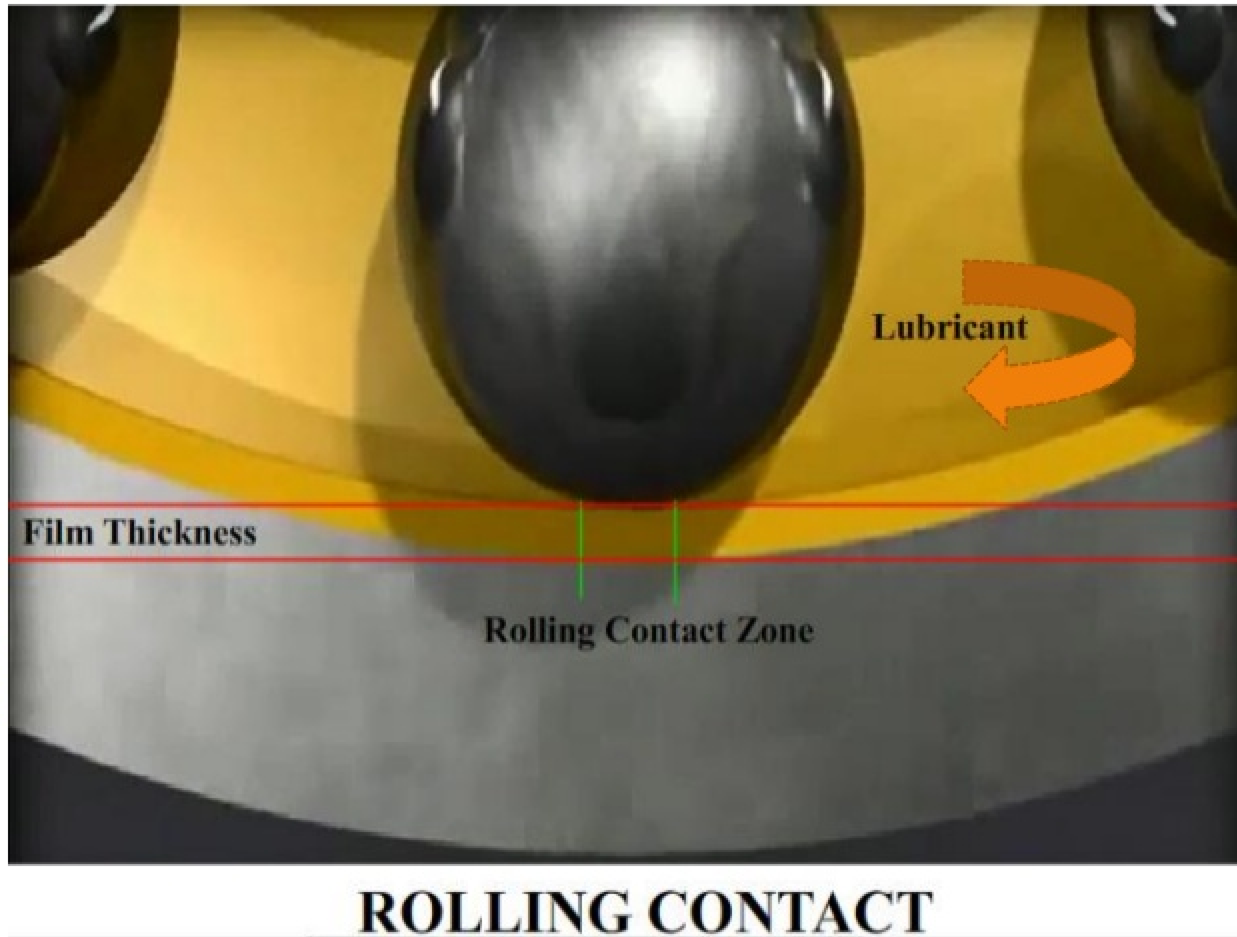
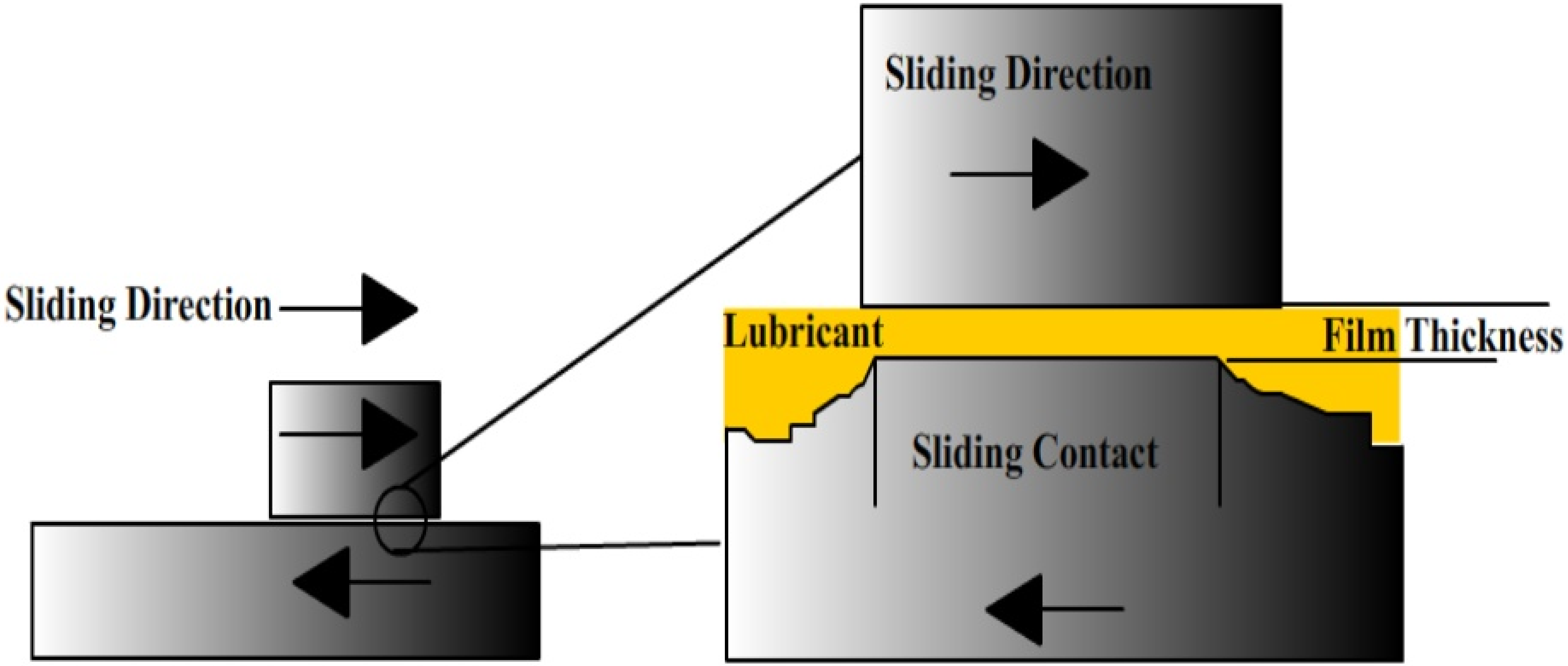


Figure: Schematic Diagram of Rolling Contact

Sliding Contact

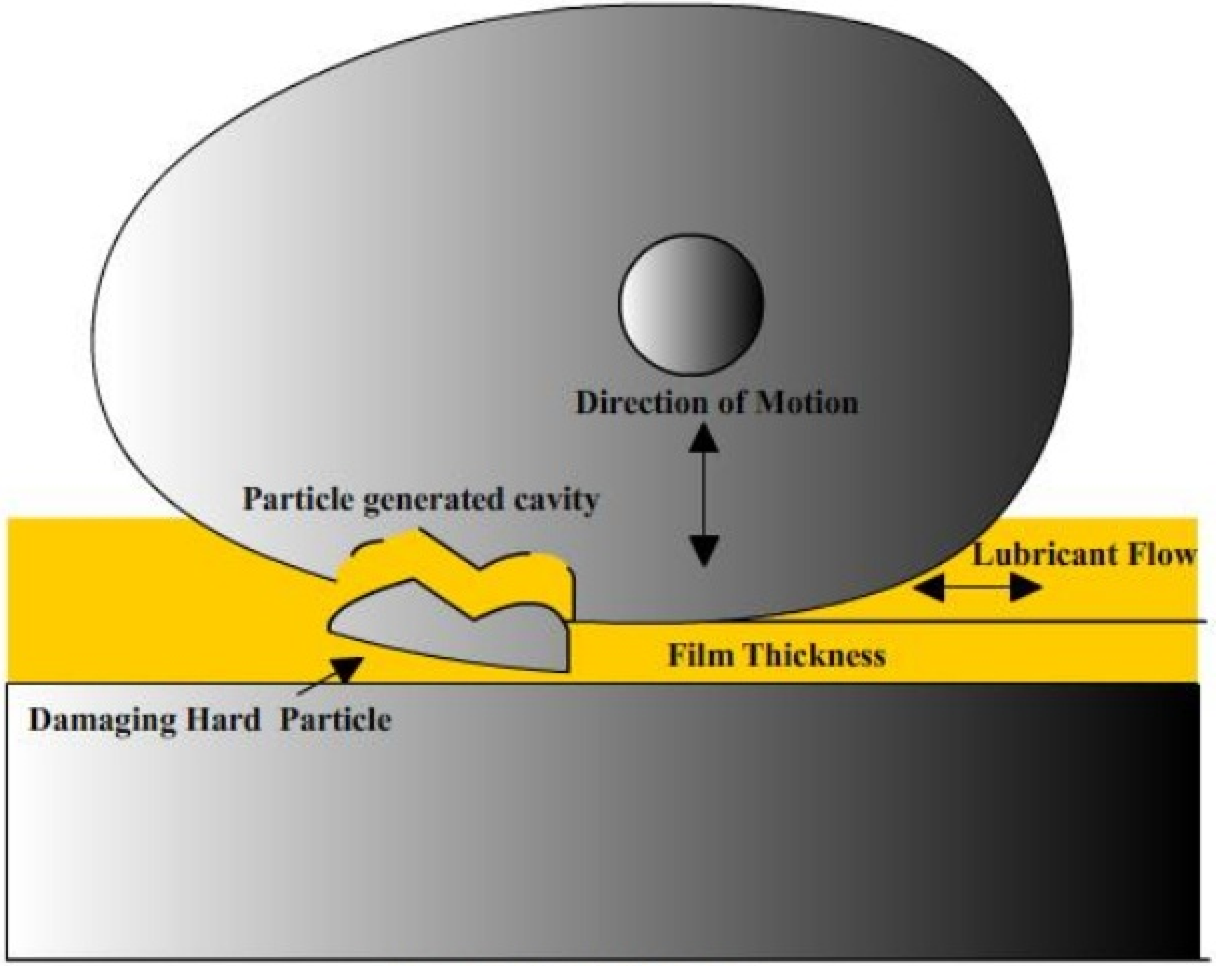
Sliding Contact takes place in journal bearings and ring-cylinder contacts. During sliding contact the lubricant is swept into the contact zone by the relative motion of the two surfaces. The presence of **particles larger than the dynamic film thickness leads to severe abrasive wear**. Hard particles cut away material from the component surfaces, with the simultaneous generation and release of new contaminant particles into the fluid.



SLIDING CONTACT

Squeeze Contact

Squeeze Contact takes place because of linear forces and vibration. The valve-to-cam follower contact is a good example. In squeeze contact, motion perpendicular to the opposing surfaces forcing lubricant in and out of the contact zone. Particles caught between the surfaces will roughen and dent the components. This leads to abrasive removal of material, fretting, and fatigue.



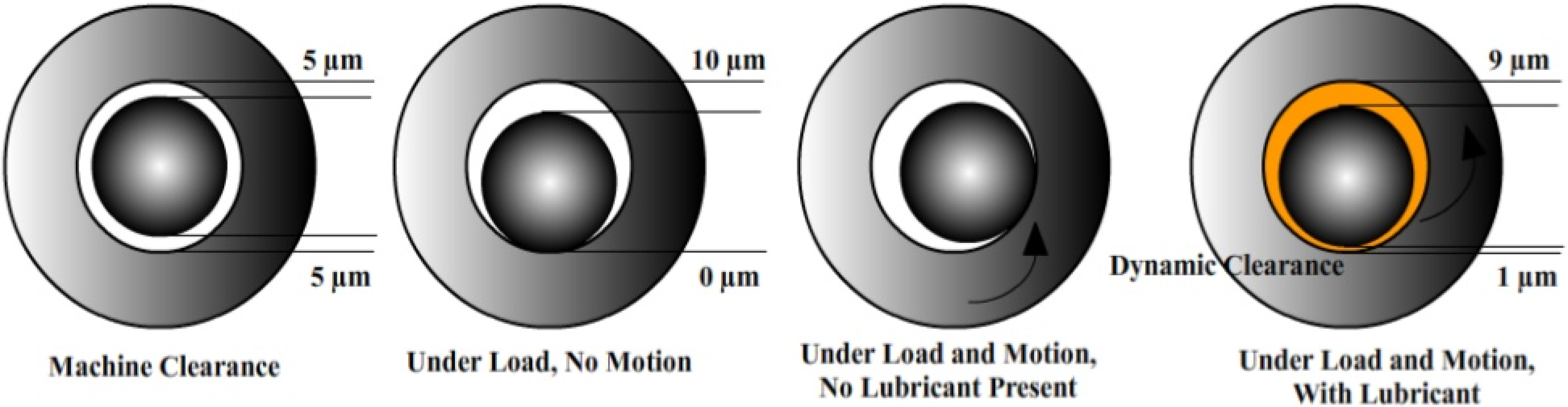
SQUEEZE CONTACT

Dynamic Clearances and Critical Film Thickness

In lubricated contacts, dynamic clearances are maintained by oil films between moving surfaces. The lubricant film thickness, as shown in Figure , is the distance between the two moving surfaces. Compressive forces (the load) act to push the moving surfaces together. Tangential forces (shear) tend to displace the surfaces horizontally. A film of oil supports the load between the opposing surfaces and keeps them separated. The thickness of the oil film is related to the mode of lubrication that we will discuss in subsequent slides.

DIESEL ENGINE COMPONENT OIL FILM THICKNESSES

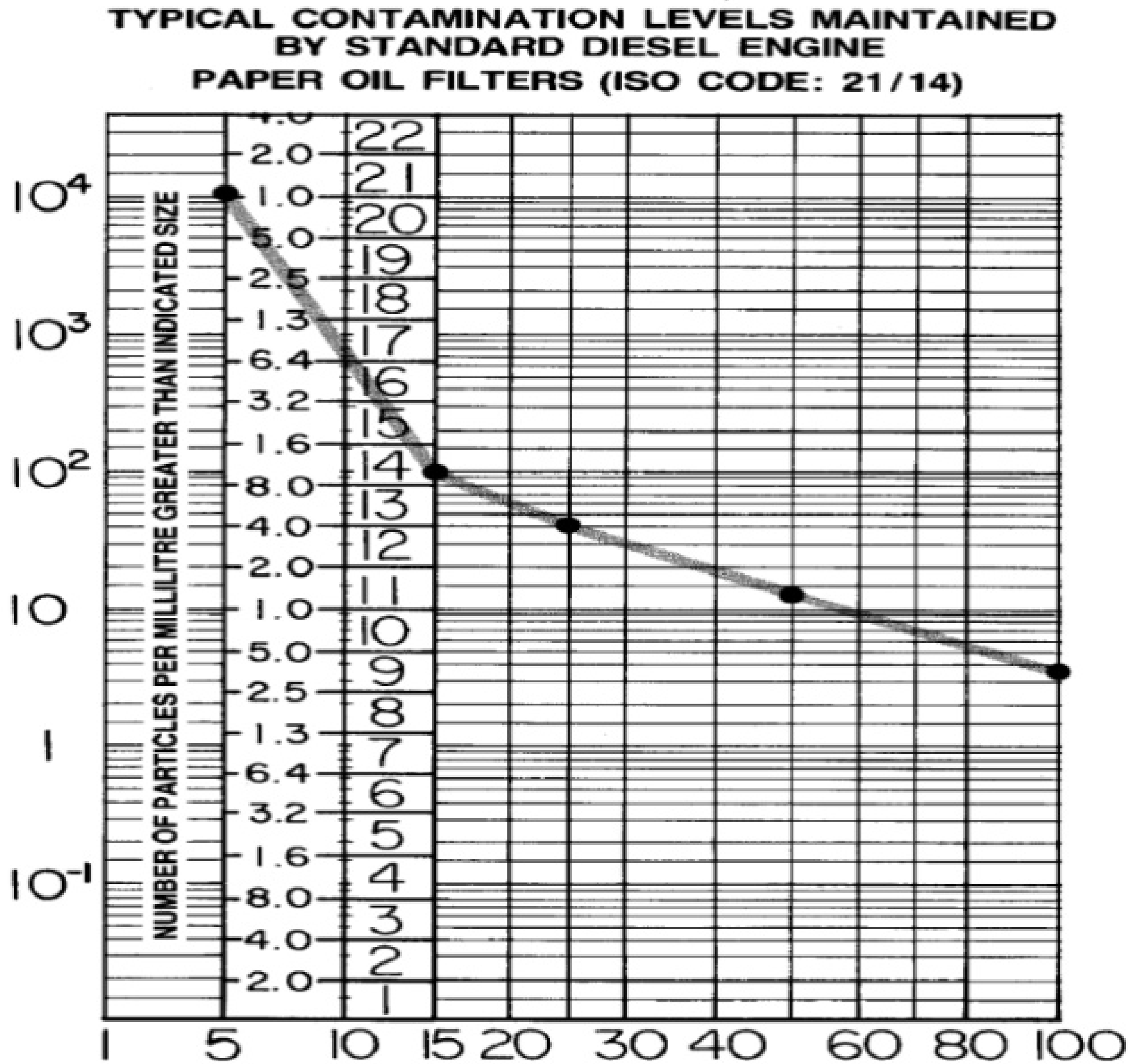
Component	Oil Film Thickness (microns)
Ring/Cylinder	0.3 - 7
Rod Bearings	0.5 - 20
Main Shaft Bearings	0.8 - 50
Turbocharger Bearings	0.5 - 20
Piston Pin Bushing	0.5 - 15
Valve Train	0 - 1.0
Gearing	0 - 1.5



When two interacting surfaces in relative motion are separated by a lubricant film, dynamic clearances are not equal to the machine clearances, but depend on load, rotational or linear speed, and oil viscosity

DYNAMIC CLEARANCES

Particle Size Distribution in Used Diesel Engine Oil



PARTICLE COUNT SUMMARY:

PARTICLES GREATER THAN SIZE SHOWN	NUMBER PER MILILITER
5 µm	10,671
15 µm	104.2
25 µm	41.7
50 µm	14.2
100 µm	3.7

Figure: Particle Size Distribution in Used Engine Oil

Based on above figure, more than 99% of these particles are less than 20 micron in size

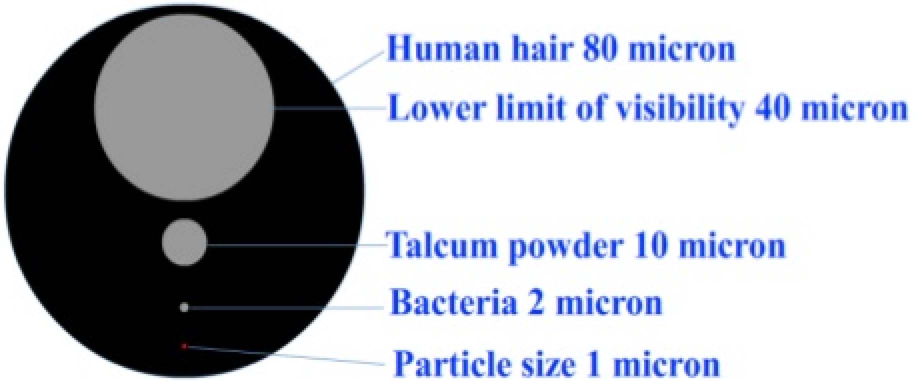
ISO 4406:1999 Cleanliness Rating Number

The cleanliness rating of engine oils is measured via the lube oil particle count. Most particle counter reports results at six particle diameter size ranges: **4μ, 6μ, 14μ, 21μ, 38μ and 70μm**. An ISO Cleanliness rating number is derived from the results of three smallest sizes, therefore the minimum particle count test should furnish results at **4μ, 6μ, 14μm.** Before discussing about particle size we need to refocus our perception about micron size.

What is the meaning of "micron" in particle size? Below figure can help your perception about micron size

Sizes of Familiar Particles in Microns

Grain of table salt	100 μm	Talcum powder	10 μm
Human hair	80 μm	Red blood cell	8 μm
Lower limit of visibility	40 μm	Bacteria	2 μm
White blood cell	25 μm	Silt	<5 μm



ISO 4406:1999 Cleanliness Rating Number

What Actually The Code Represents?

ISO/Range Code	Min particles /ml	Max particles /ml < or equal to
1	0	0.02
2	0.02	0.04
3	0.04	0.08
4	0.08	0.15
5	0.15	0.3
6	0.3	0.6
7	0.6	1.3
8	1.3	2.5
9	2.5	5
10	5	10
11	10	20
12	20	40
13	40	80
14	80	160
15	160	320
16	320	640
17	640	1,300
18	1,300	2,500
19	2,500	5,000
20	5,000	10,000
21	10,000	20,000
22	20,000	40,000
23	40,000	80,000
24	80,000	160,000
25	160,000	320,000
26	320,000	640,000
27	640,000	1,300,000
28	1,300,000	2,500,000

Particle Size	Particles per Milliliter	ISO 4406 Code Range	ISO Code
$4\mu m_{[c]}$	**151773**	**80000~160000**	**24**
$4.6\mu m_{[c]}$	87210		
$6\mu m_{[c]}$	**38363**	**20000~40000**	**22**
$10\mu m_{[c]}$	8229		
$14\mu m_{[c]}$	**3339**	**2500~5000**	**19**
$21\mu m_{[c]}$	1048		
$38\mu m_{[c]}$	112		
$68\mu m_{[c]}$	2		

Particle Size	Particles per Milliliter	ISO 4406 Code Range	ISO Code
$4\mu m_{[c]}$	**69**	**40~80**	**13**
$4.6\mu m_{[c]}$	35		
$6\mu m_{[c]}$	**7**	**5~10**	**10**
$10\mu m_{[c]}$	5		
$14\mu m_{[c]}$	**0.4**	**0.32~0.64**	**6**
$21\mu m_{[c]}$	0.1		
$38\mu m_{[c]}$	0.0		
$68\mu m_{[c]}$	0.0		

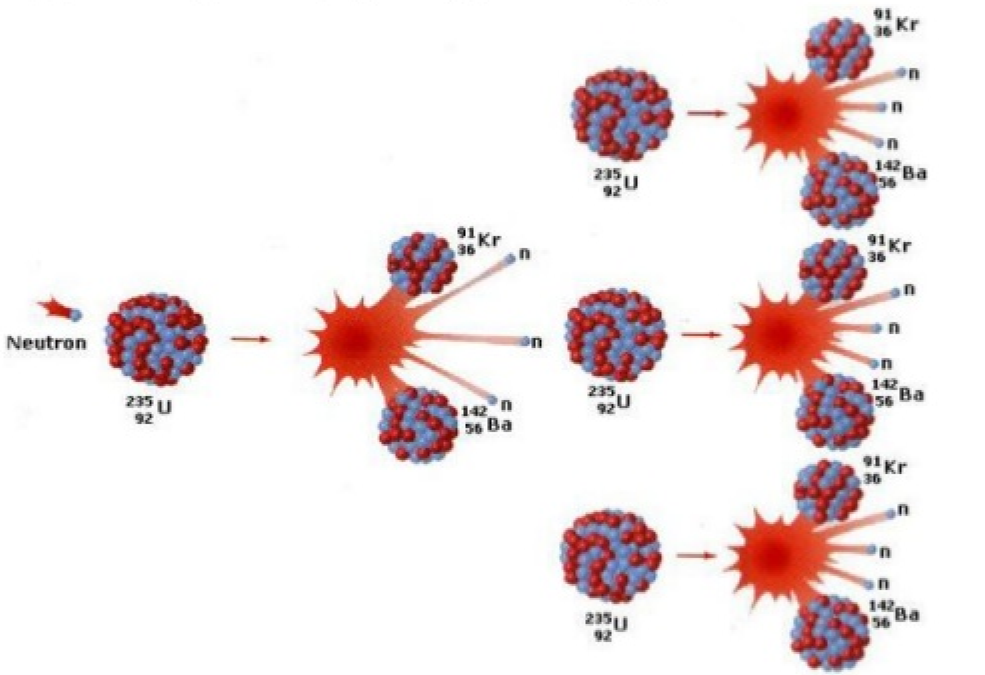
Chain Reaction of Wear

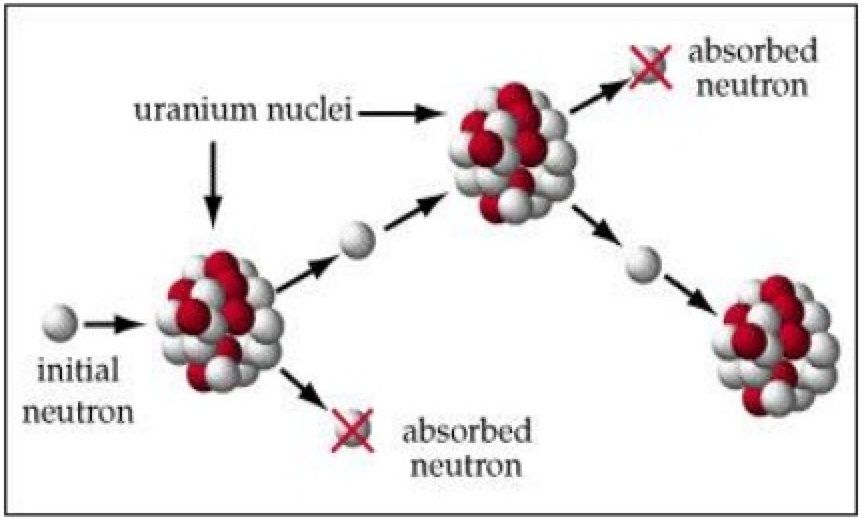
Breaking The Chain Reaction Of Wear:

In a study by Dr. E. Rabiniwicz of M.I.T., the observation was made that 70% of component replacements or "loss of usefulness" is due to surface degradation. In hydraulic and lubricating systems, 20% of these replacements result from corrosion, with 50% resulting from mechanical wear.

Particles generated as a result of abrasive wear are **work hardened**; thus they become harder than the parent surface**. If these particles are not removed by proper filtration**, they will recirculate and cause additional wear. This "chain reaction of wear" will continue and result in premature system component failure unless high-performance filtration is applied to break the chain.

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow 3\,{}_{0}n^{1} + {}_{36}Kr^{92} + {}_{56}Ba^{141} + \text{ENERGY}$$





Most reactors are controlled by means of control rods that are made of a strongly neutron-absorbent material such as boron or cadmium

Uncontrolled Fission Chain Reaction | **Controlled Fission Chain Reaction**

Lubrication Methods

Engine Parts Lubricated By Engine Oils

- Piston Motion in Cylinder
- Crankshaft Rotation in Engine Bearings (Main Bearings and Big End Bearings)
- Piston Pin Rotation in the Bush of Small End of the Connecting Rod
- Camshaft Rotation in Camshaft Bearings
- Cams Sliding Over the Valves Rods
- Intermediate Gears
- Turbocharger Bearings
- Pedestal Bearing
- Reciprocating Motion of Valve Stems

Types of Lubrication Methods

- Boundary Lubrication
- Hydrodynamic Lubrication
- Elastohydrodynamic Lubrication