VIGYAN 2047 Volume 2 No. 8 August 2025 Pages 21–24

Tribosystems

Kamal Mukherjee

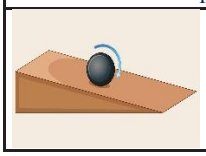
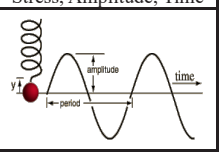
Features of tribosystems

Tribology is the study of systems where surfaces touch, move against each other & interact in relative motion, called tribosystems. Many factors affect how these systems work, so it's important to consider them when choosing materials and lubricants. These factors include the type of movement, speed, temperature, load, and the working environment.

In general, tribosystems can be understood by looking at four main parts:

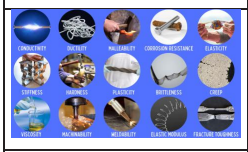
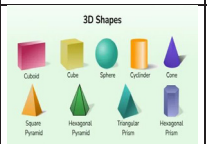
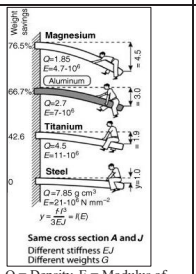
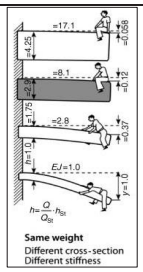
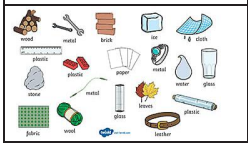
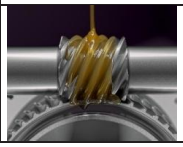
1) Operational inputs: these are which must be fed into the process e.g. operating variables like a) type of motion—if it is sliding, rolling, impact, rolling with slipping, etc. b) speed/velocity & temperature, c) load, d) stress—its amplitude, frequency, time etc. (Table-1).

Table-1: Operational inputs e.g. a) type of motion & b) load, stress amplitude, time

Rolling	Sliding	Impact	slipping	Stress, Amplitude, Time
				

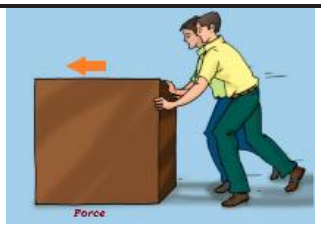
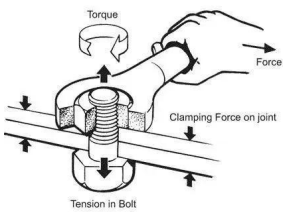
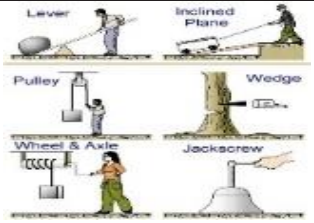
2) System structure: A system is a set of elements interconnected by structure & function. Further the structure is based on the material components of the system, its revenant properties & interrelations between the elements. Thus, the transformation of the above inputs occurs e.g. materials-metal surfaces (hardness, composition, geometry, size, shape), ambient medium e.g. air, lubricating or working oil and design (Table-2).

Table-2: Material Properties

Mechanical properties	Shape of materials	Selection of Material used	Design of components
		 Q = Density, E = Modulus of Elasticity, y = Beam Deflection	
Different Materials	Gear Oil		
			

3) Functional outputs are the desired purposes like—motion, force, torque, mechanical work, materials, resources etc. and byproducts like friction and wear- these are ultimately the loss potentials) (Table-3).

Table-3: Functional outputs (motion, force, torque, mechanical work)

Motion	Force	Torque	Mechanical Work
			

4) Loss outputs—these are mostly the unwanted byproducts like a) heating or cooling, friction, noise, vibration etc. or b) energy & material loss by way of wear (Table-4).

Table-4: Friction of disk & Wear (loss of material) of Bearing & Gear

Structure of the tribosystems

The tribosystems are used to transform the 'inputs' like force/movement and turn them into useful 'work output' through the structure. This happens by the interaction of its different parts. Structure and function of tribosystems are interconnected and may be detrimentally influenced by friction and wear processes causing the 'loss outputs' in terms of energy and material dissipation.

The working of a tribosystems: can be understood by looking at its four main parts which are interrelated surfaces in relative motion and gives rise to the friction & wear processes in most of the tribological systems which are: a) the **1st triboelement** (which can be metal or non-metal) are the parts that move against the other —e.g. Rotating shaft, gear, reciprocating slides, oscillating/spinning spherical joints etc., b) the **2nd triboelement** which generally is the stationary elements e.g. bearings, bushes, sleeves, housings, stationary gears, liners/cylinders, blocks, boxes etc.—these two are the **main interacting components,** c) the **3rd triboelement** is the **lubricants** which sits between the first two and helps them slide smoothly, act as cushions e.g. base oil-engine / gearbox / hydraulic / compressor oil, additives, resultant wear debris / contaminants (liquids / solids), dissipation & d) the **4th triboelement** is the **surrounding environment/ atmosphere**—like air, water vapour, moisture, corrosive/dusty fumes or gas, in which the system operates as shown in Fig-1.

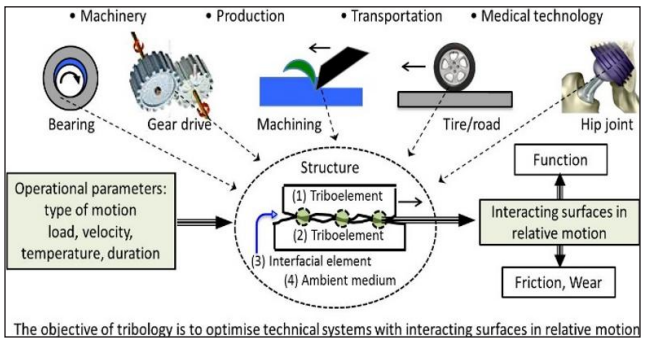


Fig-1: Examples of Tribosystems in various technology areas. ***(ref. H Czichos & M Woydt: Introduction to Tribology & tribological parameters-ASM handbook, Vol-28, Friction, Lubrication & Wear-2017)***

Let's consider a single stage speed reduction with spur gears- the inputs are given through a 'pinion' of 'high angular velocity' with 'low torque'. As per the tribosystem the conversion of these inputs take place through the contact (gear-mesh) of interacting 'gear' teeth. This causes friction & wear process. The resultant "useful output" are 'reduced angular speed' with 'increased torque' and the "loss out" in the form of generated heat.

Functions & categories of Tribosystems

The common components of tribosystems e.g. Bearing, Gear, Spring, Coupling, Chain drive, Wire rope, tyre, wheel, cylinder and similar system in the relative motion are shown here.

Bearings and guides: Bearings are mechanical components (elements) designed to reduce friction and guide motion between two moving parts, typically between a rotating shaft and stationary housing. They enable smooth rotational movement, improving machine efficiency and performance by minimizing energy loss. Due to their widespread use, especially in applications involving rotating shafts—they are manufactured in standardized sizes and types to fit on various engineering needs. The earliest linear bearing concept involved placing tree trunks under sleds to move heavy loads. Ancient Assyrians used rollers and sledges for transporting stones—possibly similar methods were used for building Egypt's pyramids (Fig. 2a & b). A wooden ball bearing from 40 BC, found in a Roman shipwreck at Lake Nemi, Italy, is one of the earliest known rotating bearing examples (Fig. 2c). Leonardo da Vinci later sketched (1452–

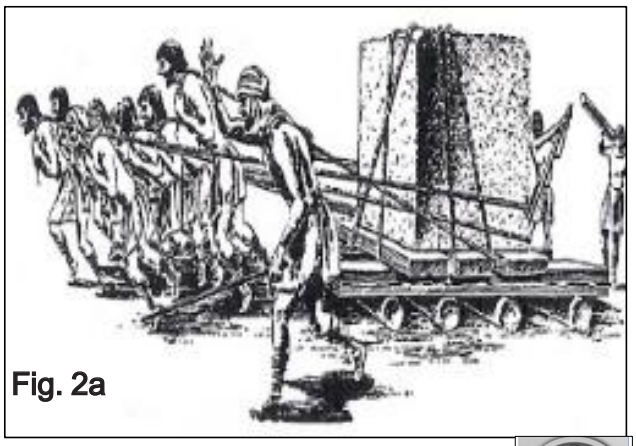


Fig. 2a

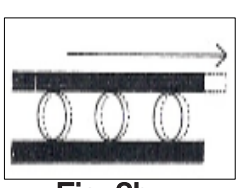
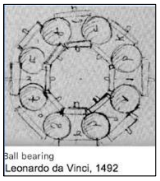


Fig. 2b

Fig. 2c



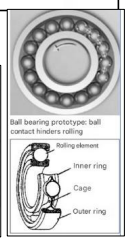


Fig. 2d

History of bearing development

1519) a bearing inside a cage in his 15th-century (late 1400) notebooks. The first caged bearing was developed by John Harrison around 1740. With the advent of steel and industrialization, modern ball bearings emerged—Philip Vaughan patented one in 1794, & Jules Suriray's bicycle application in 1869. Bearings later evolved into roller and other designs (Fig. 2d). Different types of bearings used are (Fig. 3). *Interestingly who knew when da Vinci conceptualised the first aerospace drawings for ball bearings they would someday end up on Mars?*

Fig-3: Various typres of bearings

Gears are key part machine elements used to transmit motion and power between rotating shafts through the meshing (progressive engagement) of their teeth. They work in pairs—typically a smaller one is called called "pinion" which which drives a larger one known as known as "gear" to to control speed, torque, and direction. Gears are commonly used in engines and power tools & commonly termed as a speed reducer, reduction gear box and a torque converter etc. & are popular due to their efficiency and reliability over belts or chain drives. Types include spur, helical, bevel, worm & worm wheel, and rack & pinion, among others. Their materials are steel, phosphor-bronze, nylon, and non-metallics as per the need (Fig. 4).

Fig-4: Types of Gears

Springs: These are an elastic body whose primary function is to deflect or provide cushion to reduce the effect of shock under the load, it recovers its original shape when load is released thus its main factions are absorbing, storing, and transmitting mechanical energy (forces, moments, movements) as in car/truck/rail coach/bogy. The commonly used are of coil, helical, spiral, leaf springs. (Fig-5)

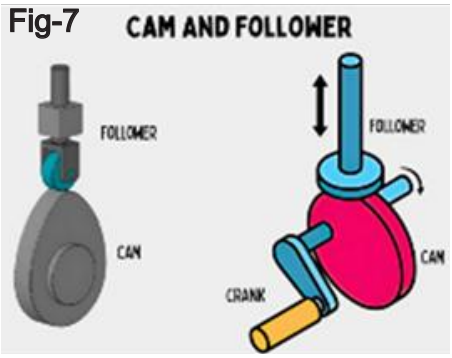
Fig-5: Different types of Springs

Seals are used to prevent fluids or contaminants from moving between chambers. They are either static (no movement) or dynamic (with motion). Static seals like O-rings (polymer-

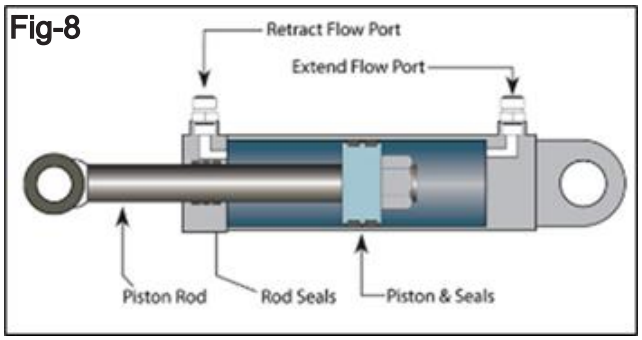
based) and gaskets (made from cork, metal, etc.) are used between fixed parts. Dynamic seals, such as lip seals and mechanical face seals, handle rotary or reciprocating motion. Lip seals are suited for low-pressure, limited-motion uses, while mechanical face seals are ideal for high-pressure systems like pumps and turbines, operating with a thin fluid film to reduce wear and leakage. (Fig-6)


Fig-6

Cam/Cam Follower: The cam/cam follower as tribological system which is often used to open and close the valves of internal combustion engines. The cam follower can be designed as a flat tappet, rocker arm, finger follower, or bucket tappet. The cam and cam followers form a typical contact. The contact pressures can be estimated using the Hertzian formulas (Fig-7).



Hydraulic Cylinder: Nowadays the hydraulic power is used due to its high power to weight ratio. The hydraulic cylinder is a hollow tube which encompasses a piston having combination of 'O' rings & flat rings to avoid the hydraulic oil to cross the piston. Pressurised hydraulic oil is allowed to enter from one end of the piston which is connected to a cylinder rod which then moves linearly under a force. Thus, hydraulic energy is used to get the mechanical energy which is generally used to move or lift an object (Fig-8)



Wire rope: Wires are the basic building blocks of a wire rope. The wire ropes are used for hoisting & haulage & for static loading e.g. guys and supporting wire for stacks, masts etc. Wire ropes are composed of independent parts—wires, strands and cores—that continuously interact with each other during service. The wire rope consists of cold drawn steel wires wrapped into strands & twisted around a hemp centre of core saturated with lubricant. The strands are helically laid together around a centre, typically some type of core, to form a wire rope. A typical 6 x 25 rope has 150 wires in its outer strands, all of which move independently and together in a very complicated pattern around the core as the rope bends (Fig-9)


Fig-9

The job of the tribosystems is to take in & transform the inputs like force, movement, rotation etc. and turn them into useful work. This happens through the interaction of its different parts. But friction and wear can damage these parts, leading to loss of desired output, energy loss and material waste. To keep the tribosystem working well, we need to regularly check and maintain it. ◆

***Kamal Mukherjee**, a prolific science writer and nutritionist, is an active member of the Tribological Society of India and has held executive leadership roles in major national organizations. He can be contacted at kamalcbm28@gmail.com.*