| ISSN: 2395-7639 | www.ijmrsetm.com | Impact Factor: 7.580| A Monthly Double-Blind Peer Reviewed Journal |

| Volume 8, Issue 2, February 2021 |

Friction- A Necessary Evil

CHETAN PRAKASH MEENA

Assistant Professor, Physics, Govt. College, Gangapur City, Rajasthan, India

ABSTRACT: Friction is a force exerted by a surface against the motion of a body across its surface. Frictional forces are the reason why your car comes to a standstill if you don't accelerate. We see examples all around us where frictional forces act. It is something that we cannot live with and something we cannot live without. In this article, we will explore friction, how it helps us, and how it harms us. We can only understand the importance of frictional force if it goes away. So let's explore a world without frictional force. Without this force, you would not be able to walk at all. With your first step out of the bed, you'd slip and fall. Imagine a world where someone has put oil all over a floor. A world without frictional force is much worse than this. Let alone walking, you wouldn't be able to use your car or bike since the wheel that helps you move around to do so by using frictional force. The friction between the road and the wheel causes the movement of the vehicle and without frictional forces, you'd just stay in one place and spin the wheels. Imagine that you eventually make it your classroom despite the absence of frictional force after a lot of slipping and falling down. In the classroom, the situation would be even worse. You wouldn't be able to lift your books out of your bag because they'd keep slipping through your fingers. Pen and pencil rely on the frictional force acting between the tip of the pen or pencil and the page to write. That's not the worst part, the teacher's blackboard and chalk wouldn't work either. The teacher would have to teach the entire syllabus orally! A world without this force is a world without sports too! You can spin/swing a cricket ball due to the frictional force between your fingers and the ball. Without friction, sports would be a dream. Wow, a world without friction seems like a nightmare, but friction is exactly the hero of the story.

KEYWORDS;friction;necessary,evil;forces;accelerate;road;worse;movement;vehicle

I.INTRODUCTION

Friction although is necessary, can be excessive at times. Most machines require repair and maintenance because of the frictional force. The friction between parts over time is responsible for a majority of the wear and tear in a machine. So if you're cycling needs to get repaired, you know who to blame. The frictional force also causes most of the injuries. When you fall down, the part of your body in contact with the ground scrapes the surface as you fall. The frictional force is responsible for the wound and blood. Without friction, it would be like slipping on ice. You'd just slip and slide away. It is also responsible for our cars and vehicles slowing down. When you are moving, you experience frictional forces due to multiple sources. The friction between you and the ground,[12,1,15] the frictional force between you and the air you are moving through. Without frictional force, you'd just have to pedal your cycle once or twice and you'd keep going on and on. Thus, when we are moving, we waste a lot of energy overcoming the frictional force opposing our motion. Even though the frictional force is a huge pain in the neck, life as we know it would have been impossible without it. Not to mention how friction holds our skyscrapers in one piece or how friction helps us turn the pages of our books. In the end, even though it makes us waste a lot of energy, causes a lot of pain as wounds and spoils our machines, life without friction is not a life worth living. The energy we waste overcoming frictional force in our daily lives is a price definitely worth paying.[28,29]

Friction is the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other.[2] There are several types of friction:

- Dry friction is a force that opposes the relative lateral motion of two solid surfaces in contact. Dry friction is subdivided into static friction ("stiction") between non-moving surfaces, and kinetic friction between moving surfaces. With the exception of atomic or molecular friction, dry friction generally arises from the interaction of surface features, known as asperities (see Figure 1).
- Fluid friction describes the friction between layers of a viscous fluid that are moving relative to each other.[3][4]
- Lubricated friction is a case of fluid friction where a lubricant fluid separates two solid surfaces.[5][6][7]
- Skin friction is a component of drag, the force resisting the motion of a fluid across the surface of a body.

- Internal friction is the force resisting motion between the elements making up a solid material while it undergoes deformation.[4]

When surfaces in contact move relative to each other, the friction between the two surfaces converts kinetic energy into thermal energy (that is, it converts work to heat). This property can have dramatic consequences, as illustrated by the use of friction created by rubbing pieces of wood together to start a fire. Kinetic energy is converted to thermal energy whenever motion with friction occurs, for example when a viscous fluid is stirred. Another important consequence of many types of friction can be wear, which may lead to performance degradation or damage to components. Friction is a component of the science of tribology.

Friction is desirable and important in supplying traction to facilitate motion on land. Most land vehicles rely on friction for acceleration, deceleration and changing direction. Sudden reductions in traction can cause loss of control and accidents.[11,17,19]

Friction is not itself a fundamental force. Dry friction arises from a combination of inter-surface adhesion, surface roughness, surface deformation, and surface contamination. The complexity of these interactions makes the calculation of friction from first principles impractical and necessitates the use of empirical methods for analysis and the development of theory.

Friction is a non-conservative force – work done against friction is path dependent. In the presence of friction, some kinetic energy is always transformed to thermal energy, so mechanical energy is not conserved.[30]

II.DISCUSSION

The Greeks, including Aristotle, Vitruvius, and Pliny the Elder, were interested in the cause and mitigation of friction.[8] They were aware of differences between static and kinetic friction with Themistius stating in 350 A.D. that "it is easier to further the motion of a moving body than to move a body at rest".[8][9][10][11]

The classic laws of sliding friction were discovered by Leonardo da Vinci in 1493, a pioneer in tribology, but the laws documented in his notebooks were not published and remained unknown.[12][13][14][15][16][17] These laws were rediscovered by Guillaume Amontons in 1699[18] and became known as Amonton's three laws of dry friction. Amontons presented the nature of friction in terms of surface irregularities and the force required to raise the weight pressing the surfaces together. This view was further elaborated by Bernard Forest de Bélidor[19] and Leonhard Euler (1750), who derived the angle of repose of a weight on an inclined plane and first distinguished between static and kinetic friction.[20] John Theophilus Desaguliers (1734) first recognized the role of adhesion in friction.[21] Microscopic forces cause surfaces to stick together; he proposed that friction was the force necessary to tear the adhering surfaces apart.

The understanding of friction was further developed by Charles-Augustin de Coulomb (1785).[18] Coulomb investigated the influence of four main factors on friction: the nature of the materials in contact and their surface coatings; the extent of the surface area; the normal pressure (or load); and the length of time that the surfaces remained in contact (time of repose).[12] Coulomb further considered the influence of sliding velocity, temperature and humidity, in order to decide between the different explanations on the nature of friction that had been proposed. The distinction between static and dynamic friction is made in Coulomb's friction law (see below), although this distinction was already drawn by Johann Andreas von Segner in 1758.[12] The effect of the time of repose was explained by Pieter van Musschenbroek (1762) by considering the surfaces of fibrous materials, with fibers meshing together, which takes a finite time in which the friction increases.

John Leslie (1766–1832) noted a weakness in the views of Amontons and Coulomb: If friction arises from a weight being drawn up the inclined plane of successive asperities, why then isn't it balanced through descending the opposite slope? Leslie was equally skeptical about the role of adhesion proposed by Desaguliers, which should on the whole have the same tendency to accelerate as to retard the motion.[12] In Leslie's view, friction should be seen as a time-dependent process of flattening, pressing down asperities, which creates new obstacles in what were cavities before.[15,11,10]

In the long course of the development of the law of conservation of energy and of the first law of thermodynamics, friction was recognised as a mode of conversion of mechanical work into heat. In 1798, Benjamin Thompson reported on cannon boring experiments.[22]

Arthur Jules Morin (1833) developed the concept of sliding versus rolling friction.

In 1842, Julius Robert Mayer frictionally generated heat in paper pulp and measured the temperature rise.[23] In 1845, Joule published a paper entitled The Mechanical Equivalent of Heat, in which he specified a numerical value for the amount of mechanical work required to "produce a unit of heat", based on the friction of an electric current passing through a resistor, and on the friction of a paddle wheel rotating in a vat of water.[24]

Osborne Reynolds (1866) derived the equation of viscous flow. This completed the classic empirical model of friction (static, kinetic, and fluid) commonly used today in engineering.[13] In 1877, Fleeming Jenkin and J. A. Ewing investigated the continuity between static and kinetic friction.[25]

In 1907, G.H. Bryan published an investigation of the foundations of thermodynamics, Thermodynamics: an Introductory Treatise dealing mainly with First Principles and their Direct Applications. He noted that for a driven hard surface sliding on a body driven by it, the work done by the driver exceeds the work received by the body. The difference is accounted for by heat generated by friction.[26] Over the years, for example in his 1879 thesis, but particularly in 1926, Planck advocated regarding the generation of heat by rubbing as the most specific way to define heat, and the prime example of an irreversible thermodynamic process.[27]

The focus of research during the 20th century has been to understand the physical mechanisms behind friction. Frank Philip Bowden and David Tabor (1950) showed that, at a microscopic level, the actual area of contact between surfaces is a very small fraction of the apparent area.[14] This actual area of contact, caused by asperities increases with pressure. The development of the atomic force microscope (ca. 1986) enabled scientists to study friction at the atomic scale,[13] showing that, on that scale, dry friction is the product of the inter-surface shear stress and the contact area. These two discoveries explain Amonton's first law (below); the macroscopic proportionality between normal force and static frictional force between dry surfaces.[29]

The force of friction is always exerted in a direction that opposes movement (for kinetic friction) or potential movement (for static friction) between the two surfaces. For example, a curling stone sliding along the ice experiences a kinetic force slowing it down. For an example of potential movement, the drive wheels of an accelerating car experience a frictional force pointing forward; if they did not, the wheels would spin, and the rubber would slide backwards along the pavement. Note that it is not the direction of movement of the vehicle they oppose, it is the direction of (potential) sliding between tire and road. The coefficient of friction (COF), often symbolized by the Greek letter μ, is a dimensionless scalar value which equals the ratio of the force of friction between two bodies and the force pressing them together, either during or at the onset of slipping. The coefficient of friction depends on the materials used; for example, ice on steel has a low coefficient of friction, while rubber on pavement has a high coefficient of friction. Coefficients of friction range from near zero to greater than one. The coefficient of friction between two surfaces of similar metals is greater than that between two surfaces of different metals; for example, brass has a higher coefficient of friction when moved against brass, but less if moved against steel or aluminum.[28]

III.RESULTS

Arthur Morin introduced the term and demonstrated the utility of the coefficient of friction.[12] The coefficient of friction is an empirical measurement — it has to be measured experimentally, and cannot be found through calculations.[29] Rougher surfaces tend to have higher effective values. Both static and kinetic coefficients of friction depend on the pair of surfaces in contact; for a given pair of surfaces, the coefficient of static friction is usually larger than that of kinetic friction; in some sets the two coefficients are equal, such as teflon-on-teflon.

Most dry materials in combination have friction coefficient values between 0.3 and 0.6. Values outside this range are rarer, but teflon, for example, can have a coefficient as low as 0.04. A value of zero would mean no friction at all, an elusive property. Rubber in contact with other surfaces can yield friction coefficients from 1 to 2. Occasionally it is maintained that μ is always < 1, but this is not true. While in most relevant applications $\mu < 1$, a value above 1 merely implies that the force required to slide an object along the surface is greater than the normal force of the surface on the object. For example, silicone rubber or acrylic rubber-coated surfaces have a coefficient of friction that can be substantially larger than 1.

While it is often stated that the COF is a "material property," it is better categorized as a "system property." Unlike true material properties (such as conductivity, dielectric constant, yield strength), the COF for any two materials depends on system variables like temperature, velocity, atmosphere and also what are now popularly described as aging and deaging times; as well as on geometric properties of the interface between the materials, namely surface structure.[1] For example, a copper pin sliding against a thick copper plate can have a COF that varies from 0.6 at low speeds (metal sliding against metal) to below 0.2 at high speeds when the copper surface begins to melt due to frictional heating. The latter speed, of course, does not determine the COF uniquely; if the pin diameter is increased so that the frictional heating is removed rapidly, the temperature drops, the pin remains solid and the COF rises to that of a 'low speed' test[20]

| ISSN: 2395-7639 | www.ijmrsetm.com | Impact Factor: 7.580| A Monthly Double-Blind Peer Reviewed Journal |

| Volume 8, Issue 2, February 2021 |

Static friction is friction between two or more solid objects that are not moving relative to each other. For example, static friction can prevent an object from sliding down a sloped surface. The coefficient of static friction, typically denoted as μ_s, is usually higher than the coefficient of kinetic friction. Static friction is considered to arise as the result of surface roughness features across multiple length scales at solid surfaces. These features, known as asperities are present down to nano-scale dimensions and result in true solid to solid contact existing only at a limited number of points accounting for only a fraction of the apparent or nominal contact area.[41] The linearity between applied load and true contact area, arising from asperity deformation, gives rise to the linearity between static frictional force and normal force, found for typical Amonton–Coulomb type friction.[42]

The static friction force must be overcome by an applied force before an object can move.

New models are beginning to show how kinetic friction can be greater than static friction.[48] Kinetic friction is now understood, in many cases, to be primarily caused by chemical bonding between the surfaces, rather than interlocking asperities;[49] however, in many other cases roughness effects are dominant, for example in rubber to road friction.[48] Surface roughness and contact area affect kinetic friction for micro- and nano-scale objects where surface area forces dominate inertial forces.[50]

The origin of kinetic friction at nanoscale can be explained by thermodynamics.[51] Upon sliding, a new surface forms at the back of a sliding true contact, and existing surface disappears at the front of it. Since all surfaces involve the thermodynamic surface energy, work must be spent in creating the new surface, and energy is released as heat in removing the surface. Thus, a force is required to move the back of the contact, and frictional heat is released at the front.[30]

IV.CONCLUSIONS

The Coulomb approximation follows from the assumptions that: surfaces are in atomically close contact only over a small fraction of their overall area; that this contact area is proportional to the normal force (until saturation, which takes place when all area is in atomic contact); and that the frictional force is proportional to the applied normal force, independently of the contact area. The Coulomb approximation is fundamentally an empirical construct. It is a rule-of-thumb describing the approximate outcome of an extremely complicated physical interaction. The strength of the approximation is its simplicity and versatility. Though the relationship between normal force and frictional force is not exactly linear (and so the frictional force is not entirely independent of the contact area of the surfaces), the Coulomb approximation is an adequate representation of friction for the analysis of many physical systems.

When the surfaces are conjoined, Coulomb friction becomes a very poor approximation (for example, adhesive tape resists sliding even when there is no normal force, or a negative normal force). In this case, the frictional force may depend strongly on the area of contact. Some drag racing tires are adhesive for this reason. However, despite the complexity of the fundamental physics behind friction, the relationships are accurate enough to be useful in many applications.

Friction is an important factor in many engineering disciplines.

Transportation

- Automobile brakes inherently rely on friction, slowing a vehicle by converting its kinetic energy into heat. Incidentally, dispersing this large amount of heat safely is one technical challenge in designing brake systems. Disk brakes rely on friction between a disc and brake pads that are squeezed transversely against the rotating disc. In drum brakes, brake shoes or pads are pressed outwards against a rotating cylinder (brake drum) to create friction. Since braking discs can be more efficiently cooled than drums, disc brakes have better stopping performance.[78]
- Rail adhesion refers to the grip wheels of a train have on the rails, see Frictional contact mechanics.
- Road slipperiness is an important design and safety factor for automobiles[79]
  - Split friction is a particularly dangerous condition arising due to varying friction on either side of a car.
  - Road texture affects the interaction of tires and the driving surface.

Measurement

- A tribometer is an instrument that measures friction on a surface.
- A profilograph is a device used to measure pavement surface roughness.

Household usage

- Friction is used to heat and ignite matchsticks (friction between the head of a matchstick and the rubbing surface of the match box).[80]
- Sticky pads are used to prevent object from slipping off smooth surfaces by effectively increasing the friction coefficient between the surface and the object.[2,25,8]

REFERENCES

1. Hanaor, D.; Gan, Y.; Einav, I. (2016). "Static friction at fractal interfaces". Tribology International. 93: 229–238. arXiv:2106.01473. doi:10.1016/j.triboint.2015.09.016. S2CID 51900923.
2. ^ "friction". Merriam-Webster Dictionary.
3. ^ :a b Beer, Ferdinand P.; Johnston, E. Russel, Jr. (1996). Vector Mechanics for Engineers (Sixth ed.). McGraw-Hill. p. 397. ISBN 978-0-07-297688-5.
4. ^ :a b Meriam, J. L.; Kraige, L. G. (2002). Engineering Mechanics (fifth ed.). John Wiley & Sons. p. 328. ISBN 978-0-471-60293-4.
5. ^ Ruina, Andy; Pratap, Rudra (2002). Introduction to Statics and Dynamics (PDF). Oxford University Press. p. 713.
6. ^ Hibbeler, R. C. (2007). Engineering Mechanics (Eleventh ed.). Pearson, Prentice Hall. p. 393. ISBN 978-0-13-127146-3.
7. ^ Soutas-Little, Robert W.; Inman, Balint (2008). Engineering Mechanics. Thomson. p. 329. ISBN 978-0-495-29610-2.
8. ^ :a b Chatterjee, Sudipta (2008). Tribological Properties of Pseudo-elastic Nickel-titanium (Thesis). University of California. pp. 11–12. ISBN 9780549844372 – via ProQuest. Classical Greek philosophers like Aristotle, Pliny the Elder and Vitruvius wrote about the existence of friction, the effect of lubricants and the advantages of metal bearings around 350 B.C.
9. ^ Fishbane, Paul M.; Gasiorowicz, Stephen; Thornton, Stephen T. (1993). Physics for Scientists and Engineers. Vol. I (Extended ed.). Englewood Cliffs, New Jersey: Prentice Hall. p. 135. ISBN 978-0-13-663246-7. Themistius first stated around 350 B.C. [SIC] that kinetic friction is weaker than the maximum value of static friction.
10. ^ Hecht, Eugene (2003). Physics: Algebra/Trig (3rd ed.). Cengage Learning. ISBN 9780534377298.
11. ^ Sambursky, Samuel (2014). The Physical World of Late Antiquity. Princeton University Press. pp. 65–66. ISBN 9781400858989.
12. ^ :a b c d e Dowson, Duncan (1997). History of Tribology (2nd ed.). Professional Engineering Publishing. ISBN 978-1-86058-070-3.
13. ^ :a b c Armstrong-Hélouvry, Brian (1991). Control of machines with friction. USA: Springer. p. 10. ISBN 978-0-7923-9133-3.
14. ^ :a b van Beek, Anton. "History of Science Friction". tribology-abc.com. Retrieved 2011-03-24.
15. ^ Hutchings, Ian M. (2016). "Leonardo da Vinci's studies of friction" (PDF). Wear. 360–361: 51–66. doi:10.1016/j.wear.2016.04.019. Archived (PDF) from the original on 2016-08-03.
16. ^ Hutchings, Ian M. (2016-08-15). "Leonardo da Vinci's studies of friction". Wear. 360–361: 51–66. doi:10.1016/j.wear.2016.04.019.
17. ^ Kirk, Tom (July 22, 2016). "Study reveals Leonardo da Vinci's 'irrelevant' scribbles mark the spot where he first recorded the laws of friction". phys.org. Retrieved 2016-07-26.
18. ^ :a b Popova, Elena; Popov, Valentin L. (2015-06-01). "The research works of Coulomb and Amontons and generalized laws of friction". Friction. 3 (2): 183–190. doi:10.1007/s40544-015-0074-6.
19. ^ Forest de Bélidor, Bernard. "Richtige Grund-Sätze der Friction-Berechnung" ("Correct Basics of Friction Calculation"), 1737, (in German)
20. ^ "Leonhard Euler". Friction Module. Nano World. 2002. Archived from the original on 2011-05-07. Retrieved 2011-03-25.
21. ^ Goedecke, Andreas (2014). Transient Effects in Friction: Fractal Asperity Creep. Springer Science and Business Media. p. 3. ISBN 978-3709115060.
22. ^ Benjamin Thompson (1798). "An inquiry concerning the source of the heat which is excited by friction," Philosophical Transactions of the Royal Society of London, 88 : 80–102. doi:10.1098/rstl.1798.0006
23. ^ Blundell, S.J., Blundell, K.M. (2006). Concepts in Thermal Physics, Oxford University Press, Oxford UK, ISBN 9780198567691, p. 106.

24. ^ Joule, J.P. (1845)."On the Mechanical Equivalent of Heat". Philosophical Transactions of the Royal Society of London. 140: 61–82. 1850. doi:10.1098/rstl.1850.0004.
25. ^ Fleeming Jenkin & James Alfred Ewing (1877) "On Friction between Surfaces moving at Low Speeds", Philosophical Magazine Series 5, volume 4, pp 308–10; link from Biodiversity Heritage Library
26. ^ Bryan, George Hartley (1907). "Thermodynamics, an introductory treatise dealing mainly with first principles and their direct applications". Leipzig, Teubner. Retrieved 23 June 2020.
27. ^ :[a b] Planck, M. (1926). "Über die Begründung des zweiten Hauptsatzes der Thermodynamik", Sitzungsber. Preuss. Akad. Wiss., Phys. Math. Kl., 453—463.
28. ^ Air Brake Association (1921). The Principles and Design of Foundation Brake Rigging. Air brake association. p. 5.
29. ^ Valentin L. Popov (17 Jan 2014). "Generalized law of friction between elastomers and differently shaped rough bodies". Sci. Rep. 4: 3750. Bibcode:2014NatSR...4E3750P. doi:10.1038/srep03750. PMC 3894559. PMID 24435002.
30. ^ "Friction Factors – Coefficients of Friction". Archived from the original on 2019-02-01. Retrieved 2015-04-27.