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The Roles of Surfactant in Tribology Applications of Recent Technology: an overview

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Abstract. In managing friction, wear, and lubricant qualities such as emulsification, demulsification, bio resistance, oxidation resistance, rust prevention, and corrosion resistance, surfactants play a crucial role in tribology. This is an important topic for the development of new materials and gadgets, particularly those created at the Nano-scale. The tribological characteristics of cutting fluids, lubricant performance in relation to steel surfaces, bio lubricants, and novel materials and approaches to friction and wear reduction will all be covered in this most recent edition. Numerous industries place a high priority on surface science and tribology. Almost all consumer and industrial products are manufactured and used with the aid of sophisticated surface and tribological knowledge.Amphiphilic molecules are those that function as surface-active agents or surfactants. Their tails are hydrophobic while their heads are polar, or hydrophilic. They are dispersible in both water and organic solvents. This article introduces surfactants' nature and physical traits with a focus on their importance in modern science and technology. The primary property of surfactant molecules is the ability to self-assemble into micelles, which gives us a way to apply surfactants. The study of the surfactants results in a number of practical application areas, including food, health and personal care goods, biological systems, mineral and petroleum processing, and even nanotechnology. The organisms, food manufacturing, crop protection, personal care products, mineral and petroleum processing, and other practical application areas serve as examples of what these in turn give rise to a range of operational application domains.

1 Introduction

The study of friction and wear is the focus of the field of tribology. The term "tribology," which derives from the Greek term "rub," refers to the study of the wear and frictional properties of surfaces that are moving relative to one another. (Winkless, 2022).
Understanding how materials deteriorate through the analysis of resistance allows us design our components to have the lowest possible frictional coefficient. As you can anticipate, tribology is crucial to our development and research. (Williams, 2005).

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For many thousands of years, people have been aware of certain features of tribology. A primitive understanding of friction was demonstrated by rubbing sticks together to produce heat and start a fire. The use of lubrication is probably documented in ancient Egyptian artefacts, where it appears that humans were moving heavy statues with the help of oil. (Peck, 2013).

Our grasp of tribology did not advance significantly until the 15th century. One of the earliest researchers to rigorously examine friction and increase our understanding of The Renaissance man himself, Leonardo da Vinci, was there. Nowadays, tribology is an interdisciplinary study that is integrated into a number of technical and scientific fields. Friction, wear, and lubrication are three interconnected categories into which we might generally subdivide the topic. By creating wear resistance, lubrication is a strategy for lowering friction and protecting the contact area. Lubrication is a technique for preventing wear and lowering friction. Friction is defined as the resistance between flat surfaces in relative motion. (Czichos, 2009).

Surfactants offer a significant deal of promise to advance nanotechnology beyond its present constraints in addition to industrial applications. In the case of hydrophobic inorganic nanomaterials like Black phosphorus, transition metal dichalcogenides, graphene, carbon nanotubes, It has been suggested that amphiphilic surfactants act as stabilizers to produce stable dispersions. Since the discovery of the first technique for exfoliating graphene in 2004, known as micromechanical exfoliation, The method has been scaled up by researchers stabilizing exfoliated graphene with solvents. (Whitener et al, 2014). Different organic solvents have been used to stabilize nanomaterials in order to get around this restriction, including N-methyl-pyrrolidone and dimethylformamide. (Mirdamadi et al, 2022).

Surfactants are organic compounds composed of two chemical components with distinct polarities: a tail group with nonpolar phase attraction and a head group with polar phase affinity. Due to their unique structural properties, surfactants are frequently used to reduce surface and interfacial tension between phases. Due to their tendency to construct self-assembled structures in solution, they can also form micelles with diameters ranging from nanometers to microns. Pharmaceutical formulations, corrosion inhibitors for steel and other pour-point metals, corrosive metals wetting agents, de-emulsifiers, oil recovery enhancers, detergents, depressants, and drug delivery systems all benefit from the amphiphilic nature of surfactants.

Surfactant is an additional crucial component in the production of tightly controlled nanoparticles. Because of their ease of use, practical applicability, affordable manufacturing, excellent stability, and high selectivity, colorimetric sensors are in high demand for a wide range of interdisciplinary applications. The use of surfactants in the synthesis of metallic nanoparticles has made colorimetric sensors possible. Surfactants applied during the manufacturing of nanoparticles are essential for increasing the sensitivity and selectivity of the sensor because they directly alter the characteristics of the nanoparticle. In addition, a novel class of magnetic surfactants has been developed that can be used in drug delivery systems. We provide a concise overview of the fundamentals of surfactants and their applications to the growth of nanotechnology in this review. (Zakharova, 2019).

2 Literature Review

While it seems unlikely that humanity will run out of energy anytime soon, energy shortages in the form we are accustomed to are an urgent threat that needs to be addressed. We have introduced several methods to combat Most of these are aimed at reducing energy wastage caused by mechanical thermal cycling and poorly insulated heating systems [6]. Direct and indirect energy losses and material savings due to wear and friction have received less

attention. Until at least 1967, a US government-sponsored report suggested that a "tribological energy conservation strategy" could save him $16.25 billion in PA [7]
Tribology has contributed to energy conservation using the UK as a case study. The approach to achieving this goal was to first identify areas of tribology related to energy savings and then to identify the main areas of energy loss due to tribological effect. Then, with the assistance of national and international business, scientific and other experts, and published data, we determine the magnitude to which tribological principles and applications may lead to enlightenment. [7]

2.1 Development of Tribology in the Field of Materials and Energy Savings

Relative motion on surfaces interacting primarily by friction and wear is multidisciplinary, including engineering, physics, chemistry, metallurgy, etc., resulting in significant economic losses. (Suparyanto, 2020), a significant portion of those losses could have been prevented. Based on the application of primarily known, the Report estimated principles of tribological science and technology can save this land in the region by Reduced energy consumption due to reduced friction, reduced manpower due to improved lubrication, reduced lubricant costs, reduced maintenance and replacement costs, reduced consequential damage due to breakdowns Savings in capital expenditure due to higher Investment savings due to increased availability and machine efficiency and extended machine life [4].

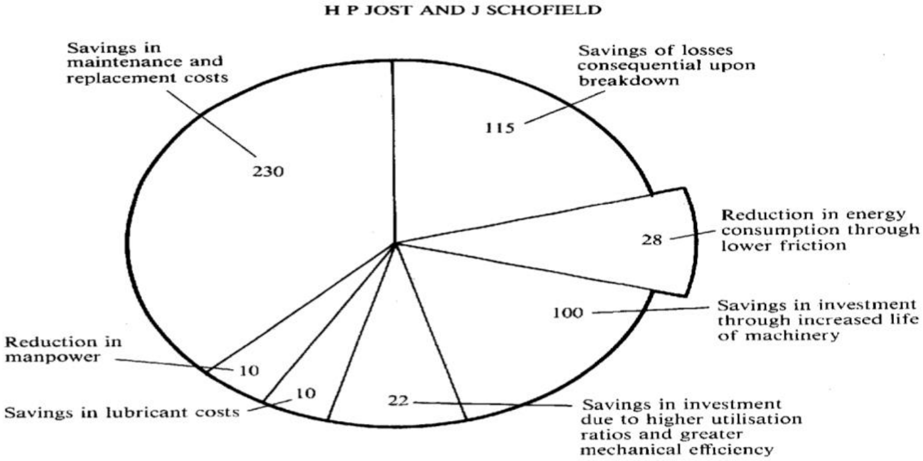

Fig 1.Jost Report [4]

2.1.1 The energy factor

When it comes to reducing friction and reducing energy consumption, the Jost report estimates that around 40 billion kW/h of electrical energy is maximized to power machinery in England each year. proof from experts shows that about one third of that was wasted on useless friction. Assuming industry rates of Id per kWh, this loss amounts to around S$6 million per year. Due to tribology, S14M is presumed to be able to avoid this. Furthermore, it is estimated that the same amount can be saved by reducing the friction of the gas-powered motors and the bodies they move and based on these counts alone (in 1965 values) M8M could be saved per year. increase. At that time, coal was $59/ton, kerosene was $7.4/ton, and electricity was $0.616/kWh. presently (1980) these costs are 7.00 S/t for coal, 76.1 S/t for fossil oil and 2.28 p/kWh for electricity[9]. The 1980 tribology reserve funds estimate was therefore on the order of £175 million per year. As the years have shown, these savings were achieved without significant investments or R&D expenditures.

Primarily because fuel costs were very low at the time, studies before the publication of the 1966 DES report found neither energy input to produce spare parts nor energy input to produce materials for such spare parts. was not considered.

It was therefore considered prudent to reconsider the energy savings derived from tribology, particularly those addressed elsewhere in his 1966 report.(Ludema *et al*., 2007)

2.1.2 The sociological significance of energy efficiency in tribology

One of the earliest applications of tribological solutions to energy efficiency problems was in ancient Egypt.. (Circa 1880 BC). As shown in Figure 2.1, the main challenge is to move huge masses over a given distance while using a given amount of energy[11]. Lubricants have reduced the effective friction in moving mass, significantly increasing the overall process's efficiency basic lubricant addition was primitive in terms of technological progress, but the solution was highly effective, convenient, and uncomplicated.

As early as 1977, the American Society of Mechanical Engineers (ASME) published a successful plan to encourage energy savings, particularly through tribology. This research had three objectives Designed to assess the potential impact of tribological innovations on Promote energy conservation and advanced energy technologies and identify areas where the application of existing or new tribological knowledge is likely to yield significant direct or indirect benefits., Promote viable research and development programs in tribological sciences. by government bodies and industry The key areas of rolling element and fluid film bearings, continuously variable power transmission, sealing technology, friction and wear reduction, automotive engines, metalworking and advanced energy technology are all addressed by this strategy.. [11]. Table 1 provides a nitty gritty outline of the likely investment funds for every one of these elements. The profit margin for improvement in each of these areas was also defined in the study as follows:

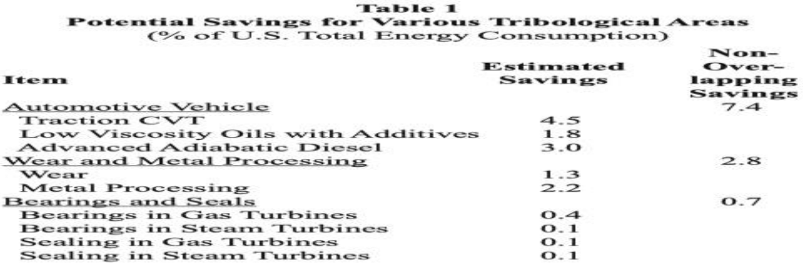

Table 1
Potential Savings for Various Tribological Areas
(% of U.S. Total Energy Consumption)

Item	Estimated Savings	Non-Over-lapping Savings
Automotive Vehicle		7.4
Traction CVT	4.5	
Low Viscosity Oils with Additives	1.8	
Advanced Adiabatic Diesel	3.0	
Wear and Metal Processing		2.8
Wear	1.3	
Metal Processing	2.2	
Bearings and Seals		0.7
Bearings in Gas Turbines	0.4	
Bearings in Steam Turbines	0.1	
Sealing in Gas Turbines	0.1	
Sealing in Steam Turbines	0.1	

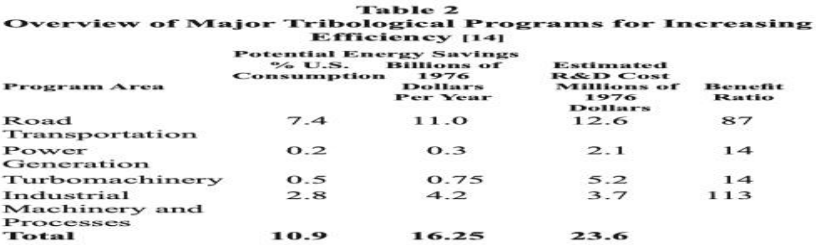

Table 2
Overview of Major Tribological Programs for Increasing Efficiency [14]

Program Area	Potential Energy Savings % U.S. Consumption	Potential Energy Savings Billions of 1976 Dollars Per Year	Estimated R&D Cost Millions of 1976 Dollars	Benefit Ratio
Road Transportation	7.4	11.0	12.6	87
Power Generation	0.2	0.3	2.1	14
Turbomachinery	0.5	0.75	5.2	14
Industrial Machinery and Processes	2.8	4.2	3.7	113
Total	**10.9**	**16.25**	**23.6**	

Table 2 provides a summary of potential energy savings and profit margins for various program areas. Industrial machines and processes as well as road transport have relatively large The benefit of increasing energy efficiency. This approach has been developed over a period of time, of more than 25 years prior to him, it was at the time the most relevant and profitable area of tribology for increasing efficiency. Since then, a lot of research has been done on materials for industrial machines and processes. Additionally, to enhance vehicle efficiency, many automobiles now feature continuously variable transmissions. So, the question remains. What next for tribology?

Spikes as of late talked about future difficulties for the tribology local area with respect to energy-proficient advances. The creation of low-friction components is one area. For energy-saving technologies, tributary issues in traction drives and high-temperature motors are particularly significant. Additionally, improved rolling bearing components are required.

Full life cycle simulation of engines, transmissions and other lubrication systems is required to realistically optimize the energy efficiency of complex systems. These excellent proposals are largely consistent with those of ASME and contain extremely specific tribological solutions for increasing energy efficiency. The transportation sector, power generation, materials-related research, incorporating life cycle analysis, and increasing recycling are some of the more popular areas. where tribology can improve future energy efficiency.

2.1.3 Materials

Both wear and friction are significantly impacted by the materials used in tribological components. In present years, there has been a greater intent to finding new and more efficient material solutions. This is because improved toughness, strength, and hardness have an impact on durability and lightness, both of which increase vehicle efficiency. At the same time, several new solid lubricants and coatings have been developed to significantly reduce wear and friction in both lubricated and dry contacts. For dry and lubricated contacts, low-dimensional materials such as buckyballs, nanotubes, nanosheets, and nano-onions made from carbon- and boron-based solids and various transition-metal dichalcogenides have been shown to reduce sliding surface friction and wear. is particularly effective for. In addition to this, tremendous progress has been made in the disciplines of surface engineering and treatment, for demanding tribological applications involving abrasive, erosive, or adhesive wear, resulting in extremely thick, hard, and slippery surfaces. Overall, there are currently several cutting-edge material technologies that can improve tribological components' friction and wear characteristics. The following is a list of some of these developments:

2.1.3.1 New components

By replacing typical cast iron surfaces with rubber-coated ones, such as those used on pumps and pipelines, the erosive wear can be lessened. As opposed to ceramics, which are tribologically advantageous to employ in both oil- and water-lubricated contacts, switching from metallic to polymeric components typically reduces friction (Statchiowak, 2006.). High-entropy alloys have recently been the subject of increased investigation, largely because these materials display exceptional physical and mechanical characteristics [13] in addition to outstanding resistance to corrosion and wear. In addition, a brand-new class of non-ferrous materials known as covetous has recently been developed. These materials promise to provide significantly improved mechanical and, as a result, The tribological properties of light Al alloys may make them suitable for sliding powertrain applications [14]. These materials include non-ferrous metals like aluminum and contain up to 6 weight percent of carbon. Although not new, it has been demonstrated that a family of novel nickel-titanium alloys, such as Nitinol 60, combine high hardness with super elasticity, permitting extraordinary load-bearing limit and other desired tribological properties [4]. Boundary lubrication conditions with castor oil, it was demonstrated that these alloys produced friction coefficients below 0.01 [15].

2.1.3.2 Material treatment and surface modification.

Surface hardness, persistence and wear defiance can be improved in various ways. Case carburizing, nitriding, and boronizing are classic processes that have long been used to reduce friction and wear in abrasive, sticky, and aggressive environments. It has been demonstrated that more advanced processes like friction-stir processing and shot-peening [16], can structurally alter top surfaces at the micro- and nanoscales, significantly improving their friction and wear characteristics both in dry and lubricated circumstances [17]. Over the past ten years, there has been a significant increase in interest in additive manufacturing for the purpose of producing three-dimensional structures, initially from polymers but more recently from metal or ceramic powders for a variety of uses. (Ian & Pulak, 2017). In addition to creating 3D structures that can contain super-hard or self-lubricating materials for improved wear and friction in a variety of applications, additive manufacturing tools have become extremely adaptable. [19]. Using a variety of processes, such as laser surfacing and particle plasma ablation, hard and low-friction materials can be incorporated into the top surfaces to significantly improve their hardness, stiffness, and wear performance. Cold-spray techniques for reducing wear and friction have also garnered more attention in recent years. They might diminish the warm contortions and remaining pressure develop that are often connected with laser cladding and different strategies that are utilized for expanded wear opposition. For magnesium and aluminum alloys with low melting points, they are especially appealing. [20]. Conventional heat diffusion techniques still play an important role in improving the mechanical, tribological, and corrosion resistance properties of iron-based alloys.. These techniques include nitriding, carburizing, vandalizing, and boriding or boronizing. This method penetrates the area near the surface of the workpiece by nitrogen, carbon, or boron, which diffuses in and reacts with the metallic components, such as Fe, to produce thick, hard reaction layers. In comparison to quenching, these thermal diffusion techniques may offer significantly greater wear resistance to corrosive, adhesive, abrasive, and erosive wear. Sadly, the warm dispersion processes talked about are all very languid. To reach the desired thicknesses or case depths, it could take many hours to an entire day. They consume a lot of energy, harm the environment by producing a lot of CO2s, and are therefore expensive. A recent development in ultra-fast boriding allowed for the creation of 50 m thick boride layers in about 15 minutes as opposed to the 6–8 hours required by the traditional pack-boriding approach. Under both dry and lubricated conditions. Such thick and durable boride layers have been shown to impart little wear to sliding surfaces. [21].

2.1.3.3 Thin surface coatings.

Adding a thin coating of another material, usually a few microns thick, to the top surface can significantly reduce friction and wear.. Techniques for physical and chemical vapor deposition are frequently used to do in vacuum chambers (PVD and CVD). Ceramic coatings made of TiN, CrN, WC/Co, AlTiN, NiSiC, etc. are effective in reducing tool and machine component wear. Amorphous and lattice materials such as diamond-like carbon (DLC) and molybdenum disulfide (MoS2) have been found to be very effective in reducing friction to coefficients of friction below 0.01.. By treating nanostructures and Nano-layered coatings, thin coatings can be further enhanced [22]. As a revolutionary idea, scientists also created catalytic activity. A smart nanocomposite layer on the friction surface that can decompose base oil long-chain hydrocarbon molecules into diamond-like carbon tribofilms and other types of carbon nanostructures. It was discovered that the resulting tribofilms were extremely slippery, highly wear-resistant, and capable of self-healing through a catalytic reaction with the lubricant when worn away.

2.1.3.4 Thick composite surface coatings.

Among the methods used to lessen wear under heavily loaded situations are thermal spraying, welded overlays, cladding, and electroplating. Typically, the coating's thickness falls between 0.1 and 50 millimeters. The new material, which frequently has a composite structure, improves the surface. In general, a coating's density and cohesive strength boost its wear resistance. Composite materials with carbide particles embedded in a metallic matrix that is frequently more elastic and tough provide excellent wear protection.

2.2 Component design

Friction and wear are significantly influenced by the mechanical systems and the components design. Because tribology is still relatively young and developing branch of technology, mechanical systems frequently have poorly considered friction and wear as design requirements. It's possible to reduce the stresses in loaded contact, Improved lubricant access, slower contact speeds, and fewer contacts are all possible, lubrication techniques can be optimized, and serious wear mechanisms can be taken into recognition with good tribology design, for example. Only a few instances of tribological approaches to better components designs are provided below:

- **Surface texturing:** Friction and wear are significantly influenced by surface topography and roughness. Well-crafted micro- or nanoscale pits, grooves, and protrusions can be very helpful. The microscale controlled lubricant flow has an enhanced loaded capacity and decreased friction. Laser surface texturing of piston rings reduced engine fuel consumption by 4%, and friction has been reduced by up to 50% because of tiny dimples made by fine particles fired into the piston rings. -[23]
- **Micro-sensors and actuators**. The lubricant qualities deteriorate over time and because of operational factors in road transportation engines, which operate in transient settings with large fluctuations in load and speed conditions across a wide working range. Because of this, the engine is frequently overbuilt to handle the worst case. As a compensating mechanism for mechanical wear protection, Advanced microsensors and actuators allow the bearing system to be tuned to maximize design capabilities throughout the engine's operating range. The innovative design may allow a journal bearing's bearing area to be changed to the location that is most severely loaded. This permits the friction loss and bearing load capacity to be adjusted.[7]

2.3 New methodologies

Designing tribological components for the best friction and wear performance is a very challenging task if all relevant contributing factors and interactions across scales from nano-level to macro-level are accurately considered. Some of the key parameters are considered in traditional design, but modern approaches allow for a more thorough and accurate optimization that takes a wider variety of interactions and consequences into account. The following three significant new approaches are developing quickly:

- **Integrated computational material engineering (ICME)**.
  based on sophisticated computer codes, finite element and other state-of-the-art modeling techniques, provide innovative tools for creating tribological interactions in Multiscale integrated materials modeling and simulation. Performance and durability can be optimized by modeling the interplay of material behavior, coatings, composite structures, and lubrication mechanisms to relevant scales. The tribologically significant yet difficult aspects—have been merged for the modeling of tribological performance [24]
- **Nanotechnology**.
  Traditionally, tribological components have been created using a more defined understanding of the interactions in tribology. Its molecular, atomic, and even subatomic size equipment for characterization of materials, computational modeling, and even empirical testing make it possible to investigate the underlying physical and chemical interaction mechanisms. Utilizing this information will allow for stricter and more precise tribological design. Graphene and additional 2D substances, such as h-BN, MoS2, and others, were the subject of several of these investigations. In recent years, a sizable body of information has grown out of this research. It appears that these materials may present an excellent potential for all types of tribological applications if the issues of cost, dependability and environmental health, and safety have been taken into consideration(Gmbh, 2022.)
- **Biomimetic**.
  Nature has found numerous brilliant techniques to regulate friction and wear that go well beyond what is possible with current technology. The usage of composite multiscale structures and hierarchical multiscale organization gives biological systems the adaptability they need to change with their surroundings. The biological materials are produced using their genetic code's instructions and recursive algorithms rather than employing final design criteria. Innovative technical solutions may be sparked by the extraordinary qualities of biological materials.

2.4 Addictive manufacturing

Addictive manufacturing uses a particular number of metals, they can be classified below:

- Nickel-based alloy
- Aluminium alloy
- Stainless steel
- Cobalt-chromium alloy
- Titanium alloy

Despite the variability showed by some of the different processes in addictive manufacturing, the results arising from this process and their by-products, each of these different elemental metal groups shows different behaviour during AM-based operations. Tend to. In addition to detailed descriptions of the surface optimization and tribology literature for all metals listed in the following sections, recent challenges and directions for each metal related to surface optimization and tribology are also discussed. Increase. [26]

Stainless steel

Stainless steel is one of the most commonly used materials in addictive manufacturing., stainless steel is trusted because of its effectiveness and exceeding mechanical properties.[27]. More importantly, many industries, from defense to chemical, use this material to make manufactured products more resistant to oxidation and corrosion.. Common techniques like selective laser melting using stainless steel can create complex and structured designs not possible with traditional manufacturing methods.

Before starting this section, it is necessary to mention the lack of literature on the mechanical, tribological and surface roughness properties of addictive production steels.. This describes various research that explore the joining of these aspects and creates connections between aspects that are lacking in the research work. A novel by [28]for steel-based AM. He stated that the main processing parameters in this study consisted of laser power, flow rate, powder mass, layer thickness, scan speed, beam diameter, beam pattern, and build direction [28] Various studies are listed, including electron beam melting, laser melting scanning, direct metal laser sintering, laser mesh forming, and direct metal deposition. and can be investigated further, randomly examining all combinations of these parameters. Using the previous section, the most important insight derived from these results is that the fluctuations in temperature induced by the laser beam significantly affects the material properties. It means that it can change. An equally interesting point to consider is the operation of the standoff distance for laser-melted steel. Given plate-to-plate spacing of 5, 10, and 20 mm, the authors found that the spacing is inversely proportional to the surface roughness parameter. Another consideration when optimizing AM steel performance is understanding surface roughness. This indicates how well the particles are fused together.For martensitic steel 1.2709, [29] found a correlation between roughness and hardness of the base surface at different orientations of his DMLS printed cubic parts with corners.

Aluminum alloys

Similar to stainless steel, there are various publications describing the tribological effects of addictive manufactured aluminum alloys. Selective laser melting and direct metal laser sintering are the main processes using this material, [30]. We have arrived at these conclusions through extensive analysis of various literature sources when comparing different material properties of these alloys in fabrication. When using aluminum alloys, their high strength properties and corrosion resistance have proven very useful in industries such as aerospace. This is because lighter materials tend to be preferred over other heavier metals. In addition to modifying mechanical properties, AM technology can also improve other properties such as material microstructure. This allows for high levels of structural integrity and anisotropic mechanical performance. [31] . The effect of partial remelting reduces the porosity of the samples studied and improves grain bonding, resulting in a denser, denser and smoother surface. These improvements were verified by evaluating the elongation properties of the improved substrates. Quantity of Raw Material for Aluminum is limited due to lack of reliable powder. The main difference between conventional additive manufacturing and additive manufacturing is that factors such as powder weldability and solidification speed are very different, which leads to unwanted voids throughout the manufacturing process. write out. Factors such as melt pool evaporation and heat transfer, and chemical reactions leading to film formation, therefore play a direct role in surface finish and material properties. Since aluminum is a fusible material, many surface defects such as voids can occur due to suboptimal melting conditions. An example of this is described in the publication of Kempen et al.], where AlSi10Mg was treated with his S.L.M. We found that many parameters need to be met during testing to optimize the alloy's performance. These parameters include uninterrupted scan path, penetration of the laser into the front layer, suitable height and 90° connection angle. In any case, over the past decade, continuous progress has been made to improve the processing of this metal, thus eliminating some of the shortcomings.

Cobalt Chrome Alloys

Unlike the other metals on this list, cobalt-chromium alloys are generally believed to have structural orientation problems due to their different mechanical anisotropies.. As a result, the metal's performance in various applications is affected[29] He is one of many pointed out in a study on the effects of build-up tendencies on material-based dental alloys. One of the most important is that different construction directions have different cooling rates, which affects the anisotropic mechanical properties. In the literature, most additively fabricated cobalt-chromium alloys tend to focus on dental applications. This is due to excellent corrosion resistance as well as excellent mechanical properties in partial denture applications. There seems to be a trend towards selective laser melting technology in some publications. This trend has the potential to improve various properties of these metals, which could greatly benefit dental and many other applications.An instance of this is defined within the e-book of [32]]. In their study, the mechanical performance of Co-Cr alloys produced by selective laser melting was investigated and compared with cast alloys commonly used in dental applications. The authors found that selectively laser-melted alloys exhibit much better mechanical strength in terms of yield strength and tensile strength. An explanation for these results may lie in the dense and compact surface of the selective laser melting process. In general, with metal-ceramics, the adhesion of the porcelain determines the performance of the base material. This is because the metal helps withstand repeated chewing forces over time. To date, no studies have focused on process optimization of cobalt-based AM materials, specifically addressing the relationship between surface roughness and mechanical and frictional properties.. Further form of research related to this topic is found in the work of [33] research on surface finishing techniques by electromechanical polishing.

2.5 Low friction CrN/TiN multilayer coatings prepared by a hybrid high power impulse magnetron sputtering/DC magnetron sputtering deposition technique

Thin layers of chromium and titanium nitrides (CrN and TiN) are known for their excellent properties such as high hardness and high wear resistance. Therefore, the interplay between their microstructure, morphology and resulting mechanical properties has been intensively studied. [2]Applying substrate temperatures up to 700 °C can often improve coating microstructure and morphology. The small number of proper substrate materials that must be thermally stable in the temperature range used is a drawback of using elevated temperatures during deposition. According to reports on TiN films, raising the bias causes the ions that assault the substrate and form the film to become more energetic, which results in densification and often a preference orientation. Enhancement [34]. High defect densities and high residual stresses are usually associated with the densification achieved by this approach. Applying a high ion/neutral ratio and low-energy ion bombardment to the formed films yields the best properties by thoroughly investigating the evolution of the TiN microstructure during film growth.. The physical vapour deposition technique known as unbalanced direct current magnetron sputtering is widely known for producing minimal ionization of the sputtered species. When the deposition temperature is below 0.2-0.3 of the film's melting point, this frequently results in porous, dense films with a high density of flaws [35]. High-power pulsed magnetron sputtering results in a much higher ion-to-neutral ratio of the sputtered species due to the higher energy consumption at the target. [36]. Multiple ionized sputtered species have occasionally been recorded for target materials with ionization rates > 40%. High-power pulsed magnetron sputtering with high bias voltages can implant metal species into substrate regions near the surface during etching. This improves the adhesion between coating and substrate. The advantage of high-power pulsed magnetron sputtering pretreatments over comparable cathodic arc pretreatments is the virtually zero drop rate, which results in even better adhesion. [37].

Additionally, the high-power pulsed magnetron sputtering process' high metal ion and plasma densities are helpful to the coating's shape and structure. As a result, high-power pulsed magnetron sputtering coatings' mechanical and tribological characteristics are enhanced in comparison to direct current magnetron sputtering coatings. We use the advantages of both methods through a controlled combination of high-power pulsed magnetron sputtering and direct current magnetron sputtering cathodes. B. produces deposits that have thick coating microstructures and rapid growth rates [38].

3 Contributions

In the light of this research work, the advances of tribology are heavily talked about in this paper showing its progression with time with the use of its application in engineering innovations and its use in energy conservation and materials.

It reviewed how with tribology, less friction is incurred by better lubrication in machine parts which in turn leads to less energy consumption and gives added advantages economically by saving costs in frequent maintenance, saving in parts replacements, and lubricant costs. It also leads to reduced manpower and aids its mechanical efficiency.

With the advances in tribology towards energy consumption, this paper expatiated how one-third of the energy being wasted can be redirected and be used efficiently by the rate of friction reduction. Also, with tribological advances, the paper reviewed how energy consumption can be reduced in moving parts such as engines, equipment, and metalworks through the application of fluid film bearings. This also helps in the reduction of the heat being produced by machine parts gnashing against one another, where tribological advances steps in cases such as internal combustion energy reduce the emission of harmful gases from the exhaust systems of the various machines

This paper also reviewed how in areas such as materials, tribological advancements have been made to reduce erosive wear in areas like pipes and how typical cast iron surfaces are being replaced with rubber-coated ones, also unwrapping the understanding that applying a degree of special coating surfaces such as tools and machine parts reduces the rate of wear that occurs on them.

Advances in tribology towards technological advancements even to the nanoscale (nanotechnology) for reducing friction in powder and colloidal form. It is also used in nanofluids such as additives in metals and contributes to their mechanical properties.

Conclusions

A global assessment of the impact of wear and friction on energy consumption, economic performance and CO2 emissions is provided. This impact study covers four major energy consuming industries: transportation, manufacturing, power generation and housing. Four previously published research studies on the automotive, trucking and bus, paper manufacturing, and mining industries served as the basis for extensive computations and benchmark data that went into these findings.

The ability of manufacturing processes (AM) technologies to create complex geometric shapes without the use of post-processing techniques has led to an increase in their popularity since their inception. AM is a method that may be applied in heat transfer analyses to boost heat exchangers' heat transfer coefficients and conserve a considerable amount of energy that would otherwise be lost to entropy and allergy generation. The link between the mechanical, frictional, and heat exchange characteristics of metal-based AM heat exchangers as well as its surface roughness is highlighted in this article. This study emphasizes the relevant literature on the impact of surface quality optimization on mechanical characteristics, surface roughness, and exchanger performance. It is a cutting-edge heat exchanger that affects energy savings by optimizing surface roughness during construction. This review aims to summarize the current body of information on each issue independently and link these procedures because there isn't much literature on such three topics.

Therefore, it can be argued that the lack of research is the present issue in this field of study. Although there are few research on the mechanics and friction of these properties, the number of articles concentrating on the enhancement of surface properties relevant to these qualities for energy-saving uses of devices that transfer heat should be examined. One reason for this could be the uniqueness of AM processes on a large industrial scale. Especially for heat-exchange equipment. This can be explained by the expensive cost of materials, low volume of production, and high cost of machining from AM. These micro- and macro-scale gaps can, however, be quickly filled as AM usage increases. Based on this evaluation, the authors advise future investigation in this field using a variety of metals to fully understand how surface roughness during construction affects weathering processes and heat exchanger energy savings without the requirement for post-treatments.

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