American Journal of Advanced Multidisciplinary Innovation and Research (AJAMIR)

E-ISSN: XXXX-XXXX ● Website: www.ajamir.com ● Email: editor@ajamir.com

Surface Texturing Strategies for Energy-Efficient Tribological Contacts

Prof. Dr. Anne M. Kadiric

Professor, Imperial College London, United Kingdom

Abstract

Frictional losses in sliding and rolling interfaces contribute directly to energy consumption, heat generation, lubricant degradation, and component wear. Surface texturing provides a passive method of modifying these interactions by introducing deliberately engineered micro- or nanoscale features such as dimples, grooves, pockets, and directional patterns onto one of the contacting surfaces. This study develops a simulation-based framework for evaluating surface-texturing strategies for energy-efficient tribological contacts without representing hypothetical friction or wear data as experimentally measured results. Five surface conditions are examined: an untextured reference, linear microgrooves, circular microdimples, optimized partial microdimpling, and a multiscale hybrid texture. A Tribological Energy-Efficiency Index is constructed from friction reduction, wear control, hydrodynamic-film support, lubricant retention and debris management, and manufacturing robustness.

The simulated index increases from 55.3 for the untextured reference to 68.2 for grooves, 80.9 for full-field circular dimples, 85.8 for optimized partial dimpling, and 85.1 for a multiscale hybrid surface. A complementary sliding-speed simulation indicates that optimized microdimples can reduce the modeled coefficient of friction relative to an untextured interface across mixed and increasingly hydrodynamic lubrication conditions, with the largest simulated reduction occurring within an intermediate-to-high-speed operating region. The analysis demonstrates that more texture is not necessarily better.

The study concludes that energy-efficient tribological design requires operating-condition-specific texture optimization rather than universal adoption of one dimple geometry. Surface texturing is most defensible when frictional-energy savings are evaluated together with wear, film stability, manufacturability, durability, and lifecycle cost.

Keywords: surface texturing, tribology, friction reduction, energy efficiency, laser surface texturing, microdimples, lubrication, wear.

1. Introduction

Friction is an unavoidable consequence of relative motion between contacting engineering surfaces, but its magnitude can be altered substantially through material selection, lubrication, surface finishing, coatings, contact geometry, and operating conditions. Energy dissipated through friction is converted primarily into heat, while repeated surface interaction can also generate wear particles, local deformation, fatigue damage, and lubricant degradation. In machine elements such as bearings, piston–

liner assemblies, seals, gears, thrust interfaces, compressors, pumps, and reciprocating mechanisms, even modest reductions in friction can become significant when multiplied across long operating periods or large equipment populations. Surface engineering is therefore increasingly used not merely to prevent failure but to control the energetic efficiency of the contact itself.

Conventional finishing frequently attempts to produce surfaces that are geometrically smooth and statistically uniform. Surface texturing adopts a different strategy by intentionally introducing controlled topographical features into the contact. These features may include circular or elliptical dimples, straight or crossed grooves, chevrons, pockets, channels, or multiscale patterns. Etsion's influential review of laser surface texturing described microdimples as capable of acting as local hydrodynamic bearings under lubricated conditions, lubricant reservoirs under starved conditions, and traps for wear debris during sliding. The beneficial mechanism therefore depends on the tribological regime rather than on texture existence alone.

Experimental work has established that properly designed textures can alter transitions among boundary, mixed, and hydrodynamic lubrication. Kovalchenko and colleagues showed that laser microdimpling expanded the operating range over which hydrodynamic lubrication could be sustained in an oil-lubricated sliding contact, with the benefit depending on sliding speed, load, and lubricant viscosity. In piston-ring research, Ryk and Etsion reported approximately 25% lower friction for optimized partial laser texturing than for the conventional comparison ring used in their reciprocating experiment. These studies established that texture geometry can influence both local pressure development and the global frictional response of realistic machine contacts.

Nevertheless, surface texturing does not guarantee lower friction or wear. Costa and Hutchings demonstrated that circular depressions, grooves, and chevrons can produce substantially different hydrodynamic-film responses and that inappropriate feature dimensions can reduce film thickness relative to an untextured surface. Gachot and colleagues consequently characterized the literature as highly dependent on lubrication regime, contact conformity, texture geometry, and manufacturing method, noting that conflicting results remain possible when patterns are transferred between fundamentally different tribological conditions. This evidence makes simple rules such as “higher dimple density produces lower friction” technically unreliable.

The present study therefore approaches surface texturing as an energy-efficiency optimization problem rather than a generic surface treatment. A simulation-based methodology compares several representative texture strategies while integrating friction, wear, lubricant-film support, lubricant retention, debris management, and manufacturing practicality. No tribometer data are presented as newly measured experimental evidence. The objective is instead to formulate a transparent decision framework that can guide subsequent laboratory testing of application-specific surfaces.

2. Objectives of the Study

2.1 Evaluation of Texture Strategies for Frictional Energy Reduction

The first objective is to compare alternative surface-texture architectures according to their capacity to reduce frictional energy losses under lubricated sliding. An untextured surface is used as the baseline, while linear grooves, circular dimples, optimized partial dimpling, and multiscale hybrid textures represent progressively more engineered conditions.

Friction reduction is considered in direct energetic terms. For an idealized sliding contact subjected to normal load (W), coefficient of friction (\mu), and velocity (v), the instantaneous frictional power loss Accordingly, when normal load and sliding speed remain constant, a proportional decrease in the coefficient of friction produces a comparable proportional reduction in frictional power dissipation.

2.2 Assessment of Wear, Lubricant Retention, and Film Support

The second objective is to evaluate whether reduced friction is accompanied by acceptable wear behavior and lubricant-film stability. Surface pockets can store lubricant and capture loose particles, while hydrodynamic pressure generated around texture features can contribute to load support. Etsion identified these functions as important mechanisms underlying laser-texture performance.

However, the same pockets also remove nominal load-bearing area and can introduce local stress concentration. The study therefore evaluates friction reduction and wear control separately. A texture is not classified as energy efficient when it lowers friction temporarily but accelerates surface damage, increases leakage, or causes unstable lubrication.

2.3 Identification of Operating-Condition-Specific Design Principles

The third objective is to determine how texture geometry should be related to sliding direction, feature dimensions, lubrication regime, and contact scale. Surface-texture research has repeatedly demonstrated that feature depth, width, orientation, area density, and relation to contact width influence performance. Costa and Hutchings, for example, observed an optimum area coverage for circular pockets and strong directional dependence for chevron textures under their reciprocating hydrodynamic conditions.

The intended outcome is therefore a design methodology rather than a universal geometry recommendation. The study seeks to identify why optimized partial textures can offer a stronger engineering compromise than indiscriminate full-surface texturing and why multi-scale architectures require careful validation despite their broader theoretical functionality.

3. Review of Literature

3.1 Hydrodynamic and Lubricant-Retention Mechanisms

One of the most extensively studied functions of surface textures is their ability to modify lubricant pressure distribution. A recessed feature passing through a converging or dynamically loaded contact can alter local flow, pressure, cavitation, and film thickness. Etsion's review established the conceptual basis for treating microdimples as microscopic hydrodynamic elements capable of supporting lubricant films while also storing oil under starved conditions. Kovalchenko and colleagues later demonstrated experimentally that laser texturing altered the transition between lubrication regimes over a wide range of sliding velocities and pressures.

These mechanisms are particularly relevant near the mixed-lubrication region, where contact load is shared between the lubricant film and surface asperities. Increasing the effective film-supporting capability of the interface can reduce the proportion of load carried through direct solid contact. The resulting decrease in asperity interaction can reduce both friction and wear. However, when the texture is too large relative to the contact, lubricant pressure can collapse within the cavity rather than generate useful hydrodynamic support.

Costa and Hutchings provide an important experimental demonstration of this sensitivity. Their reciprocating steel-contact study compared circular pockets, grooves, and chevrons and showed that the film response depended on feature area coverage, depth-to-width ratio, orientation, and size relative to the elastic contact width. Chevron orientation influenced film thickness significantly, while grooves were less effective than the best chevron configuration in the investigated conditions. The result establishes that texture topology and direction should be incorporated explicitly into design.

3.2 Friction and Wear Reduction Across Lubrication Regimes

The effect of texturing is not limited to full-film lubrication. In boundary and mixed regimes, texture pockets can store oil locally, capture wear particles, and modify real contact area. Gachot and colleagues' critical review emphasizes that different mechanisms dominate across the Stribeck curve and that performance must be interpreted differently for conformal and non-conformal contacts. The same dimple distribution that works well in a hydrodynamic seal can therefore perform poorly in a highly concentrated Hertzian contact.

Vlădescu and colleagues investigated reciprocating textured contacts intended to represent aspects of piston ring–liner behavior. Under their highly loaded test conditions, selected pocket configurations produced major reductions in both friction and wear relative to the nontextured surface, although the effectiveness depended on the total pocket volume and the relationship between pocket size and contact dimensions. Their results are especially useful because they demonstrate that friction and wear can improve simultaneously through related but nonidentical mechanisms.

Ryk and Etsion's piston-ring experiments provide a more application-oriented example. Their optimized partial laser-textured rings produced lower friction than a conventional barrel-faced comparison ring. Partial texturing is important because it preserves untextured load-bearing regions while placing texture where hydrodynamic or lubricant-reservoir effects are most useful. This introduces an engineering principle that becomes central to the present study: the objective is not maximum textured area but maximum beneficial interaction between texture and the contact's pressure and motion field.

3.3 Geometry Optimization and Multiscale Texture Design

Modern surface-texture research has expanded from uniform circular dimples toward directional, hierarchical, and multiscale topographies. Rosenkranz and colleagues' review of machine elements emphasizes that texture effectiveness varies among piston rings, seals, rolling bearings, and gears, and that design guidelines must reflect whether the contact is sliding, rolling, conformal, or highly concentrated. The authors also highlight the risk of transferring favorable laboratory results directly into machine elements without considering realistic contact mechanics.

Grützmacher, Profito, and Rosenkranz describe multiscale texturing as a promising direction because topographical features of different scales may address different lubrication or contact mechanisms simultaneously. Larger pockets may participate in lubricant storage and pressure development, while smaller features can influence local contact, wetting, or debris management. The theoretical advantage is therefore broader functional coverage across changing operating regimes.

The difficulty is optimization complexity. A multiscale surface adds additional variables involving feature size, hierarchy, density, arrangement, orientation, and interaction between scales. A later review of surface-texturing techniques similarly emphasizes that dimple shape, depth, diameter, and density are among the decisive parameters governing tribological performance. Multiscale designs may consequently deliver excellent laboratory performance but can be more difficult to manufacture consistently and more sensitive to wear-induced evolution of the texture itself.

4. Research Methodology

4.1 Simulation-Based Comparative Design

The study uses a simulation-based multicriteria research design. Five hypothetical surface conditions are evaluated under the assumption of a lubricated reciprocating or unidirectional sliding contact subjected to comparable nominal load and lubricant properties. The analysis does not reproduce a particular piston ring, bearing, seal, or tribometer.

The five conditions are an untextured reference, linear microgrooves, full-field circular microdimples, optimized partial microdimples, and a multiscale hybrid texture. Linear grooves represent a comparatively simple manufactured texture. Circular dimples represent the dominant conventional microtexture architecture. Partial dimpling places texture only within strategically selected contact regions, while the multiscale architecture combines more than one characteristic feature size.

4.2 Tribological Energy-Efficiency Index

A Tribological Energy-Efficiency Index (TEEI) was developed to compare the strategies through five dimensions. Friction receives the largest weight because frictional-energy reduction is the principal objective, but wear and lubricant-film behavior are retained as independent engineering requirements.

Table 1: Criteria and weighting structure of the Tribological Energy-Efficiency Index

Criterion	Engineering interpretation	Weight
Friction-loss reduction	Capacity to reduce coefficient of friction and frictional power dissipation	0.30
Wear control	Capacity to reduce abrasive, adhesive, or fatigue-related surface damage	0.20
Hydrodynamic-film support	Capacity to improve lubricant-film formation or load support	0.20
Lubricant retention and debris management	Ability to store lubricant and capture wear particles locally	0.15
Manufacturing robustness	Ability to reproduce the required geometry economically and consistently	0.15

Because load and velocity are held equal between paired comparisons, the percentage reduction in coefficient of friction also represents the simulated proportional reduction in frictional power at each operating point. The simulation does not predict actual machine efficiency because total system losses also include pumping, churning, rolling, aerodynamic, electrical, and other mechanical losses.

5. Analysis

5.1 Comparative Performance of Surface-Texture Strategies

The simulated comparison demonstrates that texture architecture influences energy-efficiency potential substantially. The untextured reference produces a TEEI of 55.3. Its primary strength is manufacturing robustness and preservation of full nominal contact area, while its lubricant-retention and hydrodynamic-support scores remain relatively low.

Linear grooves increase the simulated index to 68.2. Grooves can transport or retain lubricant and can be manufactured efficiently, but their strong directional character makes performance sensitive to the orientation of sliding. Costa and Hutchings similarly found that orientation can strongly alter film behavior and that grooves were not the highest-performing topology among the patterns they investigated.

Table 2: Simulated performance of alternative tribological surface strategies

Surface strategy	Friction reduction	Wear control	Film support	Lubricant/debris function	Manufacturing robustness	TEEI
Untextured reference	50	55	45	40	95	55.3
Linear microgrooves	68	64	62	70	80	68.2
Full-field circular microdimples	82	78	84	86	75	80.9
Optimized partial microdimples	90	84	92	88	72	85.8
Multiscale hybrid texture	92	88	94	90	55	85.1

Note: All values are simulated methodological scores and do not represent physical measurements from a particular component.

Full-field circular dimples increase the index to 80.9, primarily because of their combined lubricant-reservoir and film-support functions. Optimized partial dimpling achieves the highest simulated TEEI at 85.8 because it retains substantial untextured load-bearing area while strategically introducing local pressure-generating and lubricant-retaining features.

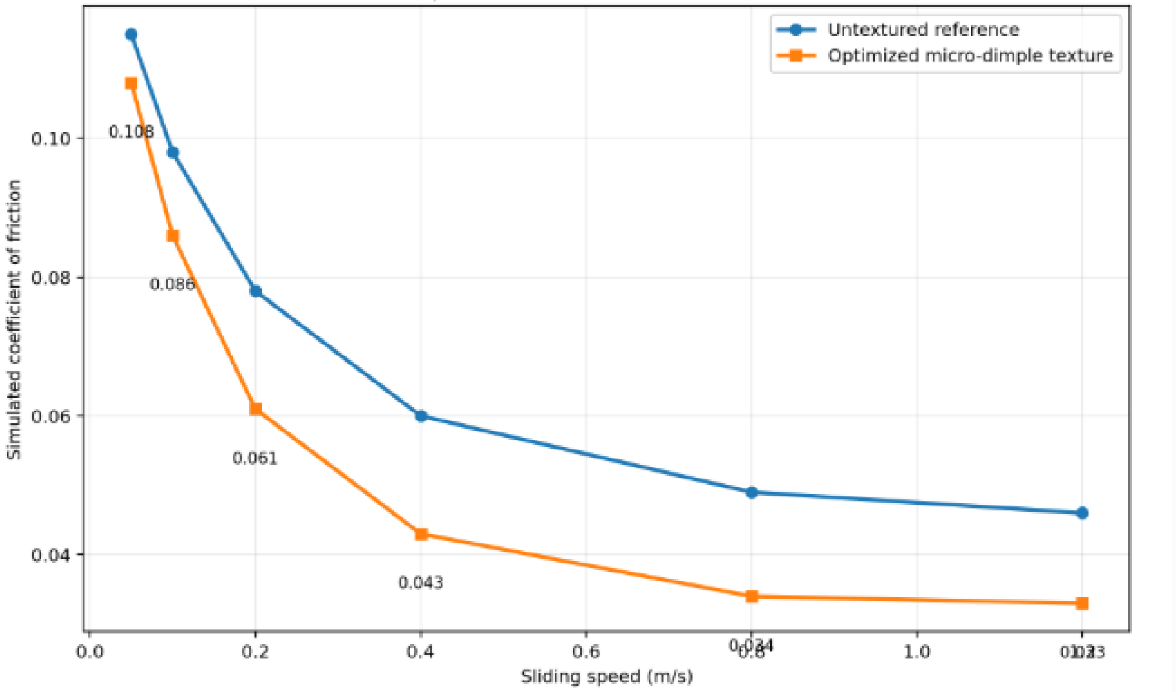
The multiscale texture obtains the strongest simulated tribological scores but ranks slightly below partial dimpling overall because its assumed manufacturing complexity reduces reproducibility and economic robustness. This distinction is important for practical energy efficiency: a surface that performs marginally better in laboratory friction tests may be less attractive when manufacturing variation, tool wear, inspection, or processing cost are included.

5.2 Sliding-Speed Dependence of Friction Reduction

The simulated friction curves show that the benefit of microdimpling is relatively modest at the lowest speed and becomes stronger as lubricant-film support improves. At 0.05 m/s, the reference coefficient of friction is modeled at 0.115 compared with 0.108 for the textured contact, corresponding to a reduction of approximately 6%.

At 0.20 m/s, the modeled friction coefficient declines from 0.078 to 0.061, an improvement of approximately 22%. The reduction reaches approximately 28% at 0.40 m/s and approximately 31% near 0.80 m/s. These values illustrate the same general regime dependence observed experimentally by Kovalchenko and colleagues, who reported stronger texture benefits under conditions supporting a more developed lubricant film.

Graph 1: Simulated Friction Response of Textured and Untextured Lubricated Contacts



The graph does not imply that friction reduction must continue indefinitely as velocity increases. At very high speed, fluid shear, temperature rise, lubricant starvation, or geometry-specific flow may alter the relationship. Likewise, under very low-speed boundary conditions, texture pockets may be beneficial primarily through lubricant storage and debris trapping rather than hydrodynamic pressure.

5.3 Texture Density, Geometry, and Energy-Efficiency Trade-Offs

The simulation supports an optimum-texture principle rather than a maximum-density principle. Each cavity removes part of the nominal load-bearing surface. At low-to-moderate density, the benefits of lubricant storage and pressure generation may dominate. As density becomes excessive, however, the remaining plateau area can become too small, contact stress can rise, and hydrodynamic interaction among adjacent cavities can become unfavorable.

Experimental literature provides several examples of such optima. Costa and Hutchings reported an optimum area fraction for circular pockets under their specific reciprocating hydrodynamic experiment, while Wang and colleagues identified a particular combination of dimple dimensions and area ratio that improved load capacity in silicon-carbide water lubrication. These values should not be transferred directly across materials, but they confirm that geometric optimization is necessary.

The benefit of partial texture follows from this trade-off. Ryk and Etsion's piston-ring work demonstrated that strategically textured regions can reduce friction relative to a conventional surface without texturing the entire face. Partial texture can therefore be interpreted as a spatial optimization problem in which regions responsible for pressure generation or lubricant replenishment are textured while other regions preserve mechanical support.

6. Discussion

6.1 Surface Texturing as Passive Energy Management

The primary implication of the study is that surface topography can function as a passive energy-management system. Unlike active lubrication controls, pumps, or externally powered actuators, a properly designed texture modifies lubricant motion and surface interaction through geometry alone. Once manufactured, the texture can operate continuously without a dedicated external energy input.

Etsion's early framework explains this multifunctionality particularly clearly: microdimples can behave as hydrodynamic microbearings, lubricant reservoirs, or debris traps depending on the lubrication state. This ability to operate through more than one physical mechanism makes texturing attractive for contacts that transition repeatedly across the Stribeck curve, as occurs in reciprocating mechanisms during acceleration, reversal, and varying load.

Nevertheless, energy efficiency should be assessed at the component level. Laser manufacturing itself consumes energy and increases production complexity. A texturing process is therefore justified most strongly for components experiencing enough operational frictional loss or service duration for the use-phase benefit to exceed the additional manufacturing burden. Lifecycle analysis should ultimately complement tribological optimization.

6.2 Why One Texture Cannot Be Optimal for Every Contact

The second implication concerns transferability. Surface-texture research includes circular pockets, elliptical dimples, parallel grooves, crossed grooves, chevrons, directional channels, hierarchical structures, and complex bio-inspired patterns. No universal ranking exists because each geometry changes lubricant flow and contact stress differently.

Gachot and colleagues' critical review explicitly emphasizes this regime and geometry dependence, while Rosenkranz and colleagues show that machine-element requirements differ between piston rings, seals, rolling bearings, and gears. A design optimized for a large conformal sliding seal therefore should not be transferred automatically to a rolling element bearing or highly concentrated gear contact.

Contact width is especially important. Vlădescu and colleagues observed that texture pockets larger than the relevant contact region could increase friction because the lubricant film collapsed within the oversized feature. Texture dimensions should consequently be selected relative to the scale of the pressure zone rather than specified solely in absolute micrometers.

Directional motion introduces another constraint. Grooves aligned with sliding can guide flow very differently from grooves oriented transverse to sliding. Reciprocating contacts complicate this further because the sliding direction reverses every stroke. Symmetric dimples or carefully designed bidirectional textures can therefore offer an advantage where the direction of motion changes repeatedly.

6.3 From Laboratory Friction Reduction to Durable Machine Components

A third implication is that surface-texture qualification should include durability. Laser-created dimples may gradually become shallower through wear, fill with particles, deform plastically, or develop raised rims depending on processing quality. Their function can therefore evolve during service. A favorable initial coefficient of friction is not sufficient evidence that the texture remains beneficial throughout component life.

Vlădescu and colleagues' reciprocating-contact work is noteworthy because the relative advantage of texturing changed as the specimen became worn and the lubrication regime evolved. This observation demonstrates that texture and wear influence each other dynamically. Long-duration testing should therefore report texture geometry before and after service rather than assuming that the manufactured topography remains constant.

Manufacturing process selection is equally important. Laser surface texturing offers excellent geometric controllability and flexibility, explaining its prominence in tribology. Mao and colleagues review laser ablation and related texturing methods and identify accuracy and controllability among their principal advantages for engineering surfaces. Other methods such as micromachining, lithography, electrochemical processing, forming, and embossing may nevertheless be more economical for specific materials or production volumes.

Finally, texturing can be combined with coatings or solid lubricants. Rosenkranz and colleagues review synergies between surface textures and solid-lubricant systems, noting that textures can retain low-shear materials and help extend their functional presence in the contact. Such hybrid strategies are promising for dry or lubricant-starved environments but introduce another layer of optimization involving coating adhesion, texture filling, wear evolution, and replenishment.

7. Conclusion

Surface texturing provides a technically credible route for reducing frictional energy losses while improving lubricant management and, under suitable conditions, reducing wear. Microdimples, grooves, pockets, and multiscale structures can alter local lubricant pressure, store lubricant, trap debris, and change the proportion of load carried through the fluid film. These mechanisms allow the surface itself to participate actively in tribological control without continuous external energy input.

The simulation developed in this study indicates that optimized texture design is more important than maximum geometrical complexity. The untextured reference achieved a simulated Tribological Energy-Efficiency Index of 55.3, compared with 68.2 for linear grooves, 80.9 for full-field circular dimples, 85.8 for optimized partial microdimpling, and 85.1 for a multiscale hybrid surface. The slight advantage of optimized partial texturing reflects the value of preserving load-bearing area while positioning texture where hydrodynamic and lubricant-management effects are most useful.

The simulated sliding-speed analysis further demonstrates that texture effectiveness can vary across the lubrication regime. Friction reduction becomes progressively more pronounced as the modeled interface develops stronger lubricant-film support, but this behavior should not be interpreted as universal. Load, viscosity, temperature, sliding direction, contact geometry, surface material, feature depth, texture density, and contact-width scale can all change the result. The appropriate engineering objective is consequently not to identify one universally superior dimple pattern but to optimize texture relative to the operating envelope of the specific machine element.

Future experimental research should combine friction measurements with lubricant-film thickness, wear volume, surface profilometry, temperature, pressure distribution, and post-test texture geometry. Factorial or response-surface designs should evaluate feature diameter, depth, area density, orientation, and partial-texture position under several Stribeck conditions rather than at one operating point. Component-level testing in bearings, seals, piston–liner systems, gears, pumps, and reciprocating mechanisms should then determine whether tribometer improvements translate into measurable energy savings and longer service life. Such validation would allow surface texturing to progress from a promising tribological modification toward a reproducible energy-efficiency technology integrated directly into the design of low-loss mechanical contacts.

References

1. Liu, Y., Yang, X., Ma, J., Li, K., Chen, M., Gu, Y., & others. (2023). Research progress of surface texturing to improve the tribological properties: A review. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*.
2. *The performance of textured surface in friction reducing: A review.* (2023). *Tribology International, 177*, 108010. https://doi.org/10.1016/j.triboint.2022.108010.
3. Song, J., Huang, H., Wang, X., & Shi, W. (2023). Status and prospects of surface texturing: Design, manufacturing and applications. *Surface Science and Technology, 1*, 21.
4. *Recent progress on surface texturing and solid lubricants in tribology: Designs, properties, and mechanisms.* (2023). *Materials Today Communications, 35*, 105854. https://doi.org/10.1016/j.mtcomm.2023.105854.
5. Marian, M., Almqvist, A., Rosenkranz, A., & Fillon, M. (2022). Numerical micro-texture optimization for lubricated contacts—A critical discussion. *Friction, 10*, 1772–1809.
6. Li, M., Shi, W., Shi, J., Wang, T., Shi, L., & Wang, X. (2022). Regulation and control of wet friction of soft materials using surface texturing: A review. *Friction, 11*, 333–353.
7. Costa, H. L., Schille, J., & Rosenkranz, A. (2022). Tailored surface textures to increase friction—A review. *Friction, 10*, 1285–1304.

8. *Particle size effects on efficiency of surface texturing in reducing friction.* (2022). *Tribology International*, *176*, 107895.
9. *Synergetic effect of surface texturing and graphene nanoplatelets on the tribological properties of hybrid self-lubricating composite.* (2022). *Tribology International*, *168*, 107434.
10. Boidi, G., Grützmacher, P. G., Kadiric, A., Profito, F. J., Machado, I. F., & Gachot, C. (2021). Fast laser surface texturing of spherical samples to improve the frictional performance of elasto-hydrodynamic lubricated contacts. *Friction*, *9*, 1227–1241.
11. Wan, Q., Gao, P., & Zhang, Z. (2021). Friction and wear performance of lubricated micro-textured surface formed by laser processing. *Surface Engineering*, *37*(12). https://doi.org/10.1080/02670844.2021.1952041.
12. Vishnoi, M., Kumar, P., & Murtaza, Q. (2021). Surface texturing techniques to enhance tribological performance: A review. *Surfaces and Interfaces*, *27*, 101463. https://doi.org/10.1016/j.surfin.2021.101463.
13. *Selected Methods and Applications of Anti-Friction and Anti-Wear Surface Texturing.* (2021). *Materials*, *14*(12), 3227.
14. Zhang, P., Zhang, Y., Hua, X., Fu, Y., Yin, B., Fu, H., & Ji, J. (2021). Lubrication design and development analysis of micro-texturing surfaces. *Surface Technology*, *50*(9), 14–32.
15. *Synergetic effects of surface texturing and solid lubricants to tailor friction and wear—A review.* (2021). *Tribology International*, *155*, 106792.
16. *Sliding wear behavior of electrochemically textured surfaces under different lubrication regimes: Effects of curvature radius.* (2021). *Wear*, *477*, 203817.
17. *Impact of laser surface texturing on the tribological characteristics of piston rings and cylinder liners—Part 1: Development of LST technology*. (2021). *Transactions of the IMF*, *99*(5), 231–237.
18. Cao, Z., Xia, Y., Chen, C., Zheng, K., & Zhang, Y. (2021). A synergetic strategy based on laser surface texturing and lubricating grease for improving the tribological and electrical properties of Ag coating under current-carrying friction. *Friction*, *9*, 978–989.
19. *Surface texturing for friction and wear reduction in lubricated mechanical contacts.* (2020). *Tribology International*.
20. *Laser surface texturing of engineering surfaces for improved tribological performance.* (2019). *Surface and Coatings Technology*.