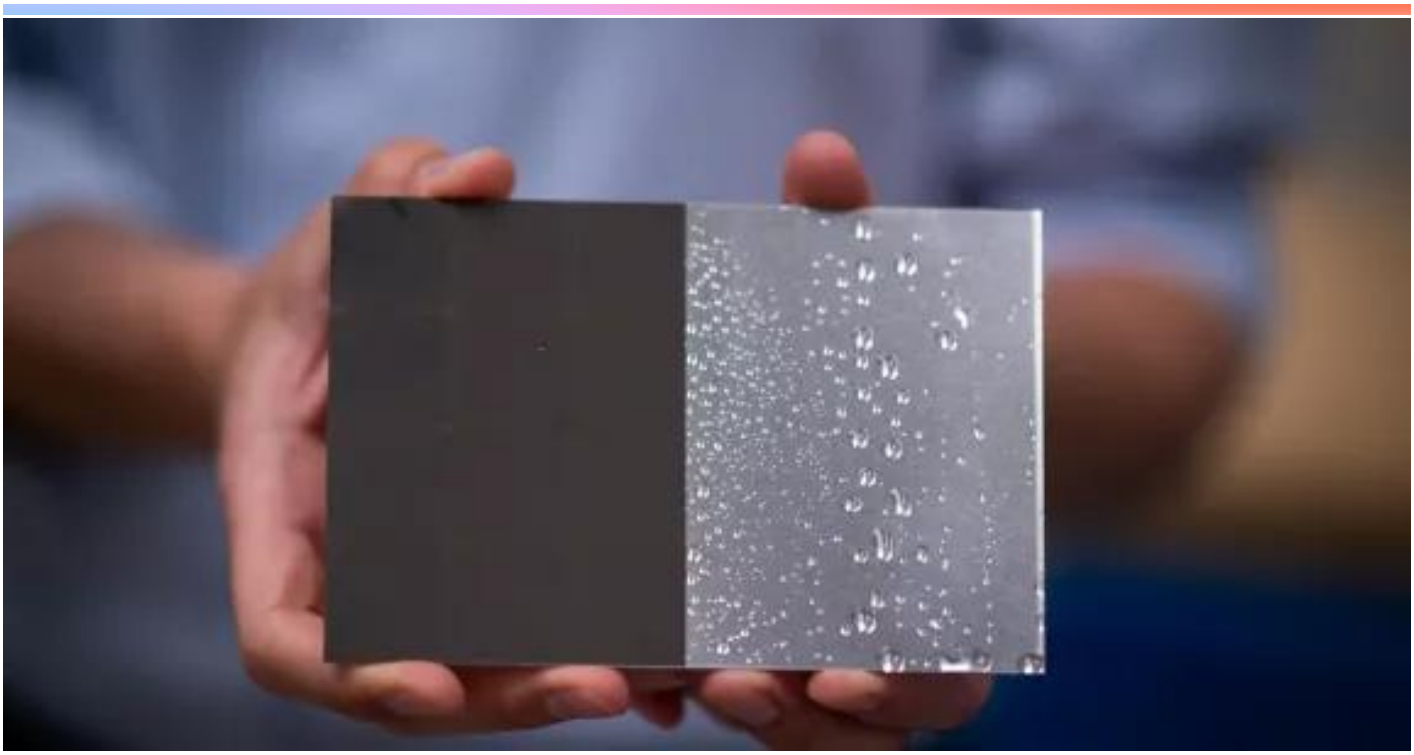


Laser texturing vs. hard chromium coatings in bearings | Series of LCA studies - part 4

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Reducing friction in bearings is vital for machinery performance, energy efficiency, and longevity. Traditional methods to introduce anti-friction properties to stainless steel surfaces may involve hard chromium coatings, which significantly enhance wear and friction resistance but introduce severe environmental and health risks due to the presence of hexavalent chromium.

The problem with chromium coatings

Hard chromium is a highly toxic and carcinogenic substance, contributing extensively to occupational health risks, environmental contamination, and biodiversity loss. The manufacturing and application processes of chromium-based coatings typically result in substantial water and soil pollution, carcinogenic airborne emissions, and critical environmental contamination, impacting ecosystems and human health severely.

Femtosecond laser as a clean alternative

Femtosecond laser texturing emerges as an effective alternative, entirely eliminating the requirement for hazardous chromium compounds. This innovative technique employs precision laser pulses to structurally modify surfaces without chemical interventions, significantly reducing carcinogenic emissions and environmental hazards.

LCA-based comparison: coating vs. laser texturing

To understand the sustainability potential of this approach, a life cycle assessment (LCA) was conducted comparing femtosecond laser surface texturing to a conventional process involving hard chromium coatings on bearing components. The study focused on a 0.07 m² area, corresponding to a representative surface on a bicycle wheel bearing.

The chromium-based method included mechanical pre-treatment through sandblasting, followed by electroplating using a bath of hexavalent chromium. The process also required post-treatment cleaning, rinsing, energy-intensive drying, and significant waste management infrastructure. Each of these steps contributes to the environmental load through chemical usage, energy consumption, and emissions of pollutants.

The femtosecond laser alternative, on the other hand, included a pre-cleaning step and then surface structuring via a galvanometer scanner. The only notable emissions came from air filtration components and cleaning textiles, which have a negligible environmental burden when compared to chemical waste from electroplating.

Key indicators: laser outperforms across the board

The LCA considered multiple environmental indicators. These included climate change potential, water and soil acidification, non-renewable energy sources, resource depletion (minerals and metals) and human carcinogenic toxicity impacts.

Environmental indicator	Hard chromium coating	Femtosecond laser texturing	Reduction
PEF single score (mPts)	1,37	0,05	96%
Climate Change (kg CO2 eq)	10,74	0,45	96%
Acidification (mol H+ eq)	0,06	1,42×10?³	98%
Energy resources: non-renewable (MJ)	207,38	7,13	97%
Eutrophication, freshwater (kg P eq)	7,58×10?³	6,13×10??	99%
Human toxicity: carcinogenic (CTUh)	1,2×10??	3,57×10?¹?	99%
Material resources: minerals and metals (kg Sb-eq)	1,75×10??	1,73×10??	90%

Broader industrial relevance

Beyond bearings, friction-reducing surfaces are critical in numerous applications: automotive parts, turbines, industrial conveyors, and aerospace components. Many of these sectors currently rely on hard chromium coatings despite regulatory concerns. The European Union, for example, has placed hexavalent chromium under strict regulation due to its known carcinogenicity, and alternatives are actively being encouraged through REACH legislation.

Conclusion

Femtosecond laser surface texturing consistently outperformed conventional coatings across all three use cases: anti-icing, antibacterial protection, and friction reduction, by significantly lowering environmental impacts such as emissions, toxicity, and resource use. The technology presents a compelling path forward for industries seeking both functionality and ecological responsibility. Laser surface texturing reduces toxic waste and emissions by up to 99%, offering a sustainable alternative to hexavalent chromium coatings in bearing systems.

Discover the FEMTOFUNC project

This case study is part of the broader FEMTOFUNC research on biomimetic surface functionality.

Discover the FEMTOFUNC project

Series of LCA studies on the application of femtosecond lasers

In a series of 4 parts, we briefly describe our findings and show the extent to which a femtosecond laser outperforms coatings in terms of ecological footprint:
Part 1: femtosecond laser texturing as a sustainable surface solution
Part 2: laser texturing vs. hydrophobic coatings in wind turbines
Part 3: laser vs. antibacterial coatings on door handles

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