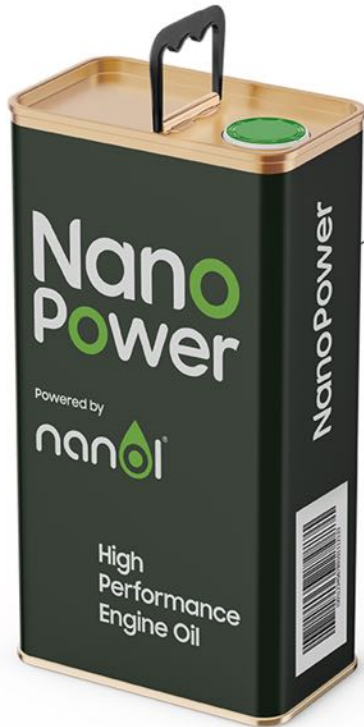


NanoPower

Innovative and Patented
SWEDEN - FINLAND
Technology



NanoPower

High Performance Lubricants



Patented Lubricant Additive



MADE IN FINLAND

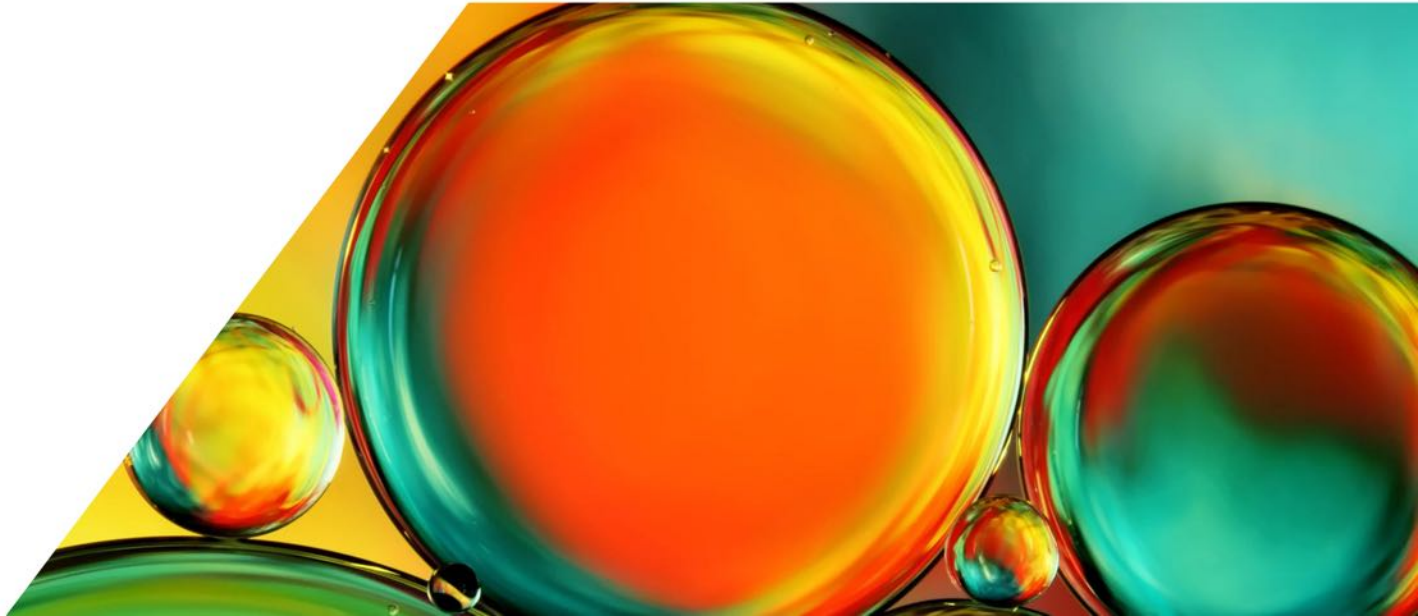


INTRODUCTION

Nanol Technologies is a Swedish-Finnish Company founded in 2010; that produces an innovative patented additive solution.

The Nanol lubricant additive is designed for oils and greases in a wide range of automotive, marine, industrial, and off-highway applications. It lowers friction by forming smooth tribofilms that prevent direct metal-metal contact.

Nanol is also unique because it regenerates itself to provide continuous performance and protection. It is safe and contains no harmful chemicals. In contrast, conventional lubricant additives often contain phosphorus and sulphur, that are harmful to the environment. These are also sacrificial additives that quickly lose performance.





WHAT IS NANOL?

Energysaving, emission reduction, reduced equipment maintenance costs, extended service lifetimes, and less waste

Nanol Technologies provides green lubricant additives that enhance protection of the environment by reducing harmful emissions and cutting waste, as well as extending the service life of mechanical equipment and engines. The additives contain copper nanoparticles that differ significantly from the larger particles usually contained in conventional additives. The nanoparticles deliver great performance advantages in lubricating oils and greases. They help to minimise friction and wear on the contact surfaces of moving parts, which reduces energy losses and improves wear resistance, as well as boost load carrying properties. They also provide many sustainable benefits, including energysaving, emission reduction, reduced equipment maintenance costs, extended service lifetimes, and less waste. These benefits are achieved because the nanoparticles are extremely small. They can penetrate the small gaps between moving parts and separate the surfaces which improves tribological performance.

The particles form tribofilms which reduce the contact area. This is especially important in highly stressed operating conditions, with high loads, low viscosity lubricants, and repeated start-stop operations. An added advantage with the Nanol nanoparticles is they are not consumed or depleted. The additive system carries on working. This ensures there is no loss of performance. As a result, friction, reduction and wear protection are sustained throughout the service life of the lubricant. The is able to regenerate itself which is further evidence of the green credentials of Nanol additives.

In contrast, conventional additives like zinc dialkyl dithiophosphates (ZDDP) actually increase friction, which reduces energy-saving. Also, ZDDP tribofilms are hard and brittle. As a result, abrasive particles are formed that actually increase wear. They are consumed which limits the useful life. A further problem is that some conventional additives bring about hydrogen embrittlement, micro-pitting, and white edging cracks (WEC) which causes metal fatigue. Nanol is different and better because it carries on working which enables the formulation of a new class of sustainable and extended life lubricants.



PATENTED TECHNOLOGY

Nanol has developed a unique technology with an exceptional customer value proposition

COPPER-BASED TECHNOLOGY

- Nanol is a copper-based technology with no negative impact on people or the environment
- The additive consists of copper oleate particles in stable molecules which ensures that it is truly oil soluble

ADDED TO ENGINE OIL OR FORMULATED INTO LUBRICANT

- Nanol mixes with engine oils and lubricants without affecting base oil properties or other additives
- Only 0.3 percent of Nanol is required to attain full benefits of the nanol solution
- Nanol upgrades the properties of lubricants by reducing friction and improving the anti-wear characteristics

INTERMIXING WITH SURFACES

- The Nanol additive acts as a friction modifier and anti-wear component as it intermixes with metal surfaces to form a self-repairing tribofilm. The copper oleate particles continuously seek out the surfaces
- experiencing the highest friction, resulting in immediate, efficient, and long-lasting effects
- The copper oleate particles reduce friction immediately, irrespective of the components being new or old

THREE MAIN REASONS TO USE NANOL

FUEL COSTS

Lower fuel consumption of 2-6%

In general, a factor of 10x ROI in fuel savings for Nanol customers

For e.g. large commercial truck fleets, at least 25% of operational costs refer to fuel

WEAR AND TEAR

Reduced wear and tear of components

Leading to prolonged service intervals and less downtime

EMISSIONS

Reduced emissions

Because of less fuel needed as well as reduced wear and tear of components, emissions from combustion engines can be reduced

Nanol is part of the solution for reduced global emissions and to keep environmental goals



PROVEN BENEFIT

FRICITION



UP TO **30%**

Reduced friction and increase energy

EMISSION



UP TO **30%**

lower emission and reduced waste

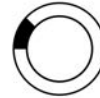
EQUIPMENT



CA. **20-35%**

Downtime with longer service interval

FUEL



UP TO **6%**

Reduction in fuel consumption

WEAR AND TEARS



UP TO **10%**

Reduce wear and tears, lead to longer life time of component

MAINTENANCE



CA. **10-20%**

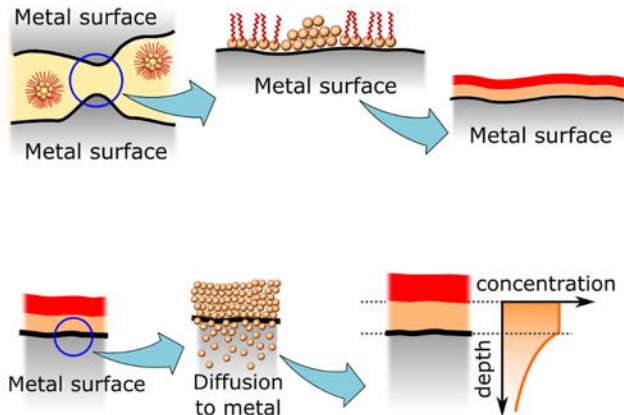
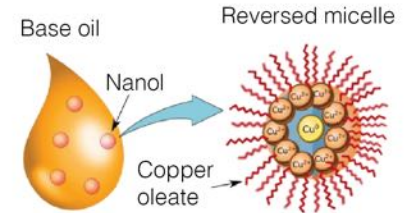
increased service and maintenance cycle

- Reduced frequency of oil changes
- Tribofilm Properties
- Reduces operating temperature
- Extend life of engines and machinery
- Less Downtime
- Heat Dissipation
- Higher Load Carrying
- Increased Energy Efficiency

Nanol is proven to reduce total cost of ownership by ~5-10%

STRUCTURE AND CHEMISTRY

- The structure of Nanol comprises a central copper atom surrounded by Cu^{2+} ions connected to a hydrocarbon chain which is nonpolar towards the base oil – a reverse micelle
- The micelles float in the base oil and do not segregate. In addition, since the structure is nonpolar there are no adsorption to the surfaces, because friction the surfaces are mainly polar



- Once the micellar structures become confined in the friction contact and experience shear, the micelles flatten at the surface and become attached to the surface with the help of polar head groups
- This effect takes place only in the friction interface, at the surface
- Disrupted micelles form brush-like structures on top of friction surfaces with low shear resistance which reduces friction on contact
- Disrupted micelles let out Cu^{2+} ions which undergo redox reaction to form nano-thin layer of copper metal
- Intermixing and tribochemical reactions forms a third body which becomes a self regulating lubricant

NANOL TRIBOFILM PROCESS

There are essentially six stages in Nanol tribofilm formation:

- 1 Initiation** Nascent iron surface reacts with oxygen to form a thin oxide layer, which provides a good foundation for the Nanol tribofilm to bond, but there is no tribofilm and wear occurs at this stage. Any running-in of the metal surface will also occur at the same time.
- 2 Exfoliation** Nanol micelles are disrupted, under high pressures and shear stress in boundary conditions, to release copper nanoparticles, but there is no tribofilm and wear still occurs.
- 3 Formation** Copper nanoparticles are deposited on the metal surface, accompanied by tribochemical reactions with the steel surface and oxide layer; which enables tribofilm formation to start, but at the same time there is also film removal and wear. It has been reported that metal nanoparticles (like copper), which can participate in redox reactions with iron to form iron oxides, are more likely to form more strongly adhered tribofilms.
- 4 Growth** Deposited copper nanoparticles are organized into an expanding tribofilm; film growth dominates over removal at this stage, and wear is reduced.
- 5 Equilibrium** Dynamic balance between formation of the robust Nanol tribofilm and removal; wear is also minimised at this stage.
- 6 Mending** Nanol nanoparticles will also repair any surface damage and are squashed under pressure to fill any cracks, in order to ensure that the tribofilm that has a levelling effect to produce a smooth surface, which reduces boundary friction. The filling of cracks will also control micro-pitting. Note that the Nanol tribofilm layer will stay attached to the friction contact surfaces, even if the oil is drained.

APPLICATION

The technology can be used in a wide range of different applications within transport, energy production and industrial applications.

TRANSPORT



- Marine
- Heavy vehicles
- General automotive & B2C
- Other (e.g. trains, agriculture)

ENERGY PRODUCTION



- Power plants (e.g. diesel generators)
- Wind turbines
- Other turbines
- Other (e.g. oil & gas)

INDUSTRIAL APPLICATIONS



- Bearings
- Mining
- Industrial machines
- Other (e.g. metal)





SOLUTIONS & PRODUCTS



Nanol offers its products from the raw paste to ready blended solutions – designed to serve customers in different segments.

concentrated Nanol-products:

NANOL® ADDITIVE

Paste, wax-like multipurpose product to be blended into the lubricants.

blended Nanol-products (NANOL® POWER+ products designed to serve our customers various needs in different segments):

NANOL® POWER+ ML / MH

Especially designed for the Marine segment's Low / High sulphur fuel users.

NANOL® POWER+ E

Especially designed for the Energy / Power-sector (power plants, generators)

NANOL® POWER+ T

Especially designed for the Transport-sector (cars,buses, trucks, trains, etc.)

NanoPower

We produce only lubricants bringing real benefits and technological innovation in the market. We've always pursued reliability and performance to make our products become synonym of excellence.

NANOPOWER PASSENGER CAR LUBRICANTS are characterised by the high quality of the base stocks and latest generation nanol Technology. NanoPower takes care of the needs of both new and older generation cars with dedicated product rangers.

NANOPOWER BUS AND TRUCK LUBRICANTS are formulated to exceed the most up-to-date specifications set by manufacturers and international institutions, thus guaranteeing long-term, stable and reliable

Energysaving

Emission reduction

Extended service lifetimes

Less waste

Reduced equipment maintenance costs





OPERATIONAL EVIDENCE

- Nanol Technologies has conducted 9 years of research at Fraunhofer Institute (Germany), VTT (Finland) and Helsinki University (Finland)
- Fuel savings confirmed independently by NAPA and verified by Lloyd's Register
- Used successfully in more than 15 different engine types and with 7 different commercial oil brands
- Nanol's performance has been proven in over 500,000 hours of operational use in marine diesel engines
- Growing customer base in marine segment with leading shipping companies, e.g. Spliethoff/Transfennica, P&O, Bore



"[Nanol] lubricant presents up to 3% improvement in power and torque. the [Nanol] lubricant is confirmed to improve the performance"
Millers Oil / University of Leeds

"For our test engines running with Nanol lubricant additive, fuel consumption was reduced by a 4% in 2011 as compared to 2010. We accredit this remarkable reduction to the use of Nanol"
Rederi AB Lillgaard - Baltic maritime service

"Fuel consumption was reduced by 4% over the first 12 months of running with Nanol. Taking into account all relevant factors affecting consumption, we believe that Nanol is the cause of this reduction"
Bore Ltd - International Shipping

"We have used Nanol in one of our ships, MS Ailas main engine and we can see positive results regarding fuel savings." The vessel is chartered by Containerships PLC.
Langh Ship Oy Ab - Multi-purpose vessel

Customer	Sector	Measured fuel savings
Rederi Ab Lillgaard	Marine	4%
Transfennica	Marine	2%
Langh Ship	Marine	4%
TallinkSilja	Marine	4%
CEPM	Power plant	1.5%
ADDINOL Lube Oil	Lube blender	2-6%



Analysis of Nanol tests by VTT Technical Research Centre of Finland

- In 2018, VTT Technical Research Centre of Finland¹ published an analysis of a compiled set of 36 research reports, dating from 2010 to 2017, all testing the effects of the Nanol additive in various settings
- 16 of the included reports were based on field tests, 4 were based on bench tests and 15 were based on laboratory tribotests
- VTT concluded that throughout the tests there were no reports of negative side effects of the additive

MARINE

Tests: 11 field tests

Results: 4% reduction in fuel consumption for middle sized (1,600-10,000 kW) diesel engines and 1-2% reduction for large (12,600-15,600 kW) engines

DIESEL ENGINE

Tests: 4 bench tests

Results: single observations showed 4% reduction in friction, 0 and 3% reduction in fuel consumption, and 1% increase in torque and power in engines of various sizes (60-4000 kW)

TRUCK

Tests: single field tests

Results: 4.3% reduction in fuel consumption in a test with two trucks; 38% reduction in lubricant oil consumption (22,500 km interval) in a test with three trucks

POWER PLANT

Tests: single field tests

Results: 2% reduction in fuel oil consumption and 2% reduction in heath rate

TRIBOMETER

Tests: 15 laboratory tests

Results: on average a 20% reduction in friction and a 25% reduction in wear with 0.3-3% Nanol in lubrication oil; 2-10x life improvements regarding pitting wear and white etching cracks

TEST SHOWING BEARING LIFETIME EXTENSION OF 10X

Background

- The influence of Nanol's additive on the formation of white etching cracks (WECs) in roller bearings was tested by one of the world's leading roller bearing manufacturers

Summary of results

- With the test setup, the reference oil would produce WECs within 30 to 45 hours
- With the additive, the test reached a running time of 422 hours, after which WECs still could not be detected
- Overall, a lifetime extension of bearings of 10x was measured

Comparison to reference oil

- Nanol reached at least a **tenfold WEC lifetime** in comparison to the reference oil at mixed friction conditions (at the FE8-25)
- **Operating point:** FE8-25 o Test rig: FAG FE8
- **Drive rpm:** 750 rpm
- **Load:** 60 kN load
- **Temperature:** 100°C
- **Test runs:** 2
- **Test bearings:** Axial cylindrical roller bearings
- **Lubrication:** Circulatory oil lubricant (~0,125 l / min)

RACE CAR

Tests: single field tests

Results: 3% increase in power and torque in acceleration tests



Independent testing by the Fraunhofer Society confirming the prevention of white etching cracks-WEC

Background

- Marine oils containing Nanol's additive were tested and compared to reference oil at the Fraunhofer Institute for Mechanics of Materials, an organisation within the Fraunhofer Society
- The Fraunhofer Society is headquartered in Germany and is the leading organisation for applied research in Europe
- The organisation comprises 72 independent institutes and regularly conducts independent research on behalf of privately and publicly financed projects
- The head of the Fraunhofer IWM Micro Tribology Center, Prof. Dr. Matthias Scherge, has summarised the findings from the tests in the article 'Multi-Phase Friction and Wear Reduction by Copper Nanoparticles' which has been published in the renowned journal Lubricants

Summary of results

- The laboratory tests showed that the Nanol additive acts independently of other additives and provides good stand-alone wear protection and friction reduction
- Examination of engine parts showed that the additive regenerated and repaired surfaces which showed signs of wear and corrosion

Comparison to reference oil

- When using reference oil, formation of WEAs₁ (white etching areas) appeared
In contrast, no WEAs appeared when using the Nanol additive, indicating that it
- prevents the formation of WEAs under the used test conditions

Comment from the head of the institution / Prof. Dr. Matthias Scherge

'Nanol's copper-based product is very smart, with changes in the copper structure. The friction changes the top one hundred or two hundred nanometers of the material, and many believe that if you only cover the material with another layer then it is clear. But that's not it, and that's where Nanol's product differs from the all other solutions'

AWARDED



WE ARE PART OF THE
#1000 SOLUTIONS
TO CHANGE
THE WORLD

- The most innovative start up in 2014 in Finland
- Solar Impulse Award in 2020
- Enterprise sustainability Award from the EU in 2021
- CV Award for the most innovative additive in 2019 and 2021



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