



Московский
ИННОВАЦИОННЫЙ
кластер



Research Center

Integrator of new production digital technologies

ZENTORN technology

Technologies movement



Problems

The reserves of properties of materials used for internal combustion engine structural elements are almost exhausted.

Coating technologies do not provide durability and thermal cycle resistance for promising types of new generation engines.

The characteristics of power, efficiency, environmental friendliness and service life of modern internal combustion engines require the use of new materials and technologies.

Catalysis of the process in the combustion chamber of an internal combustion engine, which ensures a reduction in the emission of harmful emissions, is difficult to implement.

Low level of automation and decision support systems for the production cycle, taking into account external market parameters.

Scattered competence centers for technologies and new materials.

Problems



Automotive industry

- Ecology, CO emissions
- Fuel consumption
- Liter capacity



Shipbuilding

- Corrosion
- Specific power
- Forcing



Oil and gas industry

- Corrosion
- Chemical resistance
- Inertness of materials



Decorative coatings

- Anti-vandal coatings
- Species properties
- Durability



Motorsport

- High temperatures
- High loads
- Weight and strength of the CPD



Aircraft industry

- Resource life of turbine blades
- Wear resistance
- High temperatures



Construction

- Corrosion
- Decorative coatings
- Life time



Optical instruments

- Corrosion
- Product weight
- Wear resistance



Railway tr-t

- Piston wear
- Large piston weight
- Resource, reliability



Agricultural machinery

- Restoration of parts
- Import substitution
- Wear resistance



Food industry

- Sanitation and hygiene
- Wear resistance
- Restoration and repair



Ecology

- Ecology, CO emissions
- Fuel consumption
- Water purification

Innovations in mechanical engineering

Radical changes

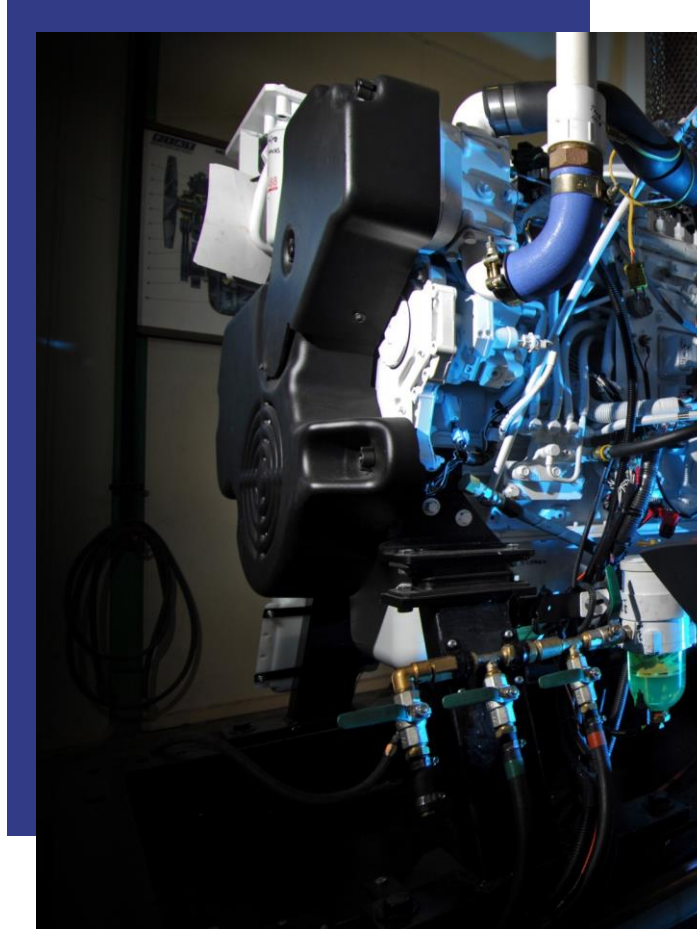
- ⚙️ Design change
- ⚙️ Materials Innovation

Modification changes

- ⚙️ Application of hybrid technologies
- ⚙️ Changing the material/surface properties of a specific part

Improvement Technologies

- ⚙️ World-competitive R&D Digital
- ⚙️ manufacturing technologies

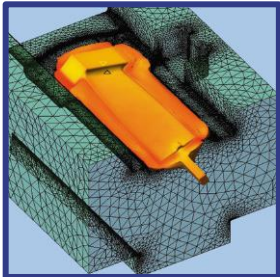


Technologies



Microarc oxidation

A promising technology that provides increased wear resistance of structures, leading to the formation of ceramic coatings (CP) on the surfaces of products made from valve metal alloys (aluminum, titanium, etc.), which have a unique set of properties.



Isothermal stamping

A cost-effective technological process for titanium and aluminum alloys, allowing to reduce material consumption and labor intensity of manufacturing compared to traditional multi-transition technology for manufacturing parts from forgings and plates.



Powder metallurgy

The powder industry has developed greatly with the development of high-tech technology requiring products made of composite materials. The difference between composites and alloys is the ability to obtain strong compounds of dissimilar metallic and non-metallic components.

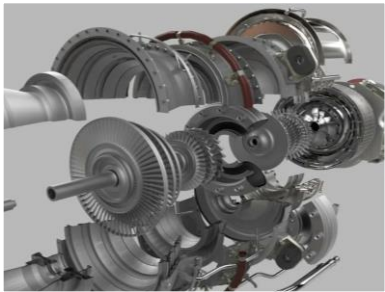
Application on valve metals



Aluminum

Thanks to its lightness, durability, resistance to corrosion and temperature influences, **aluminum** is the most popular non-ferrous metal in **mechanical engineering**.

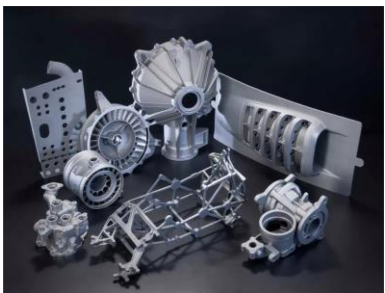
Mostly in **mechanical engineering** Rolled aluminum products, casting and extrusion are used, which are used for the manufacture of power structural elements, machine parts and various mechanisms.



Titanium

Titanium is used in a variety of parts in **aircraft manufacturing** because of its significant benefits.

Titanium and its derivatives are characterized by high melting points and electrical resistivity, strength comparable to most grades of alloy steel, corrosion resistance in air, water and chemically aggressive environments, non-magnetism and many other useful properties.



Magnesium

Usage of **magnesium in the automotive industry** and **aerospace industry**, as the lightest metal, has a significant impact on energy savings, since reducing the weight of vehicles leads to direct fuel savings. When alloyed, magnesium has the highest strength-to-weight ratio of all structural metals.

Advantages



Wear resistance of dense (3.9 – 4.1 g/cm³), a solid (over 2500HV) oxide layer and binding spinel oxide compounds designed to reduce the coefficient of friction (to a value of 0.04 - 0.09).

Catalytically active

The catalytic properties of the heat-protective coating provide an increase in thermal efficiency and a reduction in the level of harmful CO emissions into the atmosphere.

Infinite resource

Layers of metal-ceramic compounds of high-temperature polymorphs consist of elements of the base material of the product with a certain selectivity and the same CTE.

Lack of adhesion

Multifunctional metal oxide layer consisting of high-temperature modifications of Al₂O₃ and SiO₂, binding spinel oxide compounds and intermetallic compounds.



The layer (150-200 microns) has a specially selected microporous structure and oxide phase composition. As a result, we achieved a record low thermal conductivity (less than 1 W/m K) of the coating.

Thermocyclic resistance

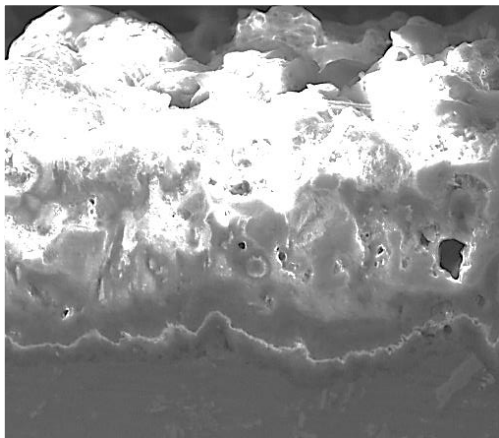
Protection against the development of microplastic deformation due to thermal cyclic load, providing thermal dynamic protection of the surface of the combustion chamber and elements.

Solutions

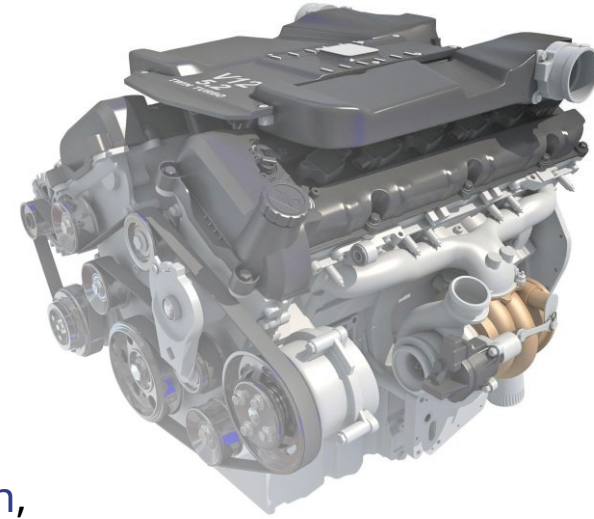
Engine manufacturing

Modification layer **"ZENTORN"** (thickness 150-200 microns) has a specially selected microporous structure and oxide phase composition.

The special combination of properties is associated with the nature of the formation of the coating **"ZENTORN"** (plasma electrolytic treatment) + alloying with special compounds.



Porous amorphous structure of a catalytically active thermal barrier coating



Coverage provides:

- ⚙️ dynamic thermal protection, guaranteeing high thermal cyclic resistance;
- ⚙️ high strength and wear resistance;
- ⚙️ lightweight design;
- ⚙️ high thermal insulation properties with a small thickness, record low thermal conductivity (less than 1 W/m K);
- ⚙️ high catalytic properties due to the special chemical composition of the coating, a large active surface with static potential;
- ⚙️ endless coverage resource;
- ⚙️ reduction of thermal load to the cooling system.

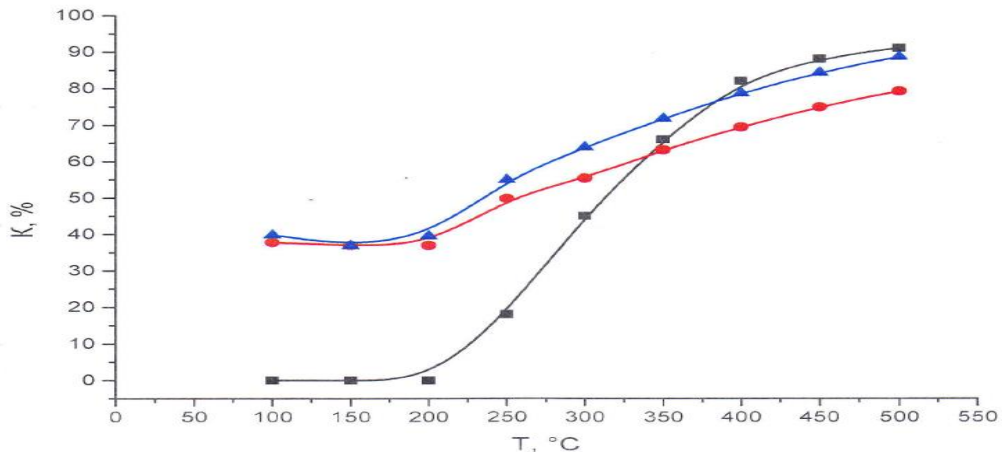
Catalytic activity

⚙️ For the first time, a catalytically active thermal barrier (KATB) coating was used on piston and on cylinder head sphere by MDO method.

⚙️ The developments are patented.

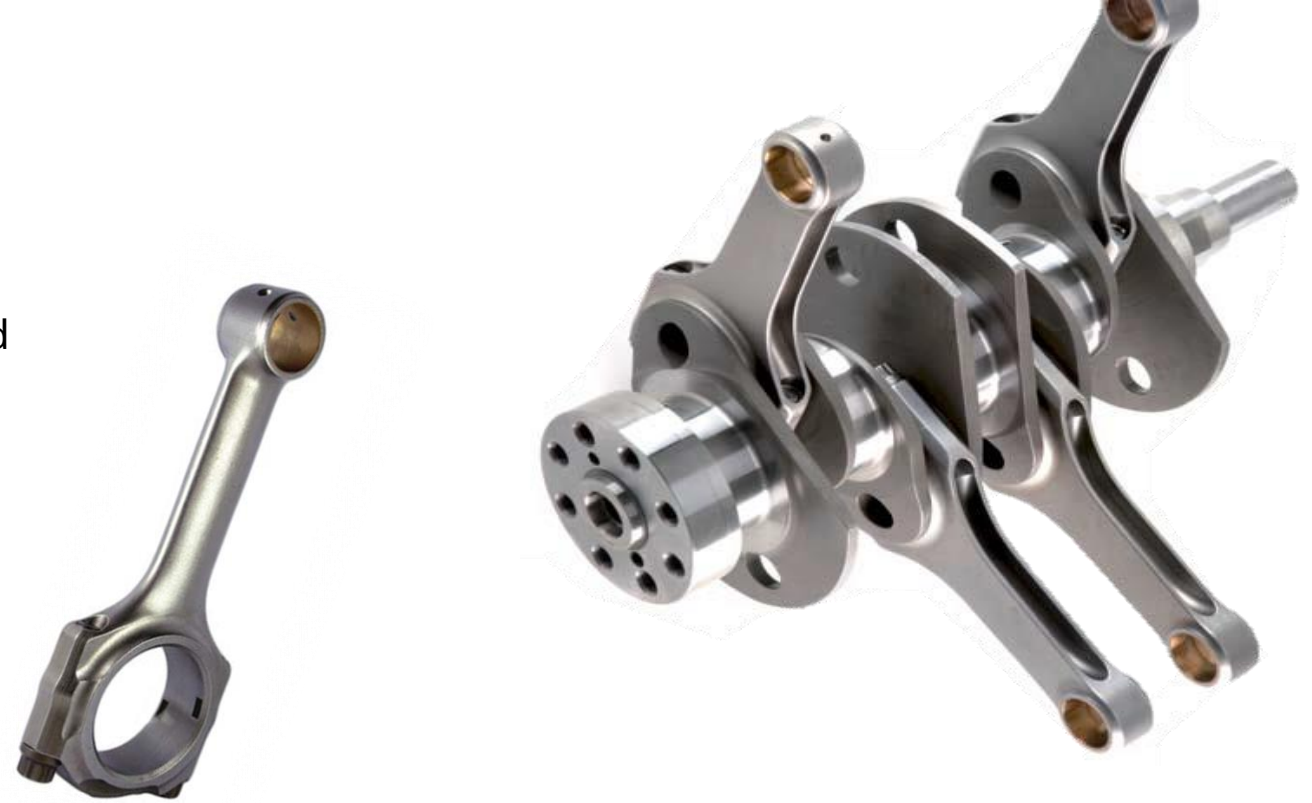
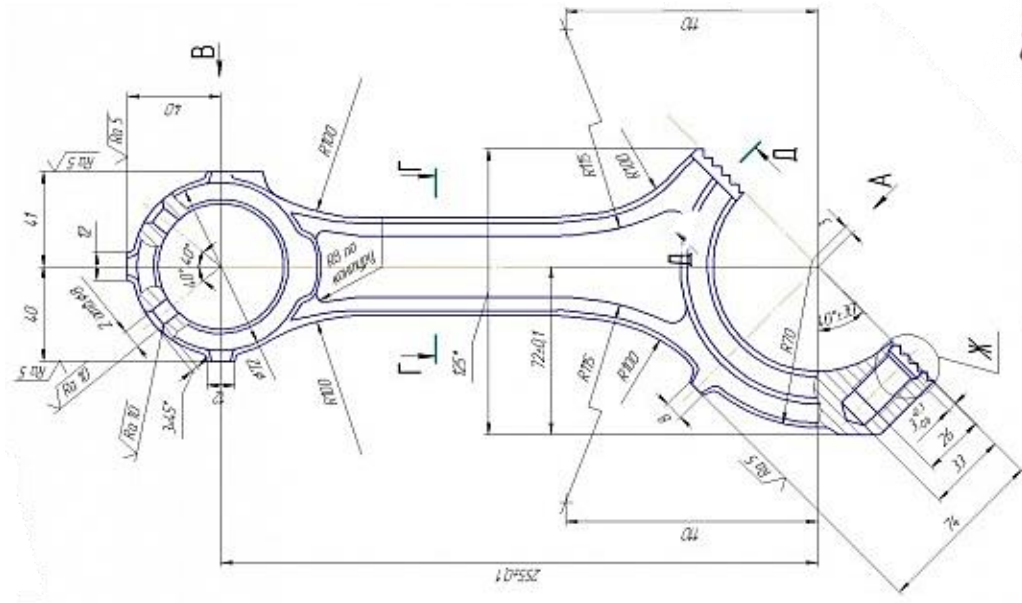
⚙️ The catalytic properties of coatings have been confirmed by research at Tomsk University - collective use center of the Skolkovo Technopark.

Graph of the degree of conversion of CO into CO₂ from the temperature in the combustion chamber



Titanium products

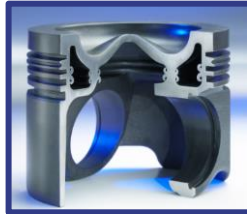
- ⚙ We offer titanium alloys as an alternative to our development "**COMPOSITE**titanium based alloyed with carbon", **increased strength and rigidity**.
- ⚙ **Economical powder technology** production of which are structural elements.



- ⚙ The main application of alloys is **movable engine elements** internal combustion, particularly connecting rods.
- ⚙ **Increase efficiency engine, reduction fuel consumption and promotion his power** without significant cost changes.

Piston comparison

Classical
Al alloy piston



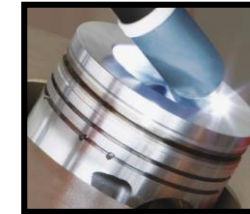
Al piston with steel
FERROTERM insert



Steel piston



Federal Mogul
Al piston DuraBowl



**AL piston
with ZENTORN coating**



Peak
pressure, bar

<170

<200

<230

<220

<230

Specific
power, kW/l

75

85

100

90

90+

Thermal efficiency

-

+

+

-

+++

Working
temperature

<300

<450

<450

<420

<600

Catalytic
properties

No

No

low

low

high

CTE of the piston

average

very high

high

average

low

Inertial
loads

low

average +

high

low

low

results

Extract from the technical certificate on the test results of the 6ChN15/16 diesel engine

4 Заключение

4.1 Испытания показали эффективность применения керамического термобарьерного покрытия для повышения надежности и работоспособности деталей поршневой группы и головок цилиндров дизельного двигателя 6ЧН15/16 при его форсировании до максимальных давлений рабочего процесса свыше 150 кгс/см². Двигатель остался в работоспособном состоянии и пригодным для дальнейших испытаний после воздействия максимального давления рабочего процесса до 172 кгс/см², что позволило получить прирост мощности двигателя 21% в сравнении с базовым (540л.с.) без снижения степени сжатия.



Uniqueness of technology

Surface modification and transition layer structuring

is achieved by implementing a sequence of series of periodic shaping electrical pulses of a special shape.

By controlling the amplitude, duration, edges and cuts, phase relationship, positional combination and frequency of pulses, plasma discharges are generated.

They synthesize solid structures of metal-ceramic compounds (composites) of high-temperature polymorphic modifications from elements of the base material with a certain selectivity, depending on the composition of the normal-activating or normal-passivating medium (pH and electrolyte composition).

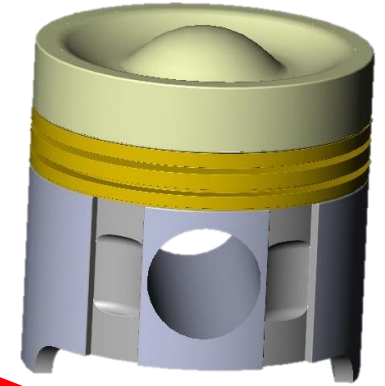


Regularities of formation of the structure of oxide layers during PES,

established during fundamental research, made it possible to provide control and management of the shape, size, phase composition, integration and interaction of elements of the submicron structure of the resulting oxide layers (composites).

This made it possible for the first time to obtain structural materials with a layered structure, several times superior in operational characteristics of traditional materials due to the manifestation in various operating environments of a set of properties inherent in polymers, metals and their oxides, combined in one composite.

Development of isothermal stamping technology for the manufacture of a forged piston with a ni-resist insert for compression rings



This stamping method ensures the production of precise workpieces from light alloys, in particular aluminum alloys, and also ensures the production of workpieces with a complex profile, including thin walls, ribs, asymmetry elements, etc.

This is possible due to the creation of conditions close to isothermal in the stamping tool.

In this case, the plasticity of the deformed material increases significantly; the resistance of the material to deformation decreases.

The resulting blanks are characterized by: increased mechanical properties, good microstructure development, minimal allowances for subsequent cutting processing.

Manufacturing a piston with a ni-resist insert using isothermal stamping followed by coating the working surface with MAO will allow:

- ✓ reduce the weight of highly loaded internal combustion engines;
- ✓ increase the efficiency of the internal combustion engine;
- ✓ increase the liter capacity of the internal combustion engine;

- ✓ protect the piston from thermal cyclic loads;
- ✓ **reduce engine inertia by replacing steel or all-component pistons onto a forged piston with a ni-resist insert.**

Wear-resistant ceramic high-strength coating for crankshaft bearings

⚙️ **Multifunctional metal oxide layer (coating),**
consisting of high-temperature modifications of Al_2O_3 and SiO_2 , binding spinel oxide compounds and intermetallic compounds (Al, Pt, etc.),
designed to catalyze the combustion process, thermal protection of the combustion chamber, reduce mechanical wear and adhesion of combustion products (preventing carbon formation) to the working surface of the combustion chamber, piston (up to the fire zone) and valve seat
(pointer "1" see figure).

⚙️ **Wear-resistant, dense (3.9 - 4.1 g/cm³), hard (over 2500HV) oxide layer,**
consisting of Al_2O_3 and binding spinel oxide compounds,
intended as an antifriction coating to reduce the coefficient of friction (to a value of 0.04 - 0.09), mechanical wear and retention of lubricant
in the contact patch of pairs of friction surfaces: cylinder wall - trunk (piston wall);
connecting rod sliding bearing - pin, liner - crankshaft journal, sliding bearing
housing - camshaft journal (pointer "2" see figure).

⚙️ **Metal oxide composite material,**
consisting of a structural base (aluminum alloy), metal oxide composite (Al_2O_3 , SiO_2 , TiO_2 etc.), binding spinel oxide compounds and intermetallic compounds (Al, Ti, Pt, etc.),
intended for the manufacture of composite honeycomb structures of catalytic
converters (neutralizers) of exhaust gases.

Layer ZENTRON-
ceramics 2500 HV

Nickel
interlayer

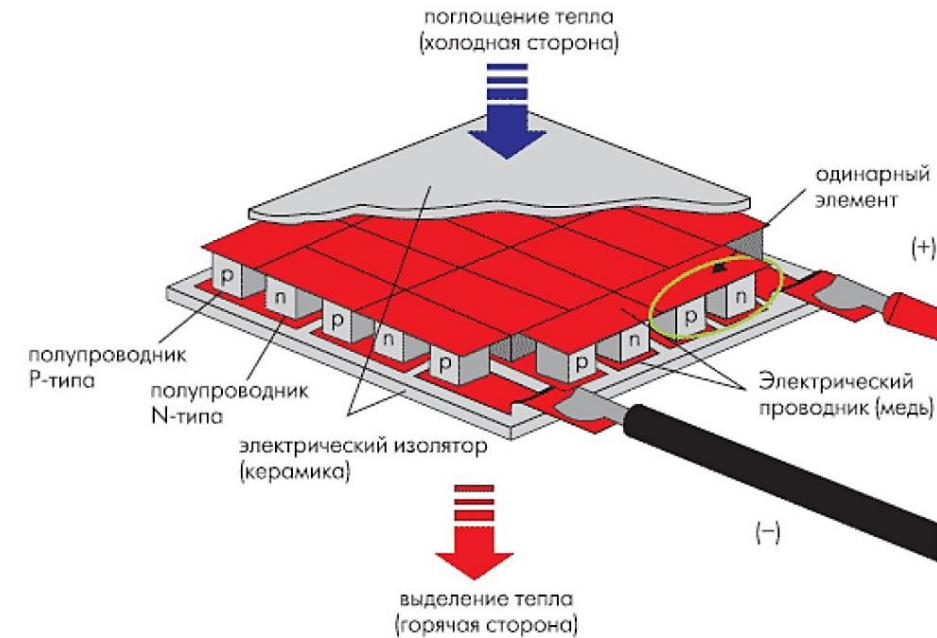
Lead layer
bronze

Steel
base



Tubular thermoelectric generator

- ⚙️ A set of technical solutions in the design of the exhaust gas exhaust tract and the internal combustion engine cooling system aimed at converting the exhaust gas and waste heat from the cooling system and exhaust gases into electrical energy through direct thermoelectric conversion.
- ⚙️ Tubular thermoelectric modules (TEMs) with radial-ring thermopiles are well arranged in the form of tubular heat exchangers and allow the generation of TEGs with megawatt power using an integrated circuit.
- ⚙️ Tubular design TEMs have increased power density, which ranges from 1.5 to 65 W/kg.
- ⚙️ Transition-switching MAO layers made of metal-oxide composites with a zone organization of a layered structure, consisting of a metallic, intermetallic and oxide three-zone layer, make it possible to organize heat-resistant and heat-resistant coupling of thermoelectric materials in installations operating on the Peltier and Seebeck effects.



Solutions

Automotive industry

Modification layer **"ZENTORN"** (thickness 150-200 microns) has a specially selected microporous structure and oxide phase composition.

The special combination of properties is associated with the nature of the formation of the coating **"ZENTORN"** (plasma electrolytic treatment) + alloying with special compounds.

Coverage provides:

1. Dynamic thermal protection, guaranteeing high thermal cycle resistance.
2. High strength and wear resistance.
3. Lightweight design.
4. High thermal insulation properties with a small thickness and record low thermal conductivity (less than 1 W/m K).
5. High catalytic properties due to the special chemical composition of the coating. large active surface with static potential.
6. Infinite coverage resource.
7. Reducing the heat load on the cooling system.

THERE

6.4

billion rubles

SAM

640

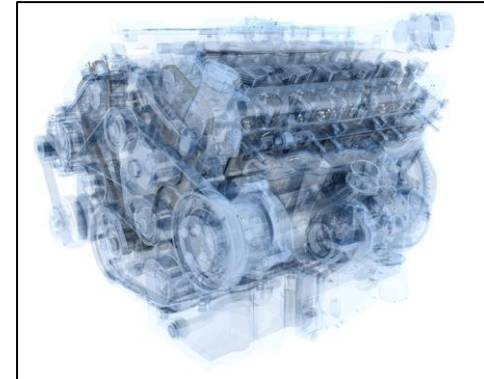
million rubles

SOM

210

million rubles

Technology readiness
level **TRL 8**



Solutions

Motorsport

THERE

2.7

billion rubles

SAM

50

million rubles

SOM

40

million rubles

ZENTORN technology provides:

- ⚙️ increased reliability of turbo engines at maximum load, 43% of breakdowns are caused by the power plant,
- ⚙️ increase in power up to 10% through Catalysis,
- ⚙️ more than 2 times reduction in piston weight,
- ⚙️ provides thermal dynamic protection of the piston, with a hardness of more than 130 units.

Technology readiness level **TRL 8**



Solutions

Motorsport

THERE

2.7
billion rubles

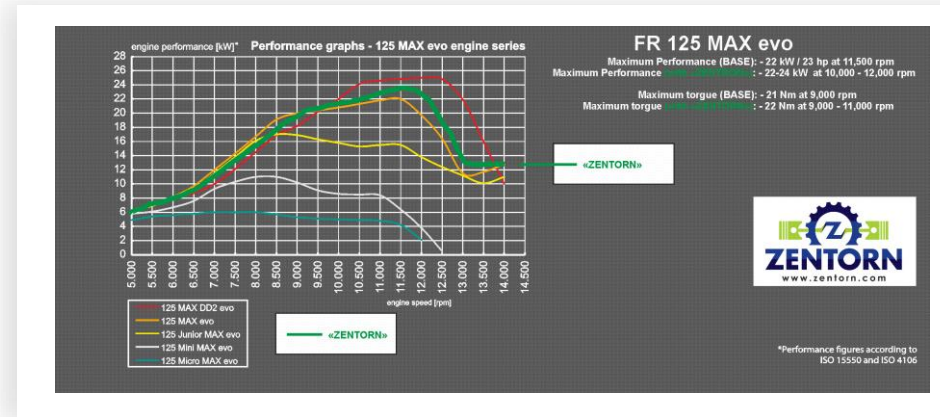
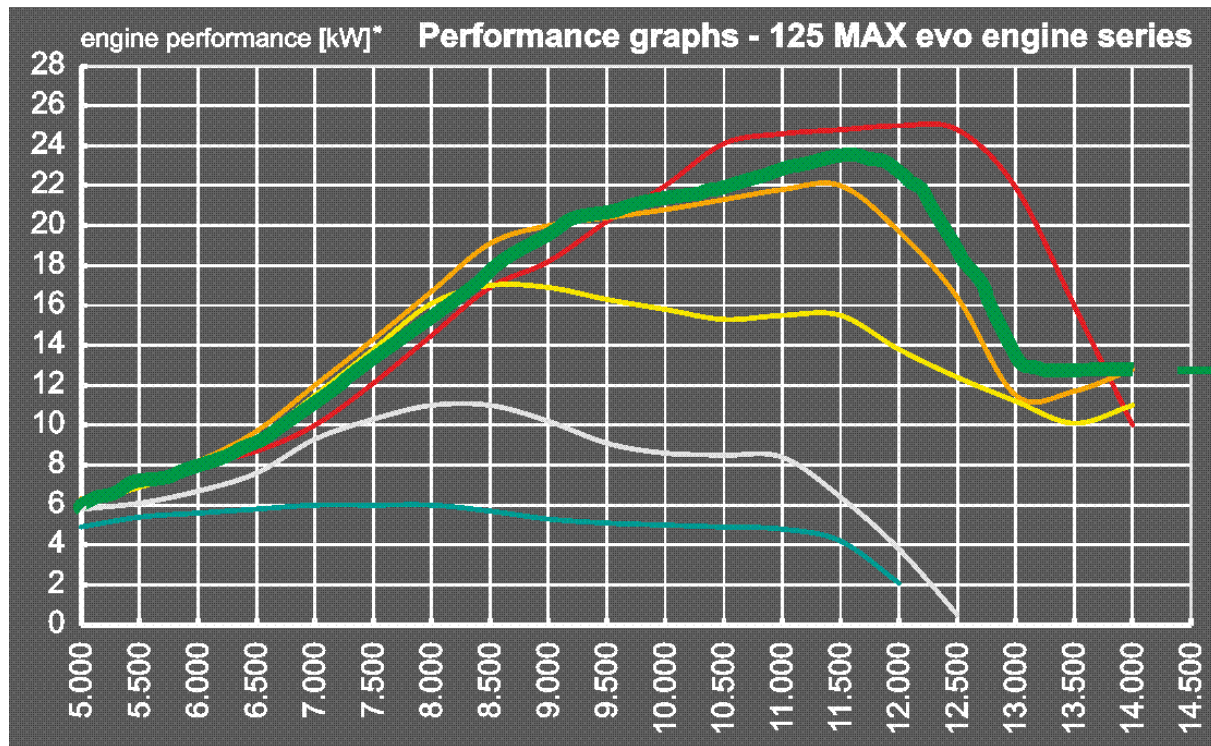
SAM

500
million rubles

SOM

40
million rubles

Technology readiness
level **TRL 8**



ROTAX



Solutions

Rail transport

ZENTORN technology provides:

- ⚙️ increased engine reliability, up to 30% of failures in the operation of locomotive components due to diesel engines,
- ⚙️ increase in service life before overhaul, according to the CIMAC international congress, diesel engines remain the backbone of the industry,
- ⚙️ reducing the thermal load on the engine, the average daily mileage of the locomotive is more than 650 km.



Technology readiness level **TRL 6+**



Solutions

Shipbuilding

THERE

1.0

billion rubles

SAM

60

million rubles

SOM

12

million rubles

ZENTORN technology:

- ensures an increase in engine power when boosting it up to 10%,
- provides thermal cycling resistance, up to 10% of total cylinder wear due to temperature cycles,
- withstands more than 2500 heating-cooling cycles,
- provides thermal dynamic protection of the piston, with a hardness of more than 130 units,
- provides a standard not lower than EURO-5, reduces the content of harmful hydrocarbons in exhaust gases.

Technology readiness
level **TRL 6+**



Solutions

Aviation industry

THERE

800

million rubles

SAM

190

million rubles

SOM

22

million rubles

Technology readiness
level **TRL 6+**

ZENTORN technology allows:

- ⚙️ reduce the number of aviation accidents, 23% of accidents are related to power plants,
- ⚙️ increase the overhaul life of turbine blades,
- ⚙️ reduce the degree of roughness of turbine blades, possible increase in efficiency up to +0.5%



Ростех



Объединенная
Двигателестроительная
Корпорация



ОДК «УМПО»

OAK

Объединенная
Авиастроительная
Корпорация



AIRBUS



ОДК
ПЕРМСКИЕ МОТОРЫ



BOEING



ФИЛИАЛ
"ОМСКОЕ МОТОРОСТРОИТЕЛЬНОЕ ОБЪЕДИНЕНИЕ
имени П.И. Баранова"

Solutions

Agricultural machinery

ZENTORN technology provides:

- ⚙️ increase in corrosion and wear resistance of parts, the average age of agricultural machinery in the Russian Federation is more than 16 years
- ⚙️ reduction of friction, up to 85% of agricultural machines fail due to wear
- ⚙️ increasing the service life of engine pistons, the load on agricultural machinery in the Russian Federation is 8 times greater than in Canada
- ⚙️ import substitution and repair

THERE

2.5
billion rubles

SAM

500
million rubles

SOM

100
million rubles

Technology readiness
level **TRL 6**



Solutions

Industrial internal combustion engines

THERE

8.0

billion rubles

SAM

1.2

billion rubles

SOM

225

million rubles

Technology readiness
level **TRL 6+**

ZENTORN technology provides:

- ⚙️ reduction in the overall wear of parts, the service life between overhauls is no more than 10,000 hours,
- ⚙️ increase in corrosion and wear resistance of parts, the failure rate of the CPG is 25%,
- ⚙️ reduction of thermal outflow, up to 20% of thermal energy is lost with cooling media (air, oil).



Solutions

Oil and gas industry

THERE

52.5

billion rubles

SAM

2.8

billion rubles

SOM

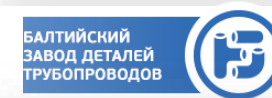
280

million rubles

Technology readiness
level **TRL 6**

ZENTORN technology provides:

- ⚙️ increasing the corrosion resistance of well telemetry materials; the operating stock of wells in the Russian Federation is more than 180 thousand units,
- ⚙️ increasing the corrosion resistance of shut-off and control valves; 25% of all accidents in the oil and gas industry are associated with corrosion.



Solutions

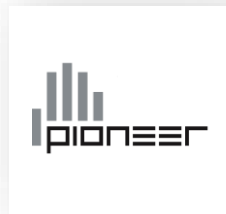
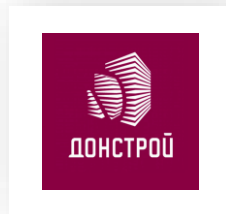
Construction



Technology readiness level **TRL 6**

ZENTORN technology has unique properties:

- ⚙️ high dielectric properties of elements and coatings, withstands breakdown up to 1600V,
- ⚙️ high resistance to surface abrasion, anti-vandalism,
- ⚙️ unique consumer (visual and tactile) properties.



Solutions

Food industry

THERE

10

billion rubles

SAM

600

million rubles

SOM

60

million rubles

Technology readiness
level **TRL 6**

ZENTORN technology provides:

- ⚙️ high sanitary and hygienic properties of materials, do not contain harmful substances that pass into food,
- ⚙️ wear resistance and durability of components and parts, have a smooth, polished surface.



Solutions

Decorative coatings



Technology readiness level **TRL 5**

ZENTORN technology provides:

- ⚙️ anti-vandal properties of coatings,
- ⚙️ unique consumer (visual and tactile) properties.



Solutions

Optics



Technology readiness level **TRL 6**

ZENTORN technology provides:

- ⚙️ corrosion resistance of materials and coatings, up to 2700 hours in salt fog,
- ⚙️ anti-vandal properties of coatings, abrasion resistance, coating from 5 microns, superior to anodizing.



Solutions

Green technologies

THERE

600
billion rubles

SAM

20
billion rubles

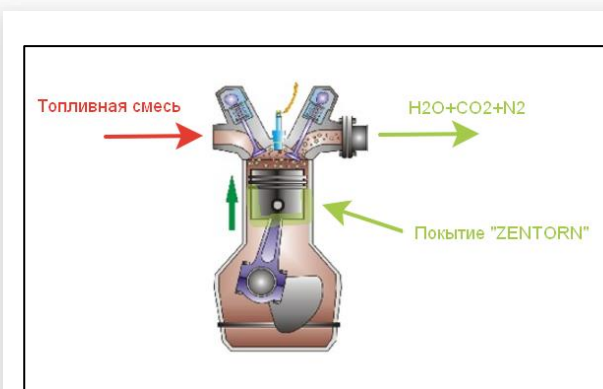
SOM

1
billion rubles

ZENTORN technology provides:

- reduction of CO emissions into the atmosphere of internal combustion engines,
Every day more than 100 thousand tons of CO are emitted into the atmosphere in the Russian Federation,
- reducing the toxicity of the exhaust gas mixture,
daily release of toxic substances into the atmosphere of more than 9 thousand tons,
ensuring environmental friendliness class EURO-5,
- solving the problem of incomplete combustion of fuel,
- increasing engine efficiency and reducing fuel consumption.

(Technology readiness level) **TRL 5**



TiClean

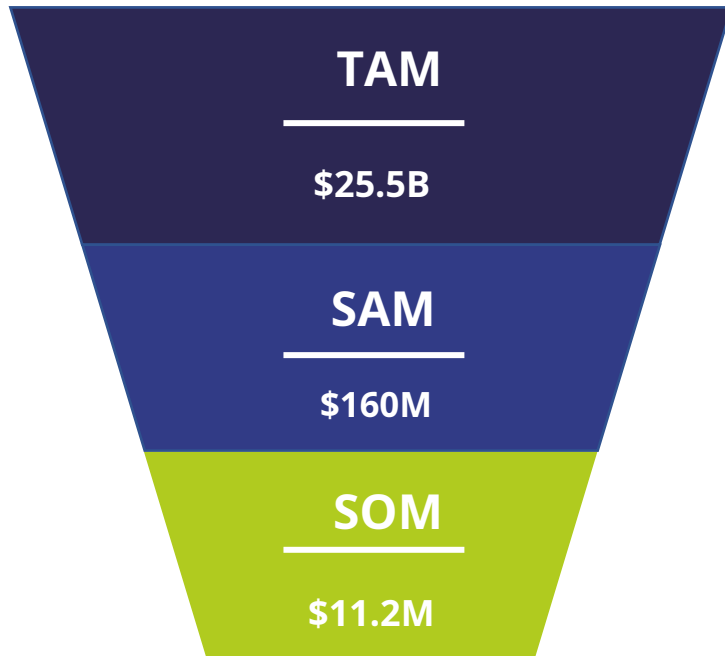
bavaria motors

EURO 6

МБК
МОСВОДОКАНАЛ



Multifunctional coatings market



Total Available Market (TAM)

Global market of thermal barrier ceramic coatings for internal combustion engine components

Source: Internal Combustion Engine Market Size & Share, Industry Report: <https://www.grandviewresearch.com/industry-analysis/internal-combustion-engine-market>

Serviceable Available Market (SAM)

Russian market of thermal barrier ceramic coatings for internal combustion engine elements

Source: Analysis of the internal combustion engines (ICE) market in Russia, <https://drgroup.ru/2258-analiz-rynka-DVS-v-Rossii.html>

Serviceable Obtainable Market (SOM) – 6-10k corps

Achievable share of the Russian market of thermal barrier ceramic coatings for automotive internal combustion engine elements*

Source: based on a production capacity of 100 thousand products per year by 2024

Key trends

1. Technologies for pre-treatment of metal surfaces will develop faster than others in the field of coating processing.
2. Development of coating technologies for thermal cycling **fortitude** new generation engines.
3. Search **alternative materials**, used for internal combustion engine pistons, due to their limited availability.
4. Development **materials for greater efficiency**, environmental friendliness and resource of modern internal combustion engines.

Source: Metal Finishing Market Report <https://www.mordorintelligence.com/industry-reports/metal-finishing-market>

Business model

- 1** Formation of ZENTORN coating on Customer's products.
- 2** Manufacturing of products with ZENTORN coating according to the Customer's drawings.
- 3** Joint development of technology application in promising products and industries.
- 4** R&D development and prototyping center services.

- 5** Scaling ZENTORN technology to the Customer's production areas.
- 6** Design, manufacture and delivery of a technological production line at the Customer's sites.



team




Roman Lebedev

Motorsports team



Motorsports team



Invest

6 million •
Ruble

manufacturing a prototype of a flow engine, purchasing office equipment and components.
Manufacturing a pilot batch of products and conducting tests for concerns
JSC NPK Uralvagonzavod, PJSC KAMAZ, ODK-Aviadvigatel (Perm).

30 ml n.
ruble th

investment round, August 2021.
Creation of an R&D center, purchase of equipment for the Skolkovo Shared Use Center, design of our own digital production of multifunctional patented coatings "ZENTORN", the only one in Russia and Europe.

400 ml n.
ruble th

investment round, November 2021 - to open our own innovative production of multifunctional coatings "ZENTORN" for all industries:

45 million rubles. – land plot 1 hectare.

40 million rubles. – connection of 2 MW of electricity

million rub.– construction of premises

250 million rubles.- Equipment for the production of

10 million rubles- working capital

Shares and Exit of the investor - discussed individually

Partners



FundZeroGravity Foundation* provides financial, management and marketing support to Zentorn



***ZeroGravity Foundation** is decentralized venture fund and international aggregator of digital, innovative and blockchain technologies

For cooperation and partnership issues

E-mail: zerogravity.foundation@gmail.com