Volume 4

A novel process for manufacturing complex shaped Fe-Al intermetallic parts resistant to extreme environments

EQUINOX

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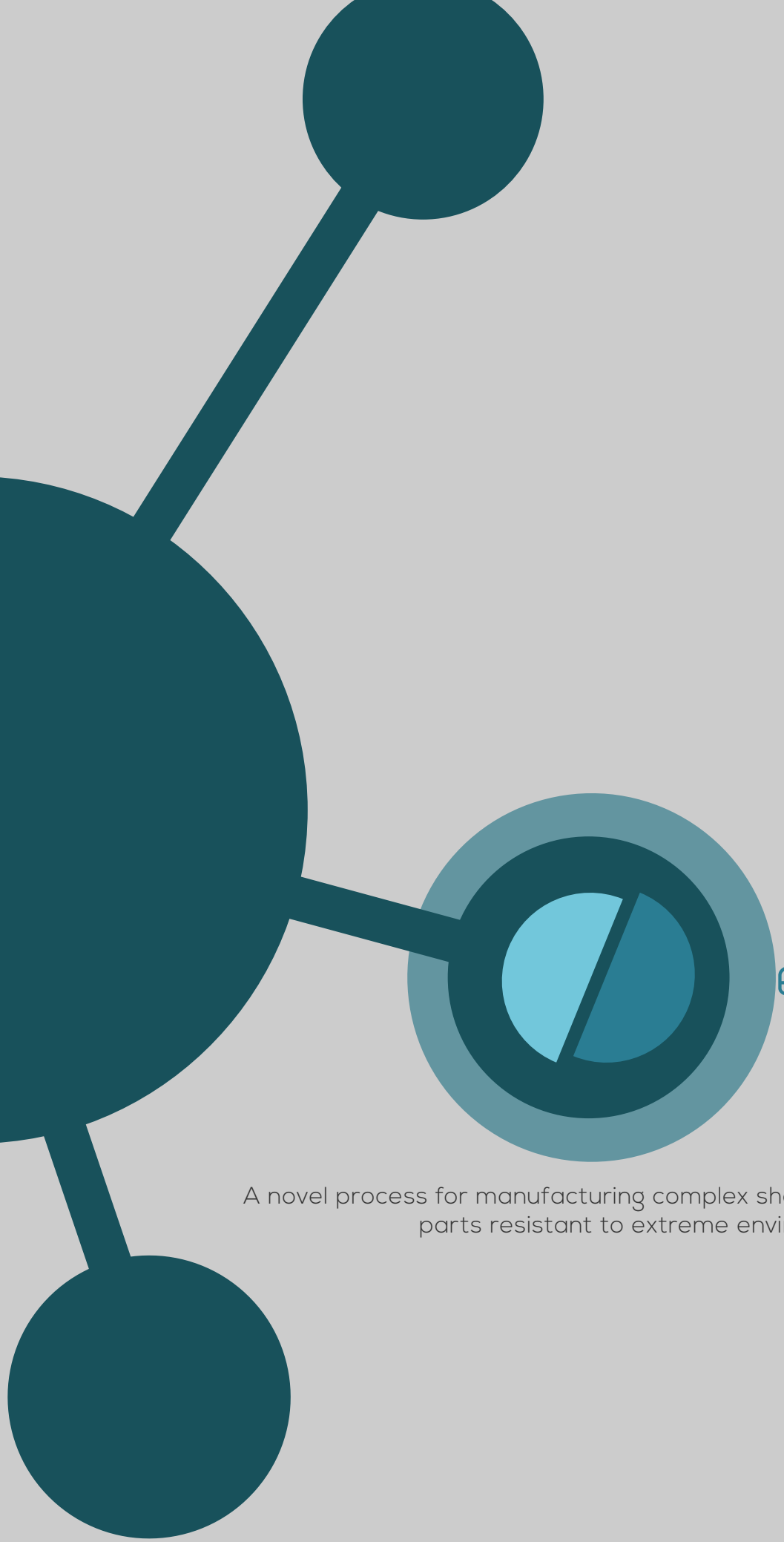

EQUINOX

A novel process for manufacturing complex shaped Fe-Al intermetallic parts resistant to extreme environments

Project background

After World War II some east European countries were facing severe problems to buy Cr and shortage Ni on the free market to cover their needs for stainless steel production and materials for high temperature using.

To overcome this shortage countries of Eastern Block initiated a research in national research institutions, universities and local industry in the 50s – 60s to develop low cost alternatives for heat resistant cast iron and stainless steel alloys based on intermetallics casted from accessible and cheap Iron, Aluminium and Carbon.

These efforts result in the past in the materials such as Thermagal© Tchugal© and Pyroferal©. Pyroferal© offered quite impressive results on high temperature corrosion resistance. It was tested against various severe conditions, such as air atmosphere, vanadium pentoxide, molten glass, carburization, nitration and the atmosphere of the natural gas cracking generators.

Though Pyroferal© was manufactured only by casting, welding was the important procedure not only to produce complicated shapes, but also to repair the faults in casts. Unfortunately, the practical use of these materials was limited due to various problems.

These problems related to instability and welding could not be overcome by state of the art in material science at that time.
In the 60s, access to Chromium was no problem any longer and the dust of history covered the knowhow on (pre-) industrial use of FeAl. But things may change again. Chromium and Nickel are listed in the table of CRMs with a current projected lifetime of 25 - 100 years.

Project overview

EQUINOX tries to blow away the dust of history from this early work on FeAl, aiming to combine latest state of the art in intermetallic metallurgy to overcome the problems that our ancestors were facing when they failed to translate unique corrosion and wear properties of FeAl into a low cost Cr/Ni-free alternative for stainless steel products.

There is a need to find solutions to replace Critical Raw Materials (CRMs) such as Chromium, Nickel, Molybdenium and Vanadium in high volume end consumer products. Steels and superalloys with considerable amounts of these CRMs are widely used in many industrial applications, particularly under extreme conditions where corrosion and wear resistance are needed.

It is generally accepted, that intermetallics in particular low cost FeAl offer outstanding material properties. Unfortunately it is difficult to translate their properties to real products, as intermetallics suffer from low ductility at ambient temperature and poor machinability.

The impact of FeAl intermetallics as a low cost Cr-free alternative for stainless steel would therefore be much higher if a cost effective industrial process would beavailable, that allows to manufacture complex 3-D geometries of almost unlimited shapes from small grain size (0.1-5 µm) high ductility material.

Objectives

The main objective of EQUINOX is to develop a novel process that allows to substitute Cr/Ni based (stainless) steel parts used in high volume end consumer products such as in the lock industry, electronics, process industry and automotive industry with a novel near net shape production technology for a new class of highlyadvanced ductile Fe-Al based intermetallics.

To produce extremely fine grained FeAl-Material with high ductility via reactive infiltration of porous iron preforms with liquid Aluminium.
To understand how ultrafine particle based porous iron structures of complex 3D-shape may be tailored to be used as optimized preforms for reactive infiltration of liquid Al-alloys.
To develop a reactive infiltration process by using two different techniques: suction and centrifugal casting.
To simulate reactive infiltration process by physically based multi-scale models based on StarCast and MICRESS.
To optimize mechanical properties of **EQUINOX** material with respect to microstructure based on process conditions and consecutive heat treatment.
To scale up the process from lab to small pilot plant with respect to the industrial needs.
To transfer the concept to at least one real demonstrator which will be tested for high corrosion and wear resistance.
To evaluate the industrial impact of **EQUINOX-concept** with respect to economic as well as technical aspects.l.

Project Partnership

Eleven partners participate in the EQUINOX project, representing academic, applied research and industrial development.

NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NTUA)
Greece

ELASTOTEC GmbH ELASTOMERTECHNIKEN (ELASTOTEC)
Germany

FUNDACION IMDEA MATERIALES (IMDEA)
Spain

KOCHANEK ENTWICKLUNGSGESELSCHAFT (KE)
Germany

TECHNICKA UNIVERZITA V LIBERCI (TUL)
Czech Republic

ACCESS e.V.
Germany

INNOVATION IN RESEARCH AND ENGINEERING SOLUTIONS (IRES)
Belgium

FRENI BREMBO Spa
Italy

YUZHNOYE DESIGN OFFICE NAMED AFTER MIKHAIL YANGEL
Ukraine

OPEN SOURCE MANAGEMENT LIMITED (OSM)
United Kingdom


OSM
IRES
ELASTOTEC
YUZHNOYE
design office
access
TECHNICAL UNIVERSITY OF LIBEREC
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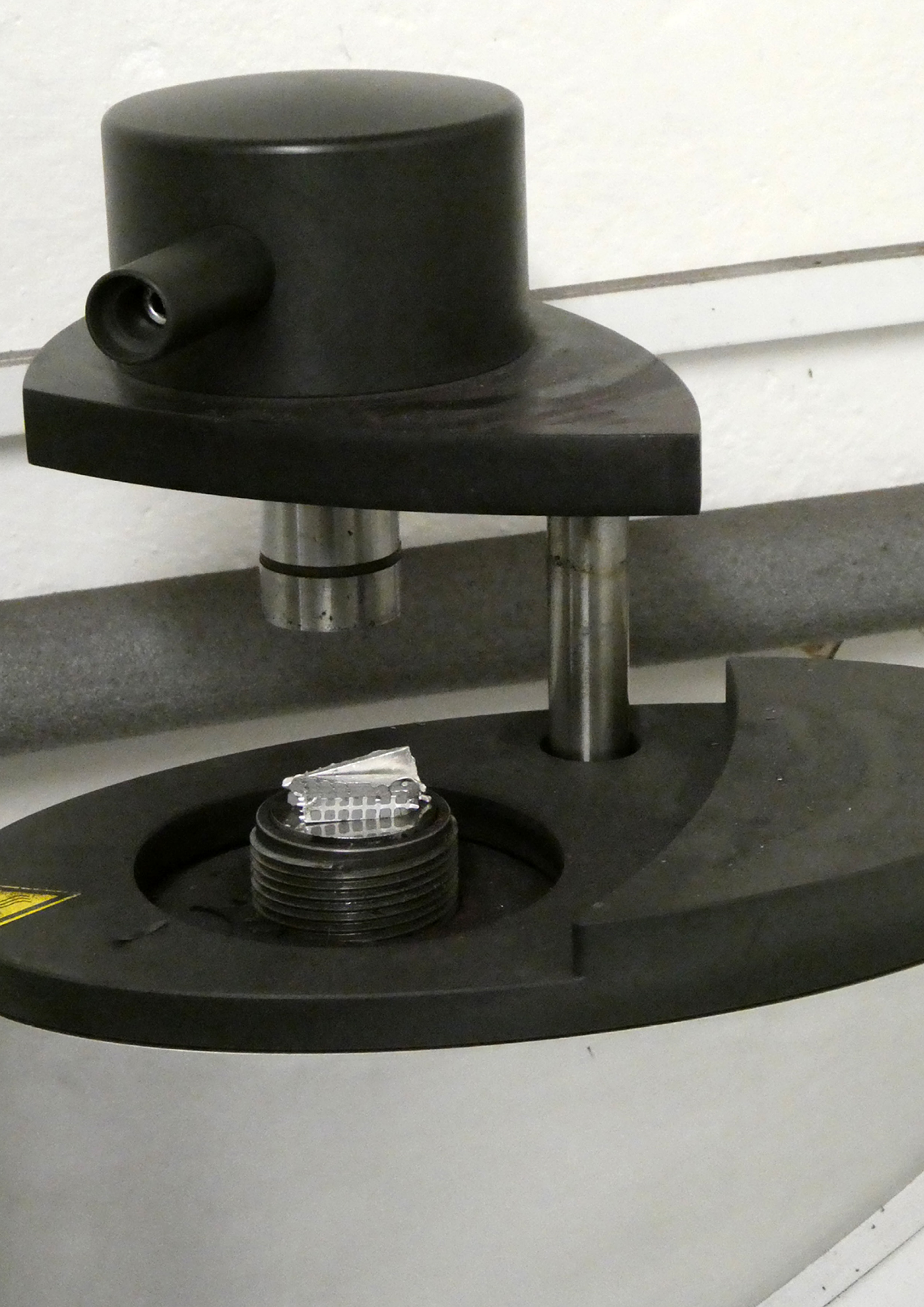
materiales
brembo

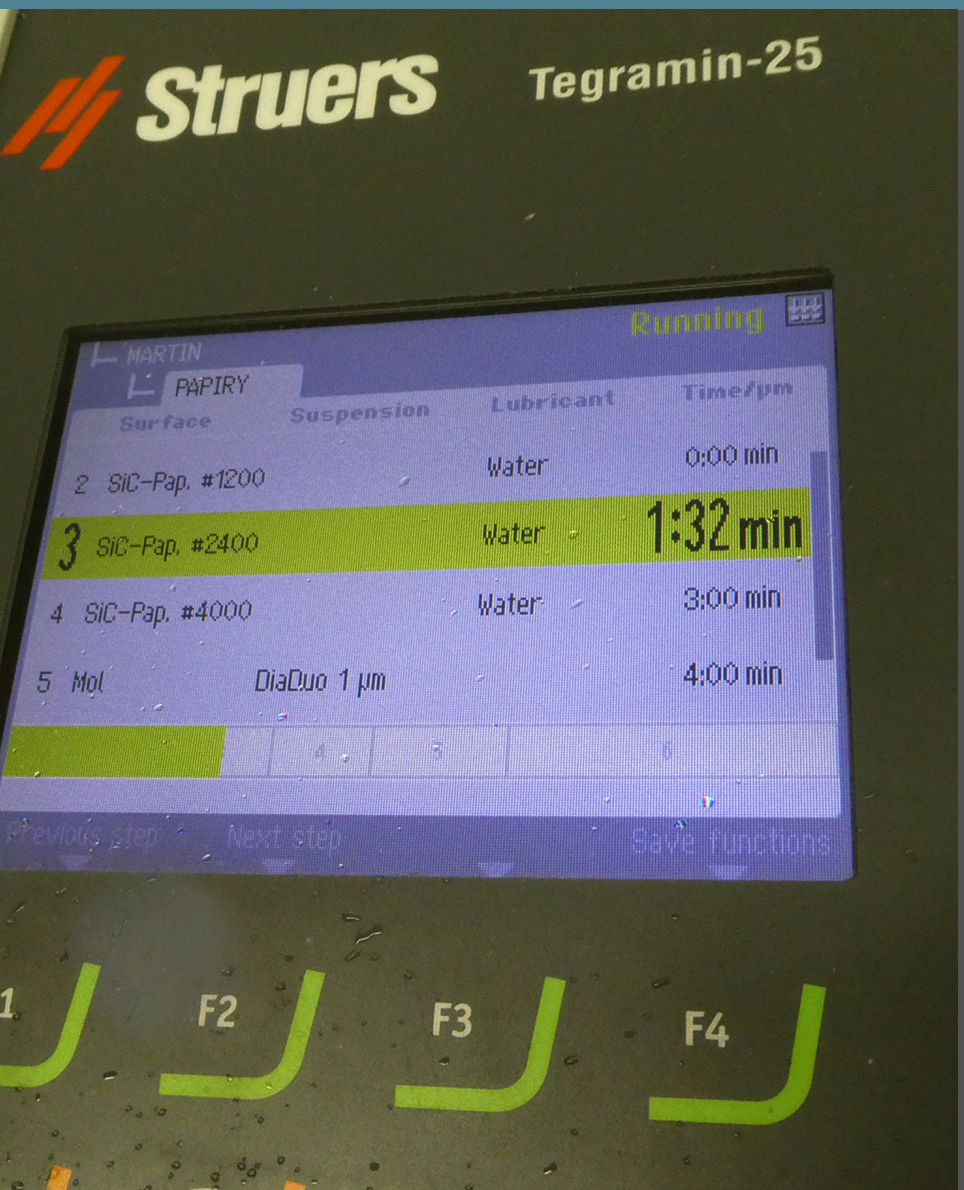
TECHNICKA UNIVERZITA V LIBERCI (TUL)

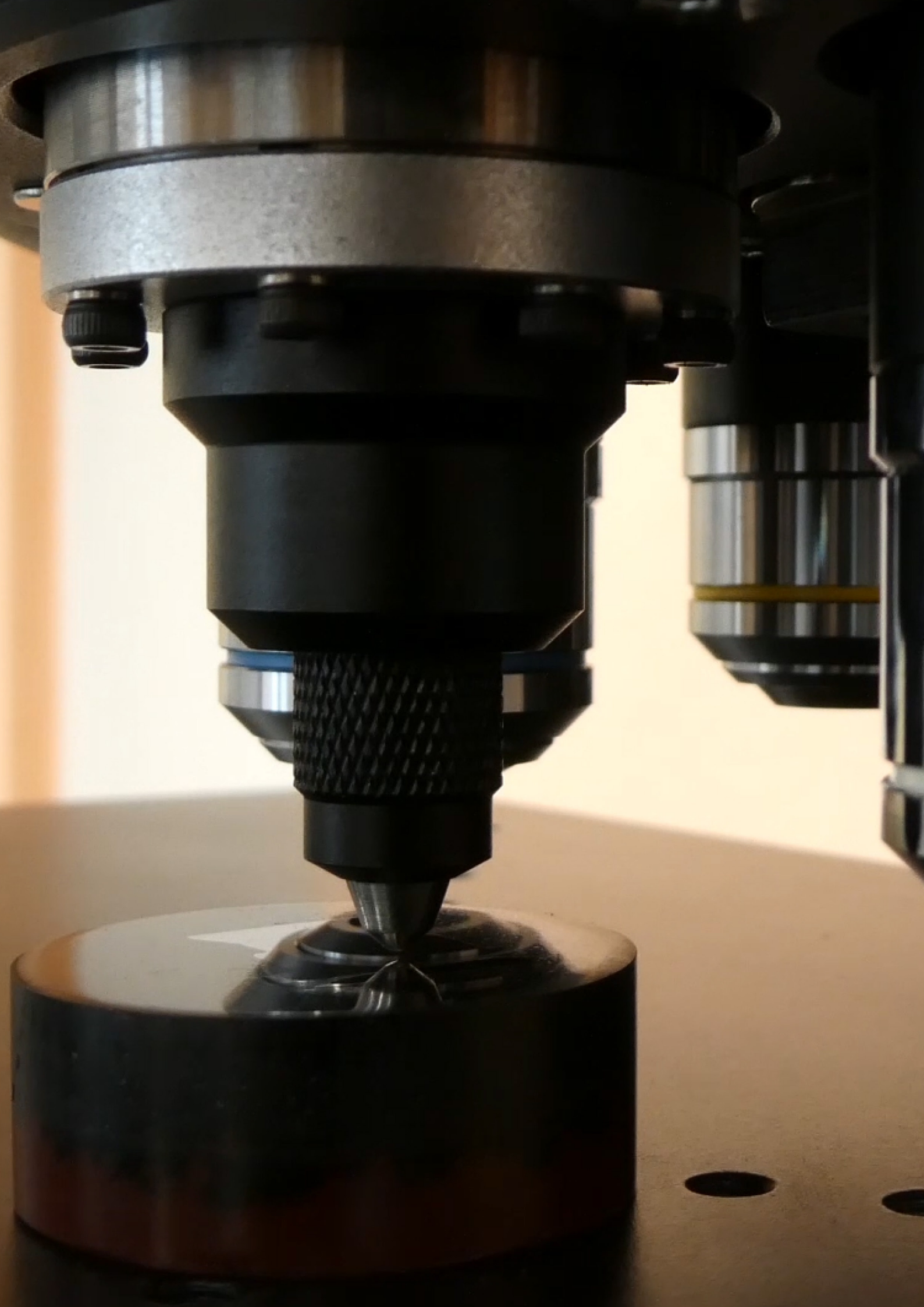
Photos from TUL laboratories



TECHNICKA UNIVERZITA V LIBERCI (TUL)

Photos from TUL laboratories





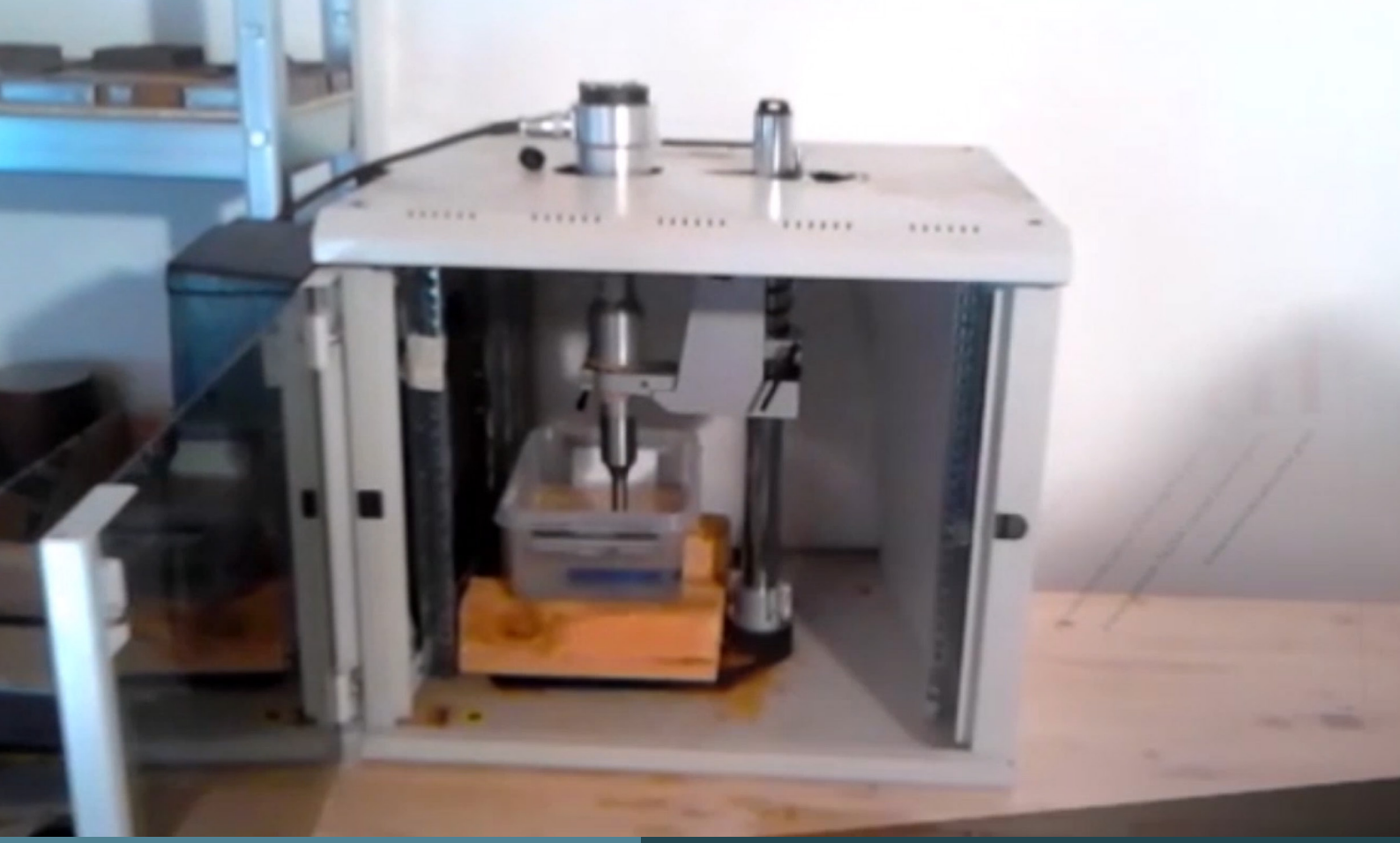
KOCHANEK ENTWICKLUNGSGESELSCHAFT

It was known from the literature that iron aluminides offer very good cavitation erosion properties. To prove this for ironaluminides developed in Equinox, we established a sonochemical cavitation erosion test according to ASTM Standard G32-92. We measured cavitation erosion resistance of ironaluminides as well as all kind of materials for comparison reasons. To get more precise data we developed a slightly modified test procedure to take up a more detailed mass loss vs. time curves. From this experimental data we extracted only the regions of periods of the strongest attack. Based on this we calculated a theoretical value for cavitation erosion resistance that worked surprisingly precise for the comparison of materials. It is planned to publish these results in the future within a scientific journal.

Cavitation Erosion Tests

Photos from KE laboratories

To be able to compare the materials it is crucial that all samples are absolutely dense (no porosity) and that they have been prepared and treated exactly the same way. It is necessary to measure a broad variety of different materials with the same setup to be able to make comparisons of material qualities.



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Photos from KE laboratories

A new material will always be characterised by a multitude of techniques. It could be demonstrated that sonochemical cavitation erosion test is able to deliver more precise data than is usually expected from this method- if it is done the way we did it. Therefore our technique might impact science of cavitation erosion characterisation- especially characterisation of intermetallics.

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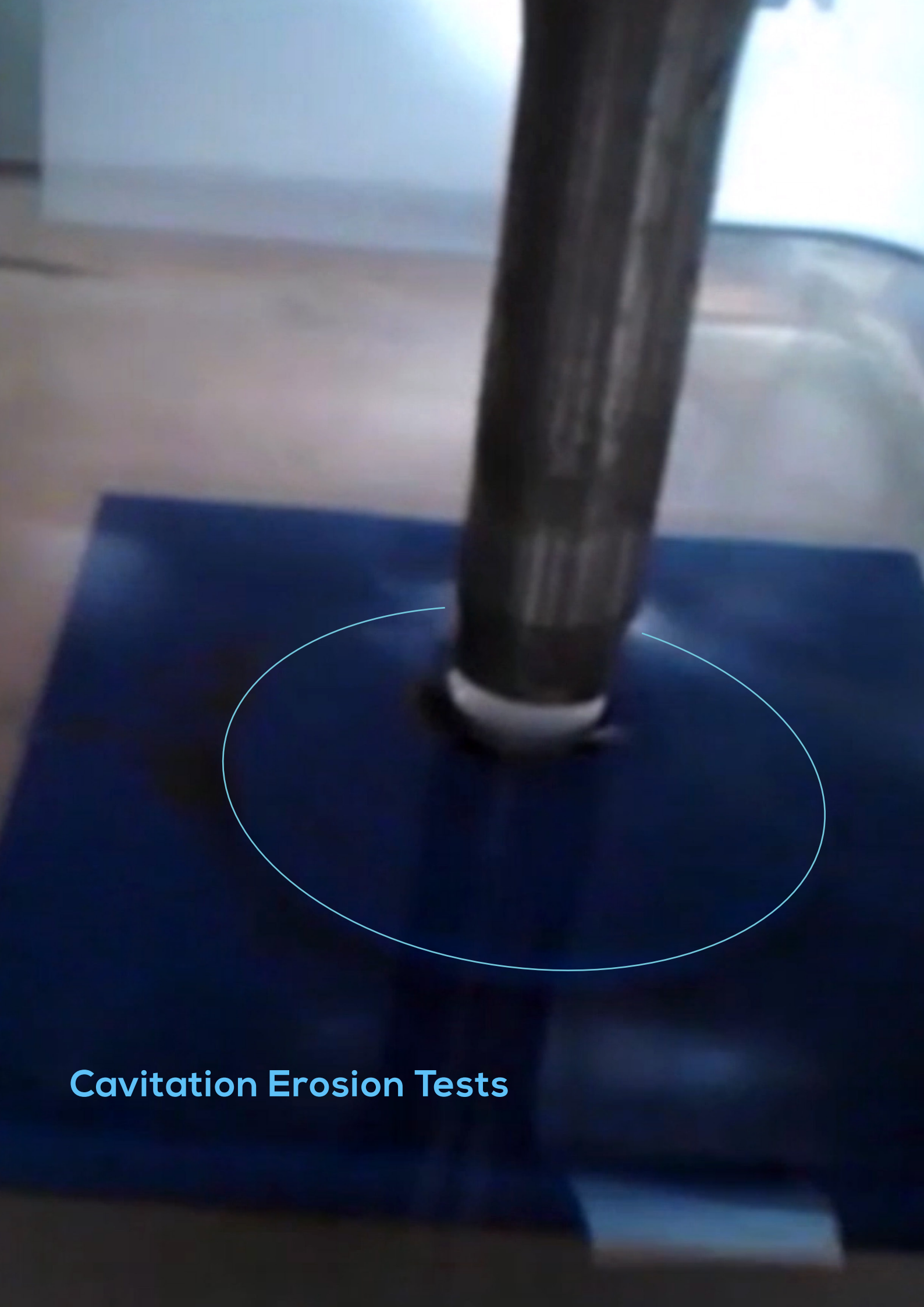
The research started in M12 of the project at partner CES and was continued from M 18 on at KE.

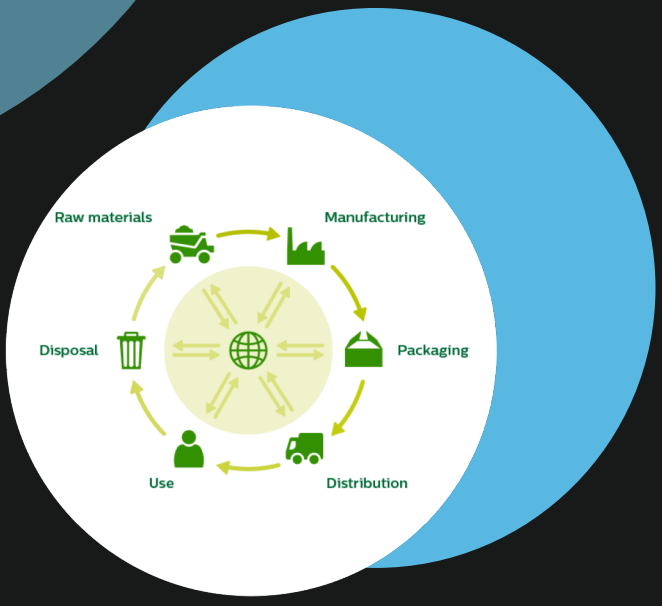
We already have measured a broad variety of materials and therefore have a sound database for comparisons. We will continue to expand this database by measuring interesting materials developed outside Equinox.



Cavitation Erosion Tests

INNOVATION IN RESEARCH AND ENGINEERING SOLUTIONS (IRES)

IRES at a glance..**The LeaDeRS approach**
In IRES, the **whole lifecycle** of products is considered, through **a holistic evaluation** of s**ocial, environmental** and **economic aspects** based on EU standards and regulations.



Life Cycle Assessment (LCA):

LCA enables a rather scientific assessment to be used and transformed into a practical decision making tool, which facilitates locating possible changes associated with different stages of the manufacturing cycle. Moreover, LCA results can be extended in order to include financial information. This is how we effectively improve strategy plan regarding the manufacturing of products and materials, from lab to fab scale.

Data Management (DM):

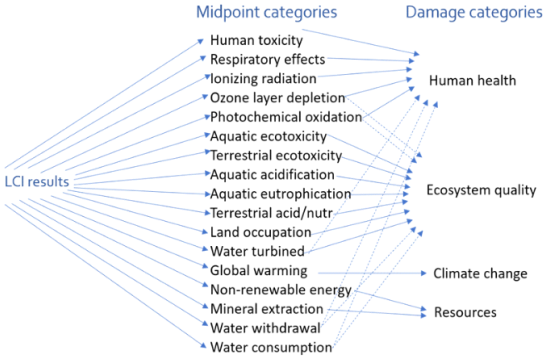
Materials data management eases the efficient mining and potential for further processing of large materials data sets, resulting in the extraction and identification of high-value materials knowledge, towards design and manufacturing.
This is accomplished by using linkages of process-structure-property (PSP) information, with the main focus of data transformations to be in the forward direction (process -> structure -> properties). As therefore high-value information requires to be linked with the manufacturing and product design routes, the main challenge is, starting from a proper data management plan, to design and build the needed databases stems (tackling challenging issues such as rich internal materials structures that span multiple length scales).

Risk Assessment:

Risks associated with hazards are consistently and formally identified, evaluated and managed within acceptable safety requirements. With the use of specific safety tools, we identify and evaluate the possible risks associated with processes and finally propose special control measures in order to increase the level of mitigation actions in case of (un)foreseen risks. Control banding, tiering, prioritisation are only few of the means.

Safety Recommendations:

Safe-by-Design approaches in the early stages of projects are implemented, emphasizing on the decision-making process regarding design, materials used and methods in order to enhance the safety of final products and control the related health risks. Following REACH compliance and depending on each case needs we provide specific guidelines regarding safe handling with nanomaterials, chemicals, medical devices, biological substances etc.



Life Cycle Assessment (LCA) :
has been applied to seven **EQUINOX** processes, which produced different end products with different technologies and methods.

LCA is an integrated approach to minimizing environmental burdens through the life cycle of a process and end product

LCA assessment is based on the so-called dominance analysis where environmental problems / impacts are tracked back through the inventory table per process because substances, or group of substances, energy usage etc. which are considered to be major contributors to high scores in negative environmental impact categories, can be identified by processes or groups of processes responsible for high scores in negative environmental impact categories

LCA identifies possible opportunities and solutions for improving the products

Supports the choices which are environmental sounds, concerning what **EQUINOX** material will replace with the aim to emerge a more ecofriendly demo.

The results of the studied processes underline that the main negative impacts on all impact categories, both in the midpoint and endpoint, are due to the high consumption of electricity. An alternative solutionin order to minimize this negative impact, is to replace electricity with other sources that includes alternative forms of energy such as energy from biomass, solar energy, wind energy. This replacement could minimizes the use of fossil fuels. In general, all mechanical processes are energy-intensive because of the mechanical equipment they needed. By analyzing the LCA for the mechanical treatment of Fe3Al intermetallic compounds with hard metal tools, it was observed that the metal waste from the process can be recycled. Metal waste consists of Fe3Al cuttings and Fe castings of hard metal tools. Recycling is a life saving solution for the materials world, making the Fe-Al intermetallic compounds capable of being used as CRM substitutes, namely Cr-Ni in stainless steel parts. In addition to the good mechanical properties of the intermetallic compounds that make them suitable substitutes, the recycled materials can be re-introduced into the system and reused.

NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NTUA)

NTUA had the following presentations:

Raw Materials Summit 2019 (EIT Raw Materials), 20-22 May 2019, Berlin, Germany. Title: "Towards a new route for the production of Fe-Al intermetallics"

Nanotexnology 2019, 2-5 July 2019, Thessaloniki, Greece.
Title: "EQUINOX and OYSTER: results from two projects with different strategies to data production and data sharing"

More info on Equinox-project

www.equinox-project.eu

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EQUINOX

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Topic: SC5-12b-2015 - Materials under extreme conditions

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