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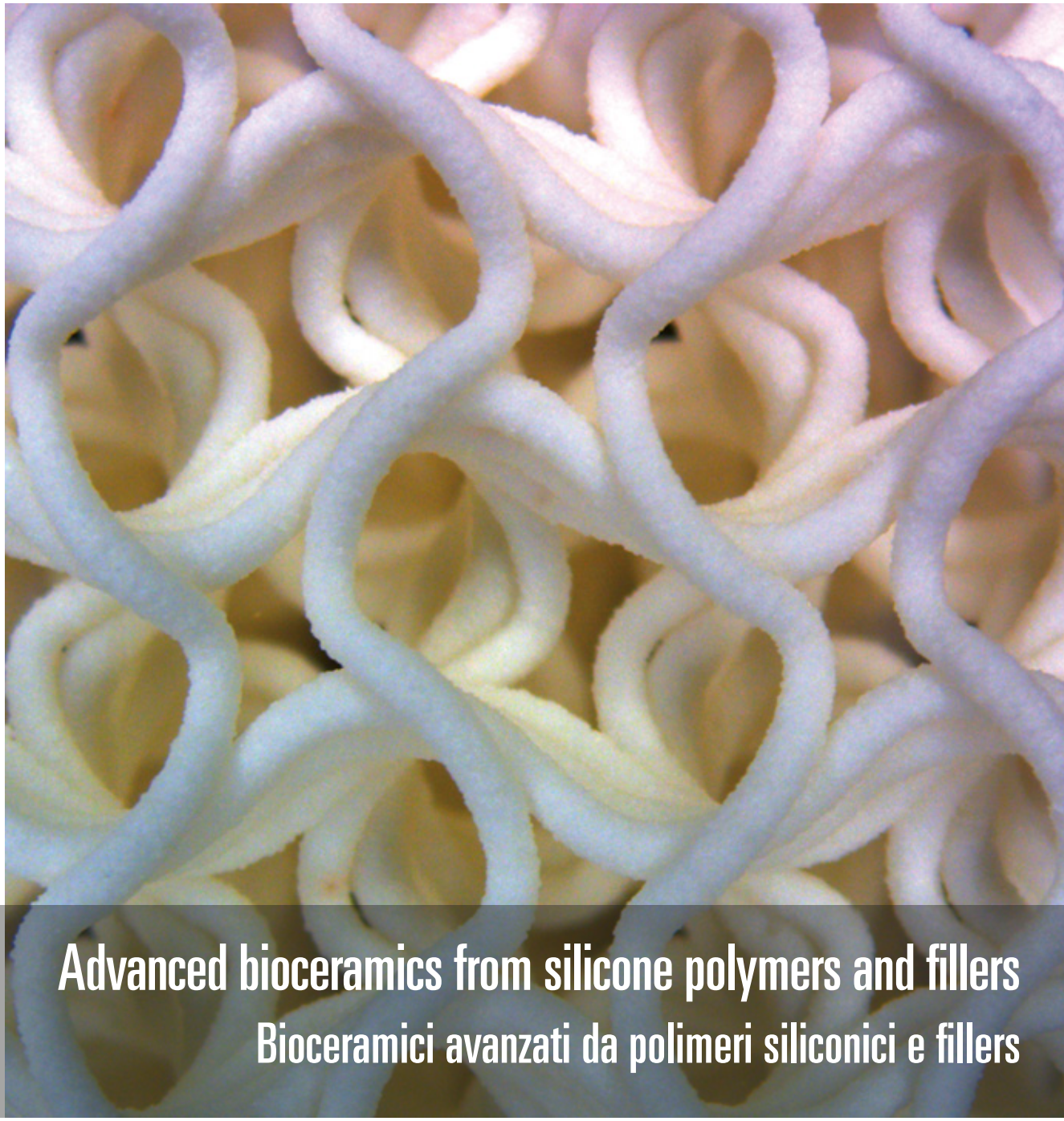
NEWSLETTER DEL DIPARTIMENTO DI INGEGNERIA INDUSTRIALE DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA



Advanced bioceramics from silicone polymers and fillers

Bioceramici avanzati da polimeri siliconici e fillers

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE
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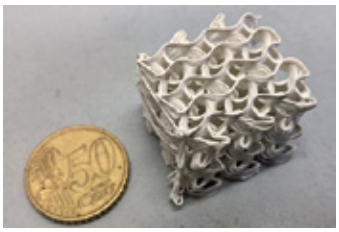

COPERTINA

Bioceramici avanzati da polimeri siliconici e fillers
Advanced bioceramics from silicone polymer and fillers

PAGINA

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Toward the development of a novel total artificial heart

Total Artificial Hearts (TAHs) are mechanical circulatory supports that replace biological hearts in case of refractory end-stage heart failure. TAHs are mostly applied as bridge-to-transplantation (BTT) devices, but they are currently receiving growing interests as destination-therapy (DT) solutions; indeed, many drawbacks are still limiting their wider exploitation (i.e. dimensions, power supply, cardiac output, …).

Through a preliminary FE analysis, the present work investigates three different ventricular chamber's geometries as possible innovative solutions for a novel TAH. The simulated material is a polycarbonate urethane (PCU), already known for its bio- and hemocompatibility.

The computational analysis aimed at a preliminary assessment the stress/strain state generated in the material during one systolic and diastolic cycle and an evaluation of the mechanical behavior of the device.

The investigated ventricular chambers are composed by three flexible compartments (Figure 1). The central compartment is separated from the lateral ones by means of two prosthetic heart valves that assure unidirectional flow. The actuation of the device operates the valvular planes moving them forward and backward. By alternate compression and expansion of the central compartment, the device will receive and eject blood. Lateral compartments are fixed at the edges, where they will be connected to patient's atrium and aorta (or pulmonic artery), respectively. The actuation will be performed by two rigid plates anchored to the valvular planes: plates will be moved by an external stator.

The simulations showed how to improve the design of the pulsatile chamber (Figure 2). Further analyses are needed to analyse the overall behavior of the device, before manufacturing a real prototype for the functional tests.

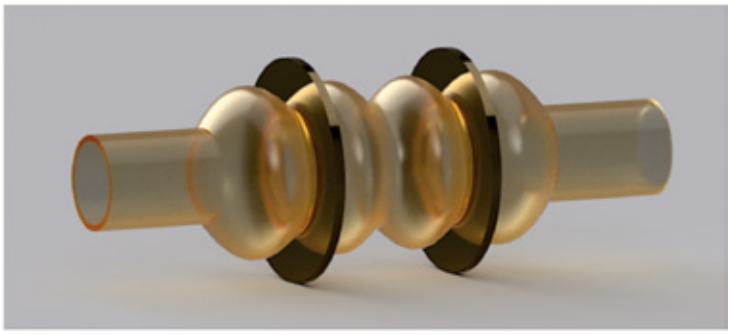

Figure 1. Example of ventricular chamber.

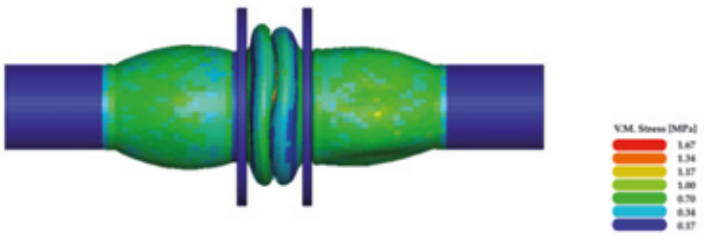

Figure 2. Example of the state of stresses simulated at the maximum compression of the central compartment.

Bioingegneria, biotecnologia e tecnologie per la salute

Bioengineering

DII research group
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The research activity has been carried out in collaboration with:

Prof. Gino Gerosa
Dr. Assunta Fabozzo
Dr. Valentina Candela
Dr. Martina Todesco

Main research topics:

- Development of numerical and experimental methods to evaluate the structural durability of mechanical components and structures
- Static mechanical characterization and fatigue of metallic and polymeric materials
- Development of local approaches for structural analysis and fatigue design of components and structures weakened by defects and notches
- Innovative biomaterials
- Biomechanical characterization of animal pericardium for prosthetic heart valves
- Functional assessment and classification of mechanical heart valve prostheses
- Analysis of skin perfusion by laser Doppler fluxmetry

Energia

Energy

DII research group
Turbomachinery and Energy System Group (TES)

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The research activity is carried out in collaboration with the Turbomachinery and Energy System Research Group (TES).

Main research topics:

- Design and Optimization of Large-Scale Thermal Energy Storage System
- Fossil Fuels based Power Generation Unit Flexibilization
- Power Generation Units Dynamic Analysis
- Waste Heat Recovery Units Design and Optimization
- Hybrid Power Generation System Optimization
- Life Cycle Assessment
- Biogas Engine Emissions Characterization
- Application of sono-cavitation for the concentration of CO_2 in a liquid flow

Life Cycle Assessment of an organic Rankine cycle unit coupled with a biomass boiler

Biomass is a renewable energy source that largely contributes to gross final energy consumption and total primary energy supply. It guarantees a stable and programmable production of heat, electricity or a combination of them. The most adopted layout to generate heat and power comprises an organic Rankine cycle (ORC) unit coupled with the biomass boiler. But, despite biomass renewability, it is mandatory to evaluate the environmental impact of this plant arrangement considering the entire life cycle. To this purpose, the life cycle assessment (LCA) analysis is used to determine the global environmental performance of a commercially available combined heat and power (CHP) organic Rankine cycle unit coupled with a biomass boiler. Data collected during 5 years of plant operation are used for the analysis.

The plant is powered by woodchip of which about 40% is birch, 24% spruce, 20% pine, 14% beech and 2% oak wood. The timber comes from dedicated cultivation placed within a radius of 75 km from the plant. Freight trucks are used to wood carriage.

The ORC module adopts as working fluid a mixture of hydrocarbons with a GWP and an ODP equal to 950 and 0, respectively. The ORC is a regenerative sub-critical cycle where the useful heat is delivered as hot water at about 80°C. To avoid risky contact between biomass combustion products and the ORC working fluid an intermediate water loop is used.

The plant is modelled in SimaPro environment. Weights, materials and mechanical processing of plant's devices as well as organic fluid mass are inserted as input. The Figure shows a simplified tree representation of the system.

Results show that the most impacting processes in terms of CO_2,eq emissions are those related to biomass production and organic fluid leakages with 71% and 19% of the total. Therefore, being fluid release in the environment high impacting, a comparison among three different organic fluids is also performed. Analysis shows that adopting a hydrofluoroolefin fluid with a low GWP instead of the hydrocarbon fluid currently used in the cycle guarantees a significant improvement of the environmental performance.

Finally, the analysis found that the system uses about 7.3 kWh of biomass for 1 kWh of electricity, but also about 0.24 kWh of fossil fuels, mainly due to biomass transport, chipping and harvesting.

Simplified tree representation of the system in the life cycle assessment. Percentages and lines refer to CO_2,eq emissions.

A Travelling Wave Fault Location Method for Unearthed-Operated High Voltage Overhead Line Grids

In the Italian transmission grid, partly owned and managed by the Transmission System Operator (TSO) Terna, about 1940 km at 50-60 kV are still operated with unearthed neutral (differently from the high and extra high voltage networks which are always operated with earthed neutral). This grid has often radial structure and mainly consists of non-homogeneous and asymmetrical overhead lines, possibly with lateral and parallel lines. The most common failure mode in such transmission lines is the porcelain insulator cracking (see Fig. 1) which causes, at the nominal voltage, a phase to ground short circuit with a very low current magnitude This is very problematic for the TSO, since the involved lines are typically located in mountainous territories, which complicates the repairing operation. Therefore, in order to locate the faulty section, the current method applied by the Italian TSO consists in a visual inspection by helicopter or ground vehicle or alternatively in the outage of the entire faulted line, with consequent repowering until fault section identification.. The choice of the eventual method is a function of the weather conditions and the fault type. It is obvious that such methods are unacceptable in terms of costs and times. In order to overcome these problems, an on-line fault location method, which makes extensive use of travelling wave theory, has been developed in this work. The implemented procedure is based on the fault current signal digital processing, (see Fig. 2) by applying both the Phase to Modal Transform and the Continuous Wavelet Transform (CWT). This approach allows estimating the arrival times of the travelling waves to the line end and its propagation velocity. These quantities, together with the Continuous Wavelet Coefficients (CWC) magnitude are used to determine the fault distance.

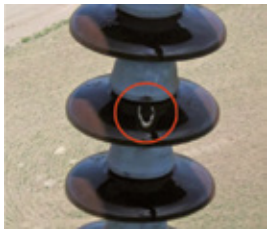

Figure 1: Insulator cracking

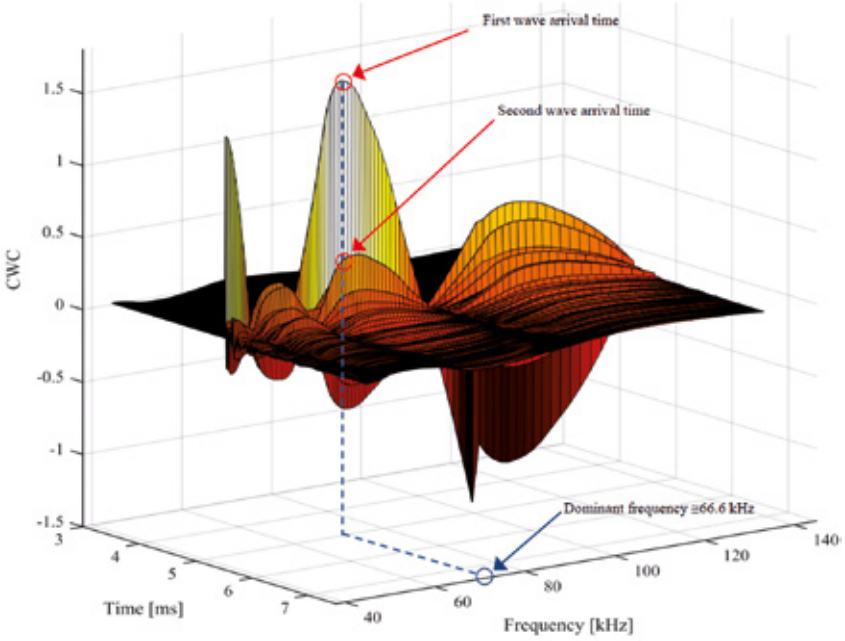

Figure 2: Fault current signal after the Phase to Modal and the Wavelet Transforms

Ingegneria dei sistemi elettrici
Electric engineering systems

DII research group

Electric systems for energy

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Terna Rete Italia
TERNA GROUP

The research activity is carried out in collaboration with Terna Rete Italia

Main research topics:

- Large-scale energy storage in the network
- EHV/HV dc and ac innovative transmission lines, e.g. insulated cables and gas insulated lines
- Synergy between railway and highway infrastructures and insulated cables
- Multiconductor cell analysis (MCA) of asymmetric systems by means of self-implemented matrix procedures
- Smart grids: the operation and control of active networks
- Voltage regulation in the distribution network with high penetration of distributed generation

Sicurezza ambientale
e industriale
Environmental and industrial safety

DII research group

DECON/DEMIL

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Contratto di ricerca DII - UNIFRONT
Spin-off dell'Università di Padova,
Prot. N. 1742/III/1943, 17/05/2018

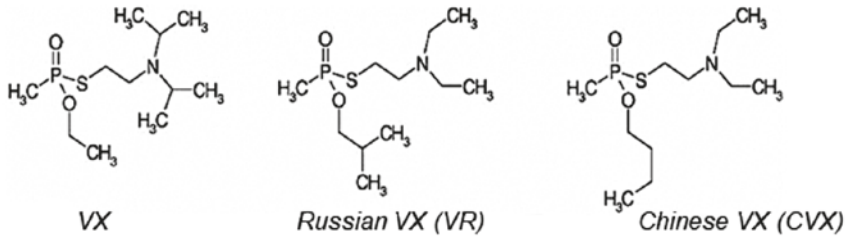
UniFRONT srl
Spin-off dell'Università di Padova

Degradation of the Chemical Warfare Agents VX, Russian VX, and Chinese VX by BX24

As has been evidenced in the case of the Novichok nerve agent attack in Salisbury, UK in March 2018, the environmental impact of incidents involving Chemical Warfare Agents (CWAs) requires highly-trained chemical operations personnel and reliable decontamination systems. In order to improve the understanding of the CBRN decontamination system BX24, a study was carried out on the degradation effects of three highly toxic nerve agents: VX, Russian VX (VR) and Chinese VX (CVX).

Introduction

Nerve agents are considered the most nefarious of synthetic chemical derivatives. They are potent acetylcholinesterase (AChE) active agents, differentiated from other chemical warfare (CW) type agents, because of their phosphorylating mode of action, derived from their organophosphonate structure (RO(O=P(R')OR").
The V-agents, VX, CVX, and VR, are highly toxic and are classified as a schedule 1 chemical as defined in the Chemical Weapons Convention.



Several evidence suggest acetylcholinesterase (hAChE) have a different stereo selectivity for V-agents: VX, Russian VX (VR), and Chinese VX (CVX).
The BX24 Decon product when dispersed in water forms a colloidal suspension used to neutralize Chemical and Biological Warfare Agents. Degradation of the VXs is strongly dependent on the chemistry of the medium in which it resides. An issue of concern is that one VXs degradation pathway, hydrolysis of the P-O bond, produces S-2-(diisopropylaminoethyl) methylphosphonothioic acid (known as EA2192), a by-product that is almost as toxic as VX.

Decontamination

Incidents involving military-grade organophosphorus compounds, decontamination methods are required to restore the initial condition. For this research an evaluation of the decontamination performance of BX24 decontamination mixture efficiency against Russian and Chinese VX in comparison with standard VX. In addition the presence of the EA2192 after decontamination was considered.

The evaluation of the activity of BX24 decontaminant is based on the In Vitro reactivity test. The desired CWA/BX24 ratio 1/100 corresponds to the expected worst case scenario of contamination equipment in accordance with NATO Standard.

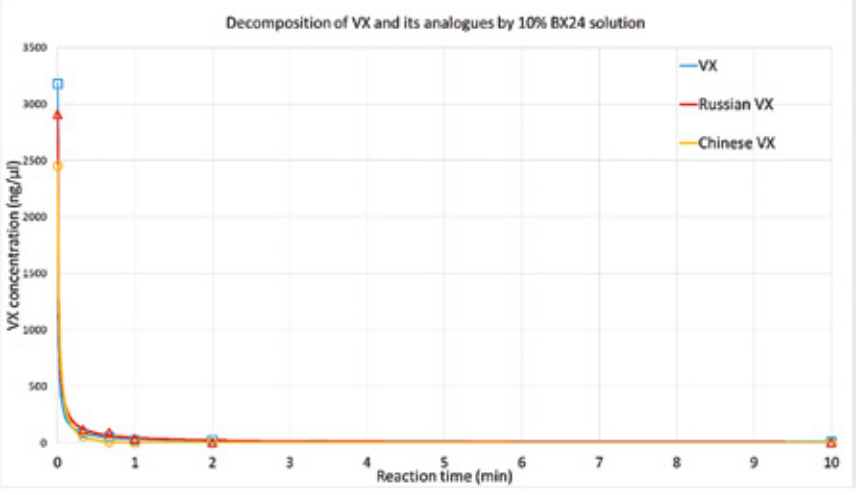
CW Agents and purities
VX O-ethyl-S-(2-isopropylaminoethyl) methyl phosphonothiolate, CAS 50782-69-9, **85.62%**
VR O-isobutyl S-2-(diethylamino) ethyl methylphosphonothioate, CAS 159939-87-4, **97.51%**
CVX O-butyl S-[2-(diethylamino) ethyl] methylphosphonothioate, CAS 1000273-60-7, **99.01%**

The CWA residuals in the extracts were quantified by the GC with FPD or FID detectors. GC/MSD and LC MS/MS were used for identification of degradation products and confirmation of the decomposition of the CWA molecules.

The figure below summarizes the average agent residual concentrations in the extracts for all reaction times.

Summary

The experimental results of In Vitro reactivity tests demonstrate the excellent decontamination efficiency of the decontamination system towards the VX chemical warfare agents family, VX, Russian VX, and Chinese VX. The tested CWA/BX24 ratio 1/100 represents the worst case scenario when 1 litre of 10% BX24 mixture is used to decontamination of 1 m² of surface contaminated with 10 g/m² of VX. The results proved that under these conditions the 99% of initial amount of VX and its analogues is decomposed within the first minute. The amount of VX residuals decreased below limit of detection within 20 minutes, in case of Chinese analogue within 1 minute.
The GC-MSD or LC-MS/MS analysis of products of decontamination reactions did not reveal the formation of toxic EA-2192 or its analogues.



Degradation kinetics of VX, Russian VX (VR), and Chinese VX (CVX) by BX24.

Main research topics:

- WMD proliferation and non-state terrorist or criminal use of CBRNE
- Environmental Remediation and Recovery

Research topic:

Electrical systems engineering

DII research group

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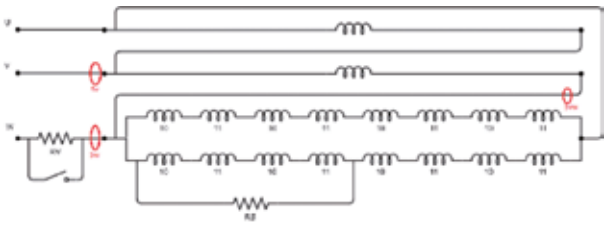
Main research topics:

- Electromagnetic analysis and optimization of electrical machines
- Simulation of integrated systems for the electrical energy generation, conversion, and storage
- Techniques for the electrical machine diagnostics
- Neural networks

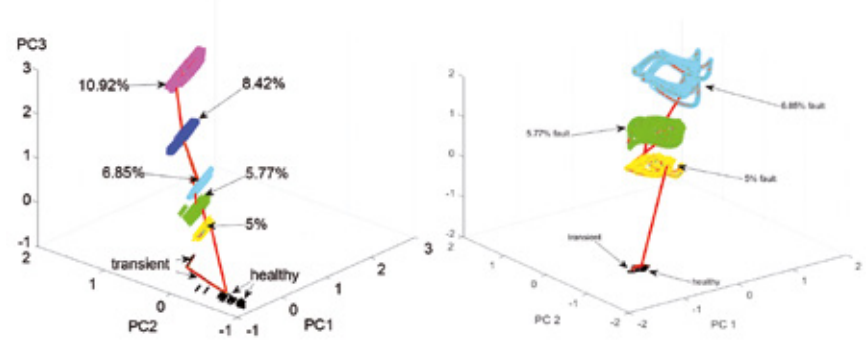
Diagnosis of Induction Machines using GCCA Neural Networks

This project is directed at improving concepts which relates to maintenance of Induction Machines (IMs) which are widely used in both industry and energy sectors. Anomalies in the IMs give rise to the non-stationary distribution in the data flow which is difficult to detect in real time systems. We propose a Growing Curvilinear Component Analysis (GCCA) Neural Network to identify and track the stator inter-turn fault (SITF) severity in IMs. The identification of a SITF is of utmost importance because the inception of insulation failure originates from an inter-turn short circuit in the windings that induces high current flow.
The GCCA neural network has been applied to temporal features derived from the extended Park vector current related to the 3-phase signals measured on IMs with different ratings and winding connections.
Prior the data topology has been analyzed by linear and non-linear techniques to deduce the correct intrinsic dimensionality. Unlike other neural networks which need constant parameters in order to track non-stationarity, GCCA does not only recognize the pre-fault situation, but also records the whole story of the machine, tracking the non-stationarity in the stream of data generated in the input space and to project it in the latent space (a lower dimension space).
Under all loading conditions (figure below), the bridges are well connected where there is a transition from Healthy to faulty region. The bridges also denote the transition from one level of fault severity to another. This is observed in all the cases upon quantization of data using GCCA.
In applying fault diagnosis and condition monitoring to the IM, the results show that GCCA is able to capture and learn the transitions from healthy to faulty cases with changes in load and in the fault severity. GCCA is a very fast and accurate indicator when it comes to tracking the fault level. By using the notion of bridges, any damage to the IM can be avoided by stopping its operation.

Test bench (37 kW IM)



Stator winding circuits: measurement layout and single branch circuit model representing the SITF



Data and GCCA quantization with different fault severities using bridges (in its first 3 principal components): (left) No Load, (right) 40% Load

Interface fires in built-up areas. A real-case study on the risk assessment of fires interacting with urban domains

Fire scenarios may pose serious risks and induce severe damages to anthropic structures, activities and business. These can be represented by typical fires in industrial facilities or also atypical scenarios involving differentiated targets as in the case of interface fires.

Risk assessment of atypical scenarios requires improved approaches since a multi-risk framework can arise including the interactions between the fire and surrounding domains (figure 1). An effective hazard investigation and management should therefore include estimations of consequences based on the results of models' simulation.

The present study deals with a preliminary risk assessment methodology applied to fires interacting with an existing urban area (WUI fires). The fire spread is approached through a dedicated tool and a GIS (Geographic Information System) -based system is used to spatially map expected consequences. Starting from these data, a preliminary risk estimation is proposed with the aim of mapping hazardous areas. In this sense, a combined approach based on fire simulation tools and exposure functions is employed.

Major risk areas for specific targets are identified in terms of risk contours (figure 2), and expected results can be used to support land planning and emergency-related operations.

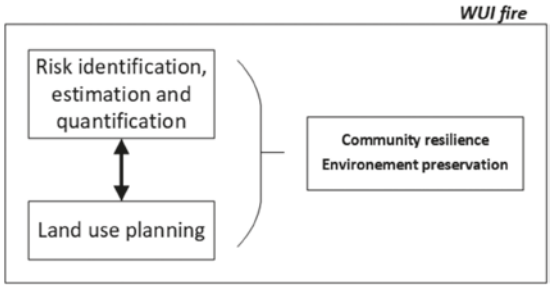


Figure 1. A synergistic approach between risk assessment and land use risk-driven planning may improve the community resilience against WUI fire occurrence.

Figure 2. Risk contours based on thermal effect on permanent light structures. (red contour: high risk, orange contour: medium risk, yellow contour: low risk).

Sicurezza ambientale e industriale
Environmental and industrial safety

DII research group

Safety group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This work was funded by the European Commission (project Interreg V-A Italy-Slovenia 2014-2020 CROSSIT SAFER) within the European Territorial Cooperation program INTERREG.

Main research topics:

- Risk analysis in the process industry
- Reliability and safety in the chemical industry
- Analysis and mitigation of emerging risks in critical infrastructures for energy supply
- Development of early warning systems for fugitive reactions
- Computational Fluid Dynamics modeling and analysis of industrial accidents (fire, toxic releases)
- Innovative techniques for risk assessment in Green Chemistry
- Interactions between seismic risk and natural risks and consequences induced on industries and critical infrastructures

Ingegneria dei sistemi meccanici

Mechanical systems engineering

DII research group

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Turbomachinery and Energy System Research Group

Main research topics

- Optimal design and management of hydro and pumped-hydro power plants
- Design and optimization of hydraulic and wind turbines (VAWT and HAWT)
- Cavitation, instability and pressure pulsations in turbomachines at design and off-design operation conditions
- Design and management optimization of energy systems by means of multi-criteria methods, Life Cycle Assessment (LCA)
- Gas turbines: development of numerical codes for performance prediction
- Aerodynamic optimization of rotors of helicopters and of high efficiency profiles isolated and detached

CFD-based optimization of scroll compressor design and uncertainty quantification of the performance under geometrical variations

Positive displacement (PD) machines have a wide range of applications in modern engineering problems (e.g. Organic Rankine Cycles, ORCs). Among the several type of PD machines available, scroll-type expanders/compressors are receiving more and more attention for their large operational range, reliability, compact structure, low number of moving parts and low level of noise and vibrations. Unlike standard approaches mainly driven by thermodynamic analysis and theoretical correlations, a CFD-based innovative design strategy to maximize the scroll efficiency by optimizing geometrical details was investigated. Three have shown a major impact on the machine performance: the orbit radius, number of wraps and the discharge port size. In particular, small orbit radius combined with large discharge port size resulted to maximize the scroll efficiency (Figure 1). As regards the number of wraps, it should be chosen so as to avoid under compression operating condition for the scroll. Minor effects have been reported because of the variation of the spiral thickness.

The high efficiency area found in the current work has two positive aspects. First, the flatness of the response surface close to the best efficiency point, meaning that the machine is able to accommodate other types of constraints (e.g. the size of the discharge port) within a relatively large range. Second, the small sensitivity of this area to small input variations in terms of manufacturing imprecision.

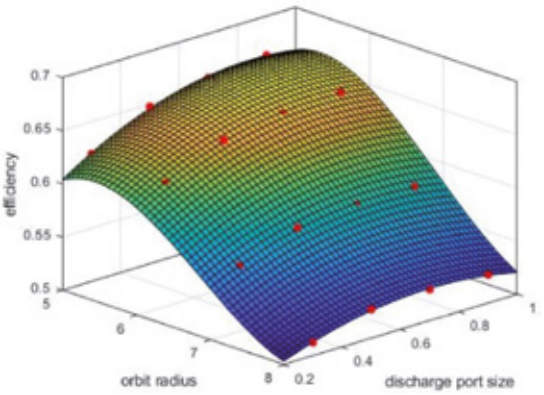


Figure 1: Scroll efficiency vs. obit radius and discharge port at constant angular velocity

A separate optimization has been carried out on the shape of the discharge port, showing a not-circular shape is more suitable for the compression dynamics. The results show that overall a bigger area is insensitive from the port shape. When for manufacturing or integration constraint the area is smaller, it is better to have a port with higher length, that follows the shape of the edge of the scroll (longer bean shape). The variation of the efficiency due to the parameters used for its definition is reported in the Figure 2.

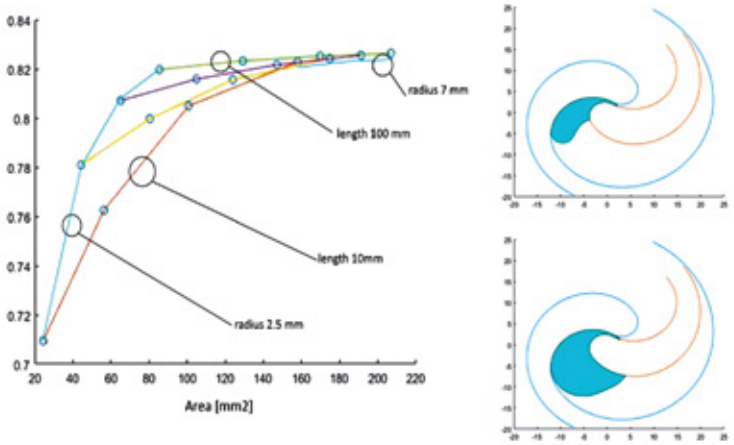
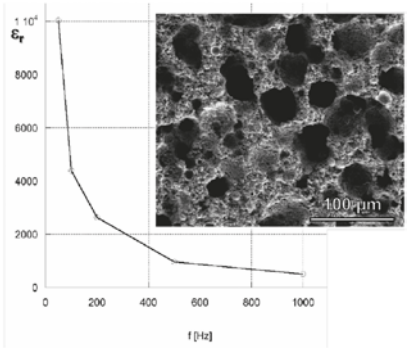


Figure 2: Results of the optimization of the scroll discharge port. Scroll efficiency vs. discharge port area and shape (port length and inner radius)

Up-Cycling of Iron Rich Inorganic Waste in Functional Glass-Ceramics

The intensive mechanical stirring of suspensions of recycled glass and inorganic waste powders in 'weakly activated' aqueous solutions (e.g. 2.5-3 NaOH) has been established as a first step for obtaining highly porous glass-ceramic foams, followed by viscous flow sintering, at 800-1000 °C. Since the foaming does not occur upon sintering, the firing aims just at the consolidation of glass powders with concurrent incorporation of pollutants from iron rich waste, such as fly ash from coal combustion (FA) and residues from the Bayer processing of aluminium ores ('red mud', RM). Engineered mixtures lead to chemically stable foams, from treatments in air, according to several leaching tests. Treatments in nitrogen are even more significant, since they extend the conditions for stabilization and determine novel functionalities. In fact, treatments in nitrogen promote the formation of relatively silica-poor silicate crystal phases, even operating with soda-lime glass; the enhanced silica content of the residual glass phase justifies the higher durability. In addition, the change in the atmosphere favours the formation of magnetite (Fe_3O_4), in turn enabling novel functionalities, such as ultra-high dielectric permittivity and ferrimagnetism.

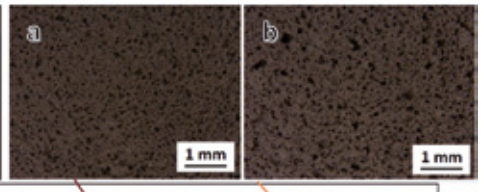
Oxide (wt%)	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	Fe_2O_3	TiO_2
FA	54.36	24.84	0.83	3.03	2.56	2.06	8.28	1.07
SLG	70.5	3.2	12	1	10	2.3	0.42	0.07



Element	800°C	1000°C	INERT
As	0.0521	<0.0049	0.5
Ba	<0.000	0.0002	20
Cd	<0.0002	<0.0002	0.04
Cr	<0.0004	0.0004	0.5
Cu	0.0023	0.0054	2
Hg	<0.0004	<0.0004	0.01
Mo	0.0158	<0.0033	0.5
Ni	<0.0014	<0.0014	0.4
Pb	<0.0047	<0.0047	0.5
Se	0.0194	0.0230	0.1
Zn	<0.0203	<0.0203	4

Fig.1 - Foam (70% porosity) from 64% FA + 36% Soda lime glass (SLG) sintered at 1000°C, with related leaching data and permittivity vs. frequency plot

	RM
SiO_2	5.2
Al_2O_3	15.2
Fe_2O_3	52.9
CaO	3.0
Na_2O	2.4
K_2O	0.6



Density		
ρ_{geom} (g/cm³)	1.07 ± 0.05	1.18 ± 0.04
Porosity		
Total porosity (vol%)	68.4 (2.0 closed)	65.2 (0.8 closed)
Strength determinations		
σ_{comp} (MPa)	1.7 ± 0.3	4.8 ± 0.6

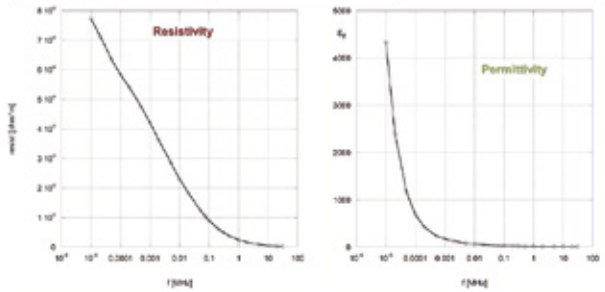


Fig.2 - left: RM- based foams (a: 20 wt% SLG; b: 30% SLG) sintered at 800°C - below: electrical properties of sample from 70% RM + 30% SLG

Materiali

Materials

DII research group

CerAMGlass, Nanotec

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Research output from the project **'MaVeRIF'** ('Materiali Vetroceramici da Rifiuti Industriali per Applicazioni Funzionali' - E. Bernardo, D. Desideri). Department of Industrial Engineering of the University of Padova, under the Twinning program

Main research topics:

@CerAMGlass

- Nanostructured ceramic composites from preceramic polymers and fillers.
- Advanced porous ceramic components.
- Bioceramics from novel formulations and processes.
- Monolithic and cellular glasses and ceramics.
- Novel building materials from inorganic waste
- Additive manufacturing of porous and dense ceramic components

@Nanotec

- Realization of nano-structuredfilms by magnetron sputtering
- Thin electromagnetic shields
- Realization and characterizationof thin piezoelectric materials for energy harvesting
- Modelling of electrical and electromagnetic devices
- TEM cell design for EMC/EMI tests

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Cover story

L'immagine riguarda lo sviluppo di scaffolds per ingegneria tissutale a base di silico-titanato di calcio (sfene, $CaTiSiO_5$) da polimero siliconico caricato con nanoparticelle di titania e microparticelle di calcite. La particolare formulazione consente l'ottenimento di ceramici ad altissima purezza di fase, nonché l'applicazione di tecnologie di manifattura additiva, quale il direct ink writing di paste siliconiche, prima della loro trasformazione ceramica. Particolare attenzione è dedicata all'ottimizzazione topologica (collaborazione con Prof. G. Savio, Dip. ICEA), al fine di ottenere strutture cellulari ad alto rapporto resistenza-densità.

Dott. Hamada Elsayed

Ha conseguito il dottorato di ricerca in Ingegneria Industriale presso l'Università di Padova nel 2017. E' ora assegnista presso il Dipartimento di Ingegneria Industriale sotto la supervisione del Prof. Paolo Colombo e del Prof. Enrico Bernardo, all'interno del gruppo di ricerca CeramGLASS (Ceramici Avanzati e Vetri). La sua ricerca riguarda l'applicazione di tecnologie di manifattura additiva in vari sistemi ceramici. Nell'ambito di materiali per applicazioni biomedicali, collabora con il Prof. Bernardo soprattutto per lo sviluppo di scaffolds dalla trasformazione di polimeri siliconici contenenti fillers reattivi micro- e nanometrici.

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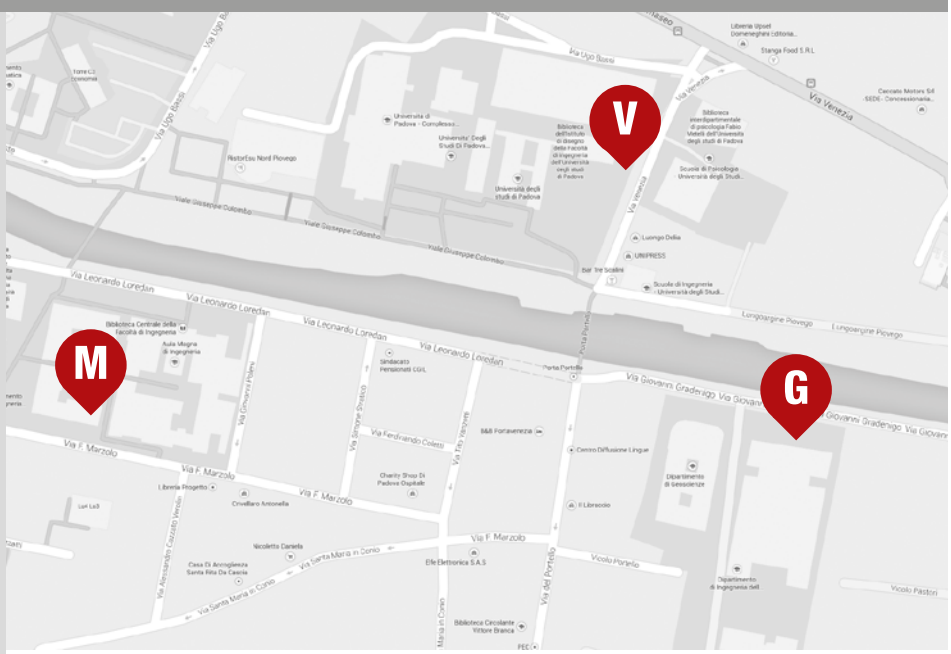

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