NEMMO : On the cutting edge of tidal blade design and materials

December 8th, 2021

Anti-fouling and cavitation resistance coatings for tidal blades

FUNDITEC

Dulce Muñoz Ph.D

tecnalia
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

canoe

SPNANO LTD

Ocean Energy Europe

NEMMO
MAKING BLADES BETTER

Objective

The **NEMMO** project seeks to generate the necessary **models, knowledge, designs and testing procedures** to develop **larger, more efficient and more durable composite tidal turbine blades.**

New materials for blades

Blade Composite

- Nano-enhanced material for higher fatigue and resistance composite

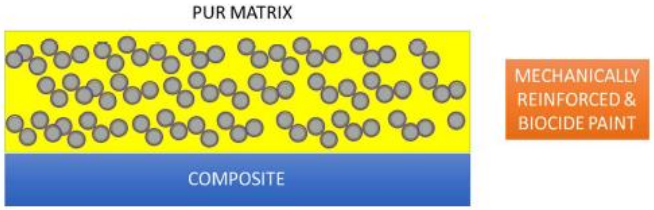
Blade Coating

- Increased fouling resistance
- Metal-like cavitation resistance

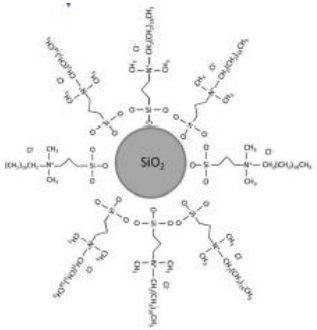
NEMMO
MAKING BLADES BETTER

WP3. Nano-reinforced composites, anti-fouling coatings and antifouling bio-mimetic surfaces

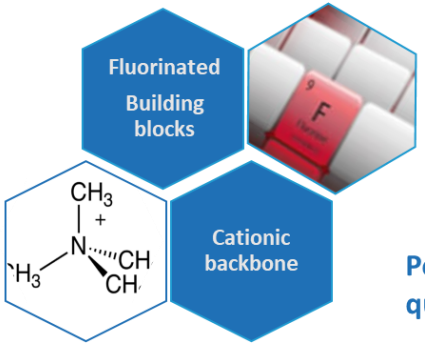
Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings



Biocide functionalised silica nanoparticles



Highly crosslinked PUR and PUD containing cationic copolymers with particles for cavitation and antifouling resistance

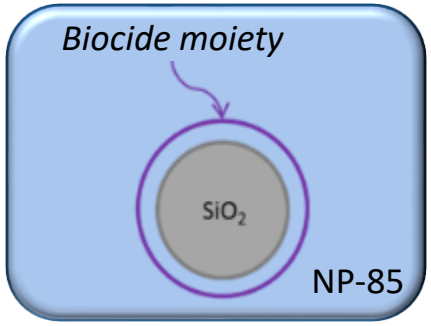


Decreasing surface energy

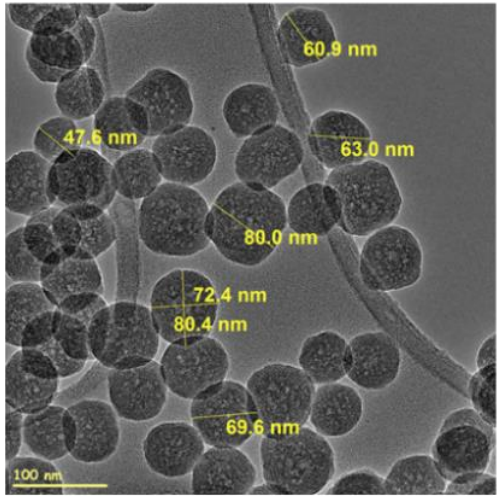
Positively charged ammonium quaternary salts

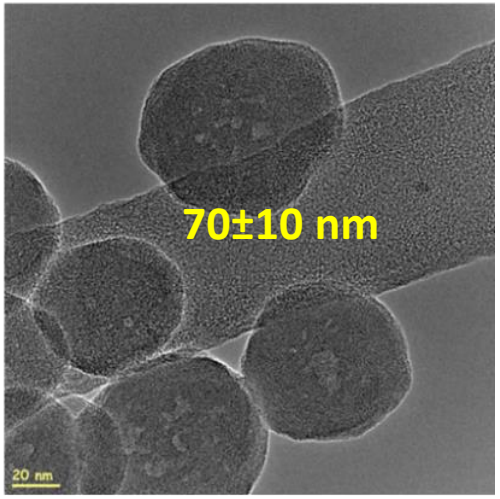
NEMMO
MAKING BLADES BETTER

Task 3.3.1. Development of biocide functionalised silica nanoparticles

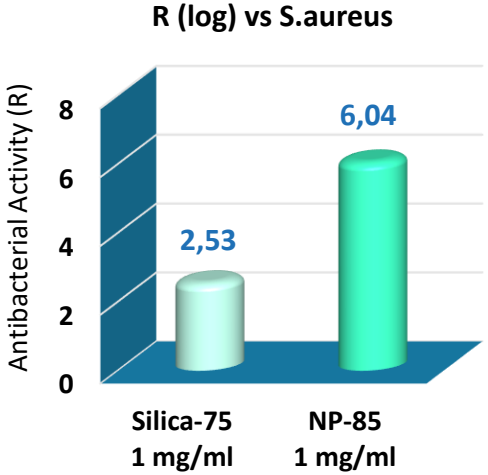


Transmmision Electron Microscopy (TEM):





Antibacterial activity of nanoparticles against Staphylococcus aureus bacteria:



Nanoparticles	DLS (nm)	TEM (nm)
NP-85	85	70±10

Functionalized nanoparticles presented high antibacterial activity.

NEMMO
MAKING BLADES BETTER

Task 3.3.2: Development of highly crosslinked PUD for cavitation and antifouling resistance

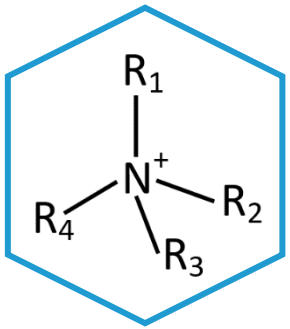
- **Synthesis of biocidal elastomeric polyurethanes by two strategies:**

Fluorinated building blocks

Decreasing the surface energy

Solvent based
2K fluorinated polyurethanes

Ammonium quaternary salts

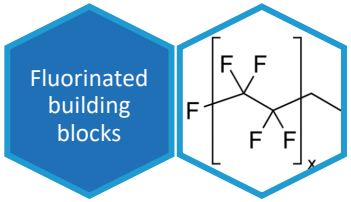


Insertion of cationic groups

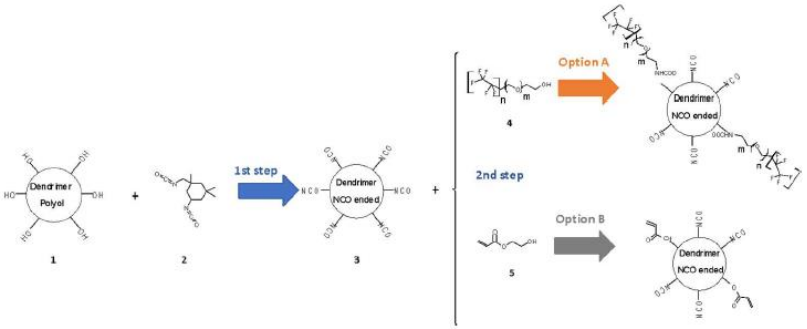
Water based
1K cationic polyurethanes

NEMMO
MAKING BLADES BETTER

Task 3.3.2: Development of highly crosslinked PUD for cavitation and antifouling resistance



		Component A FUNDITEC	Component B commercial
Solvent based 2K fluorinated polyurethanes (FPU)	**Type I**	Fluorinated polyisocyanate	Acrylic polyol
	Type II	Acrylated polyisocyanate	Fluorinated polyol



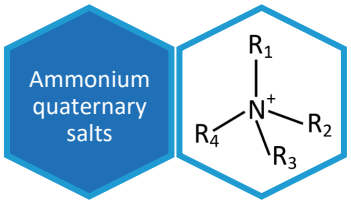
Acrylated (letf) and fluorinated (right) polyisocyanates synthesised by FUNDITEC

Physical properties of 2K FPU coatings applied on CANOE composite substrates

Code	Hardness	Adhesion	Tg (°C)
Type I	H	5B	23,8
Type II	4H	5B	28,8

NEMMO
MAKING BLADES BETTER

Task 3.3.2: Development of highly crosslinked PUD for cavitation and antifouling resistance



	Component A FUNDITEC	Component B commercial
Water based 1K cationic polyurethanes (PUD)	Polyurethane aqueous dispersion	-

Water-based polyurethane dispersion synthesised by FUNDITEC

Physical properties of 1K PUD coatings applied on CANOE composite substrates

Code	Hardness	Adhesion	Tg (°C)
Coating PUD	5H	5B	44,6

NEMMO
MAKING BLADES BETTER

Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings

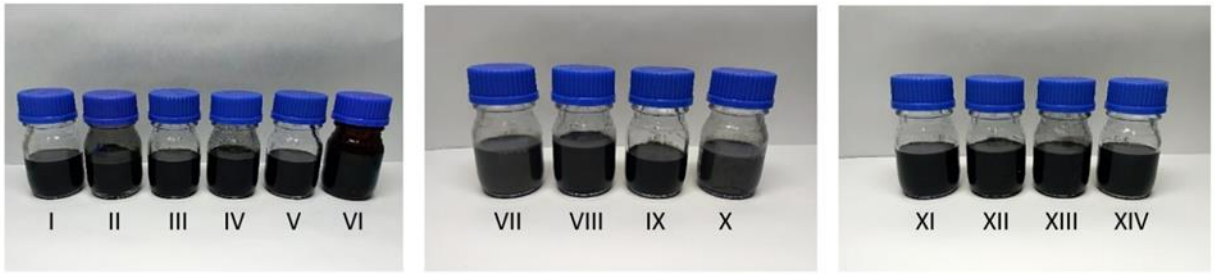
- **Incorporation of nanoparticles into the polyurethane matrix**

Incorporation of functionalised silica nanoparticles:

Silica NPs (1%wt) + component B of the 2K coatings or + 1K water-based PUD.

Incorporation of carbon nano-complexes:

Carbon nano-complexes (SP1 protein and different nanoparticles:MWCNT, SWCNT, graphene and CB) + 2K and 1K coatings.



NEMMO
MAKING BLADES BETTER

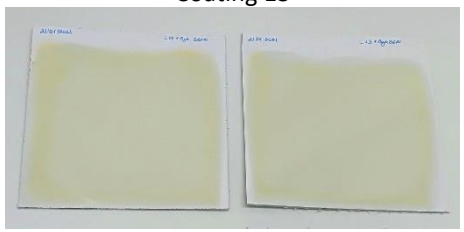
Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings

- **Application of coatings on composite substrate**

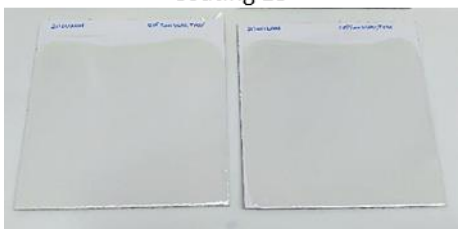
Commercial Topcoat

Commercial Topcoat

Coating 13

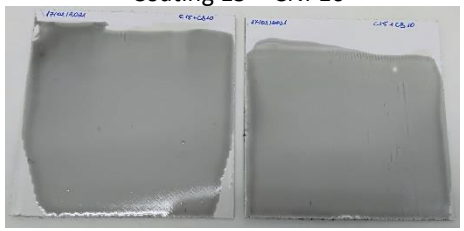


Coating 15

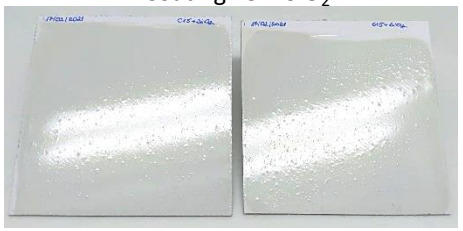


PUD5

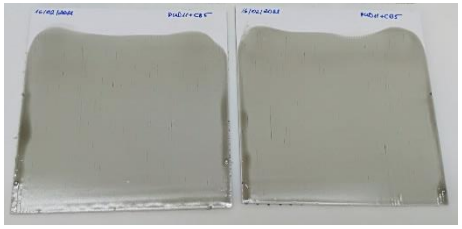
Coating 15 + CNP10



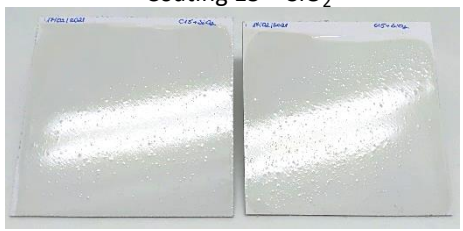
Coating 15 + SiO_2



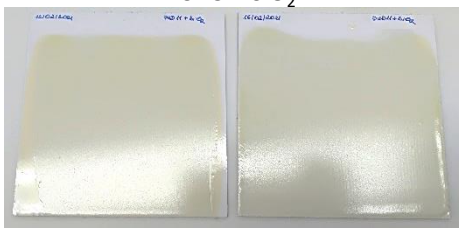
PUD5 + CNP5



Coating 15 + SiO_2



PUD5 + SiO_2



NEMMO
MAKING BLADES BETTER

Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings

TESTS: biofouling and cavitation resistance

Tecnalia's Harshlab facility

Tecnalia's Pasaia Port

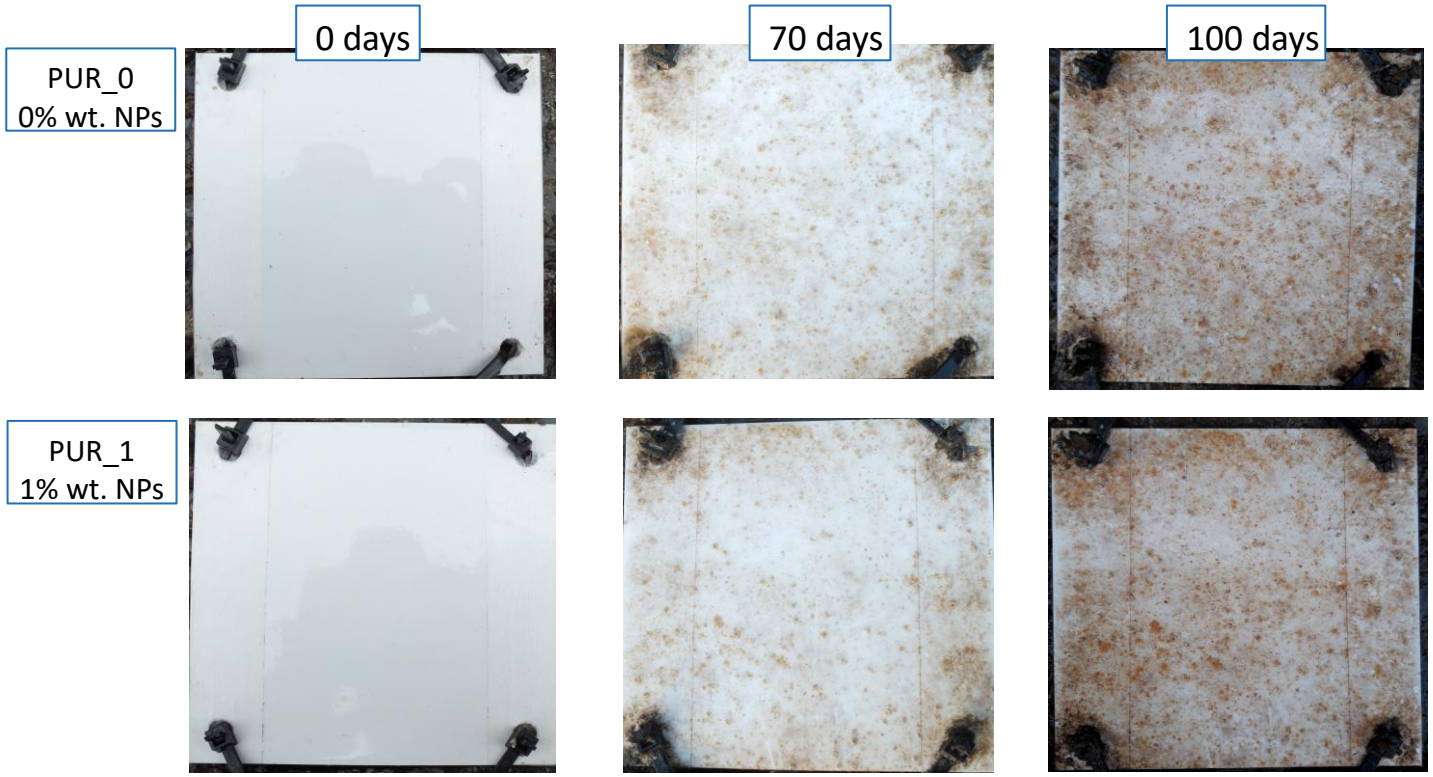
FUNDITEC's Set-up of cavitation erosion test

NEMMO
MAKING BLADES BETTER

Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings. **TEST RESULTS**

Biofouling resistant by exposure on sea immersion conditions (Port of Pasaia).

Composites + gelcoat + PUR with NPs (100 °C/1h)



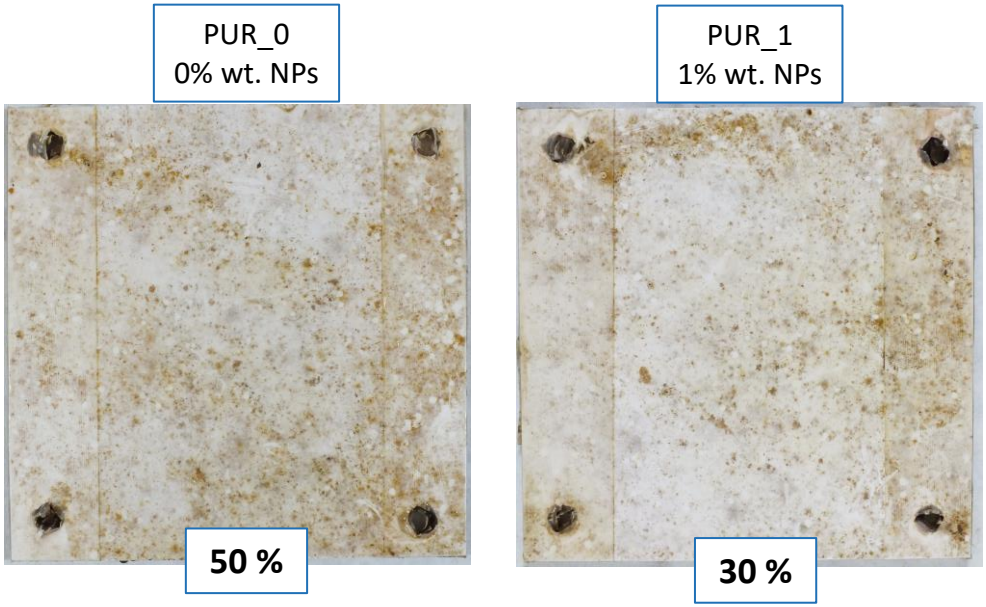
NEMMO
MAKING BLADES BETTER

Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings. TEST RESULTS

Biofouling resistant by exposure on sea immersion conditions (Port of Pasaia).

ASTM D6990-05 "Standard Practice for Evaluating Biofouling Resistance and Physical Performance of Marine Coating Systems".

Ref.	Substrate	NP-85 (% wt.)	% Fouling
PUR_0	Composite + Gelcoat	0	50 %
PUR_1	Composite + Gelcoat	1	30 %

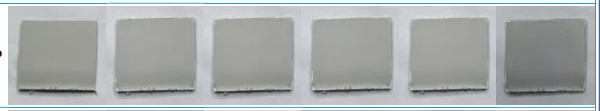
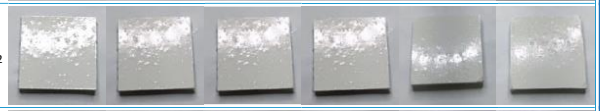


The percentage cover of fouling was reduced 20 % compared to control system without nanoparticles

NEMMO
MAKING BLADES BETTER

Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings. **TEST RESULTS**

Lab cavitation erosion tests (visual evaluation)

Code	0 min	1 min	2 min	3 min	4 min	5 min	% mass loss	Adhesion	Hardness
Commercial topcoat white							2,0286	0B	B
Commercial topcoat black							2,5881	0B	B
Coating 13							0,6385	5B	H
Coating 15							0,0187	5B	4H
Coating 15 CNP							0,0350	5B	4H
Coating 15 SiO_2							0,0813	5B	4H
PUD5							0,0175	5B	5H
PUD5 CNP							0,1576	5B	5H
PUD5 SiO_2							0,0415	5B	5H

- Improved erosion resistance,
- Better adhesion and hardness compared to commercial ones.
- PUD5 and coating 15 are more resistant to erosion than coating 13.
- Incorporation of carbon and silica NP has no effect on erosion resistance, adhesion or hardness values.
- Best topcoats: Coating15 and PUD5.

NEMMO
MAKING BLADES BETTER

Task 3.3. Permanent cavitation resistance, non-leaching anti-fouling coatings.

Coatings and composites are currently being evaluated for testing:

- Ageing resistance (natural and artificial ageing)
- Fatigue and impact resistance
- Anti-fouling performance in dynamic conditions
- Cavitation wear tests

Thank you for your attention!

Cecilia Agustin Saenz Ph. D

Gemma Berriozabal Solana Ph.D

gemma.berriozabal@tecnalia.com

Monika Tannenberg M. Sc

Sònia Sabaté M. Sc

Dulce Muñoz Ph. D

dmunoz@funditec.es

www.nemmo.eu @Nemmo_Project info@nemmo.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815278.

NEMMO MAKING BLADES BETTER