IK4 TEKNIKER
Research Alliance

Background in choppers development

Magnetic bearings, spindles, modelling, controller, mechanical design, manufacturing, testing facilities

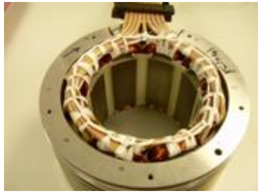
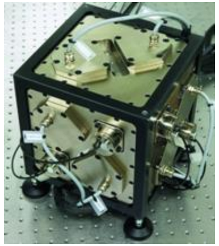
- Founded in 1981 as a privately-owned, not-for-profit technology centre.
- Member of the IK4 Research Alliance technology platform.
- Specialized in Manufacturing.
- 266 employees (2014)

Background in magnetic bearing developments.

- 2000. Basic knowledge acquiring.
- 2002. Magnetic bearings test bench development.
- 2003. Nanomahai. 6 d.o.f with 20 nm resolution.
- 2004. Magnetic bearing spindle for high speed machining. 10Kw, 36000 rpm.
- 2006. Mesa XY.
- 2006. Beginning of eddy current sensor development.
- 2007. Second generation high speed machining magnetic bearing spindle. 70 Kw, 36000 rpm.
- 2008. Real-time control electronics development.
- 2008. Beginning of rotorynamics theory analysis.
- 2009. Steel rotor flywheel. 100 kW, 20 seconds.
- 2009. Spindle for rectifier applications.
- 2010. Magnetic bearing sensors test bench.



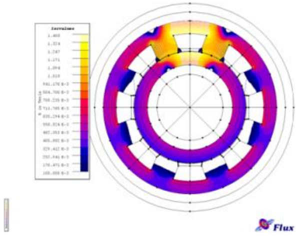


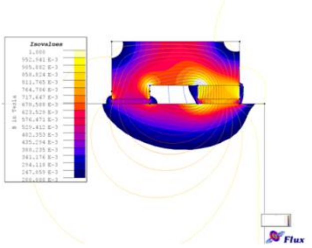




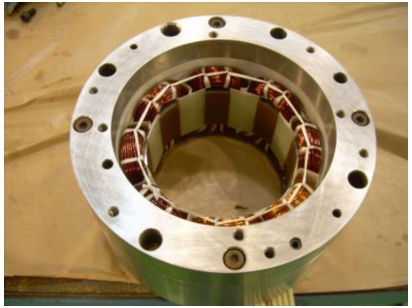
- 2010. System identification and monitoring.
- 2011. High interference rotor assembly facility.
- 2012. Corona discharge effect test bench.
- 2012. Composite rotor flywheel.
- 2012. Neutron chopper.
- 2012. Damping algorithm successful implementation in machining applications.
- 2013. Rotordynamic modelling software development.
- 2014. Successful MIMO controller implementation.

Radial and axial actuators

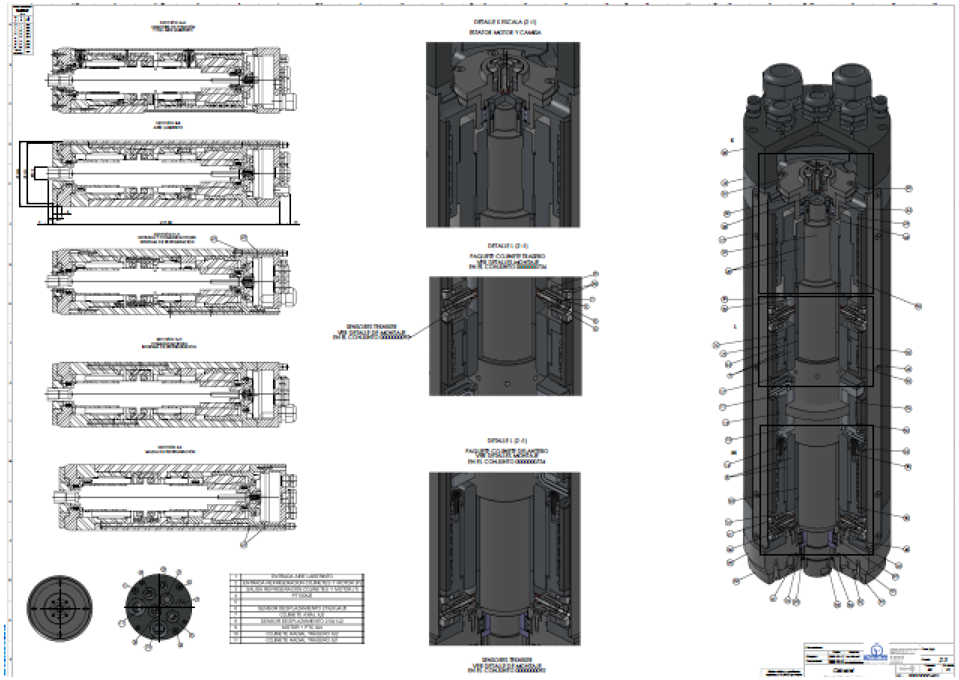
- Design
  - We have designed actuators for magnetic bearings since 2001
    - Material selection
    - Actuator design
    - Manufacturing process definition
  - Design supported by FEM calculations. CEDRAT-FLUX, ANSYS-MAXWELL
  - Natural convection and water cooled solutions
  - Rotor structural calculations and manufacturing process definition
- Manufacturing



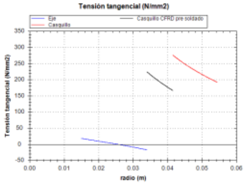


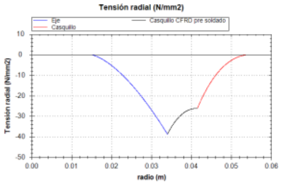


- Integration
  - Electric motor
    - Asynchronous and PM machines
  - Water cooled or air cooled
  - Different vacuum configurations
    - All parts at atmospheric pressure
    - Rotor in vacuum and stator at atmospheric pressure
    - All parts in vacuum
    - Two different vacuum levels internally
  - Electrical connectors



- Manufacturing and assembly
  - Shaft manufacturing.
    - Structural calculations. Interference definition.
    - Highest interference union made: shaft at -175ºC and hub at 380ºC
  - Rotor elements machining specification and machining process definition
  - Experience in ceramic bearing machine tool high speed spindle assembly

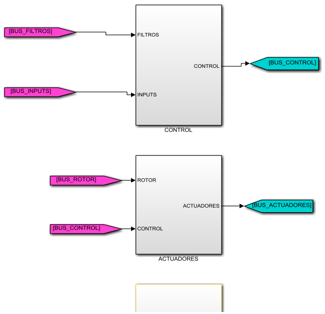


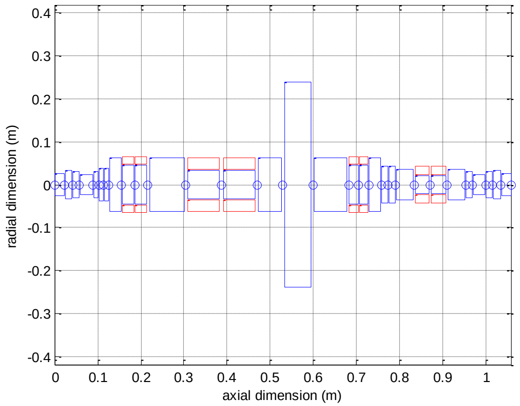


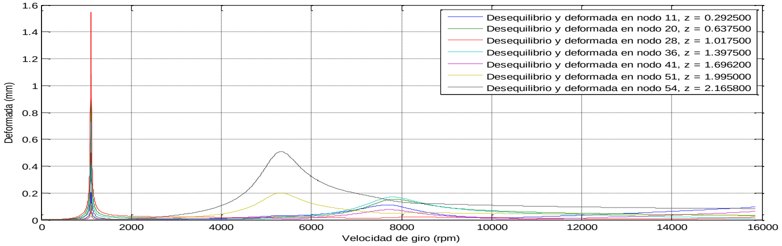
- Electrical design
  - Wiring
  - Connectors
  - Electrical protections
- Integration in electrical cabinet
  - Frequency converter
  - Magnetic bearings control electronics
    - Monitoring (event based, low speed monitoring, fft,…)
    - Calibration (natural frequency measurements, forward and backward modes,…)
    - RS232, TCP, …
  - Magnetic bearings power electronics

Modelling capabilities

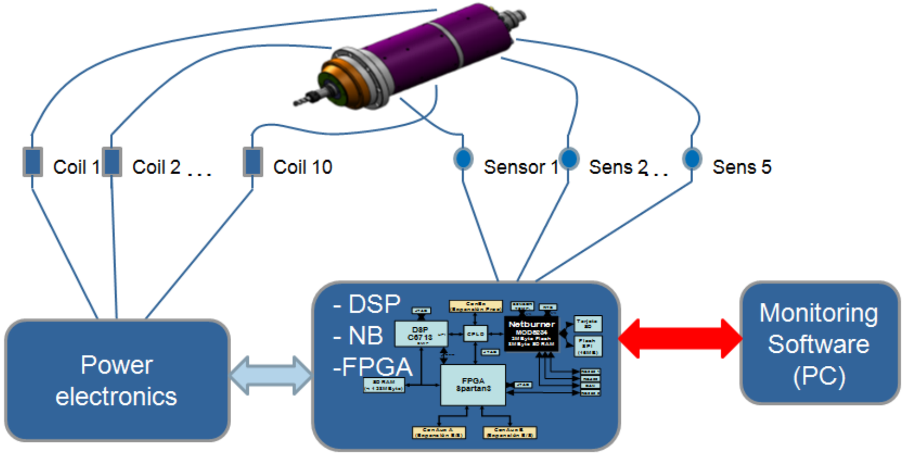
- In-house rotordynamic modelling FEM software
  - Mechanical info input using an EXCEL spreadsheet
  - Forward and backward natural frequencies and damping calculation
  - Steady state response to unbalance
  - State space model
- Time domain simulation model: rotor with two radial bearings simulator
  - Rotor model coming from state space model
  - Control system parameterization can be directly copied from simulation model to real time hardware and vice versa
  - Controllability of the system can be analyzed before it is built

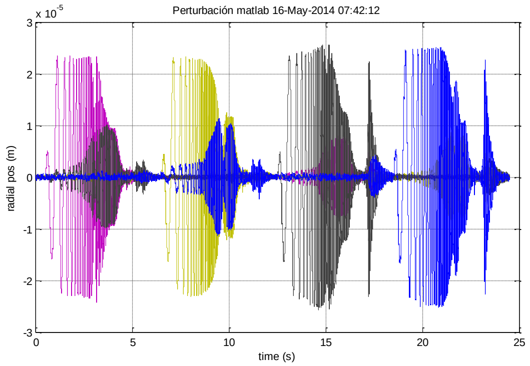


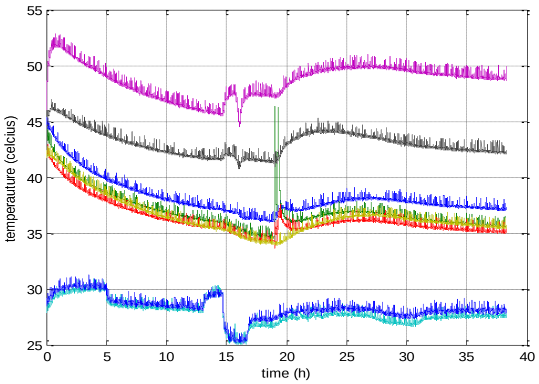




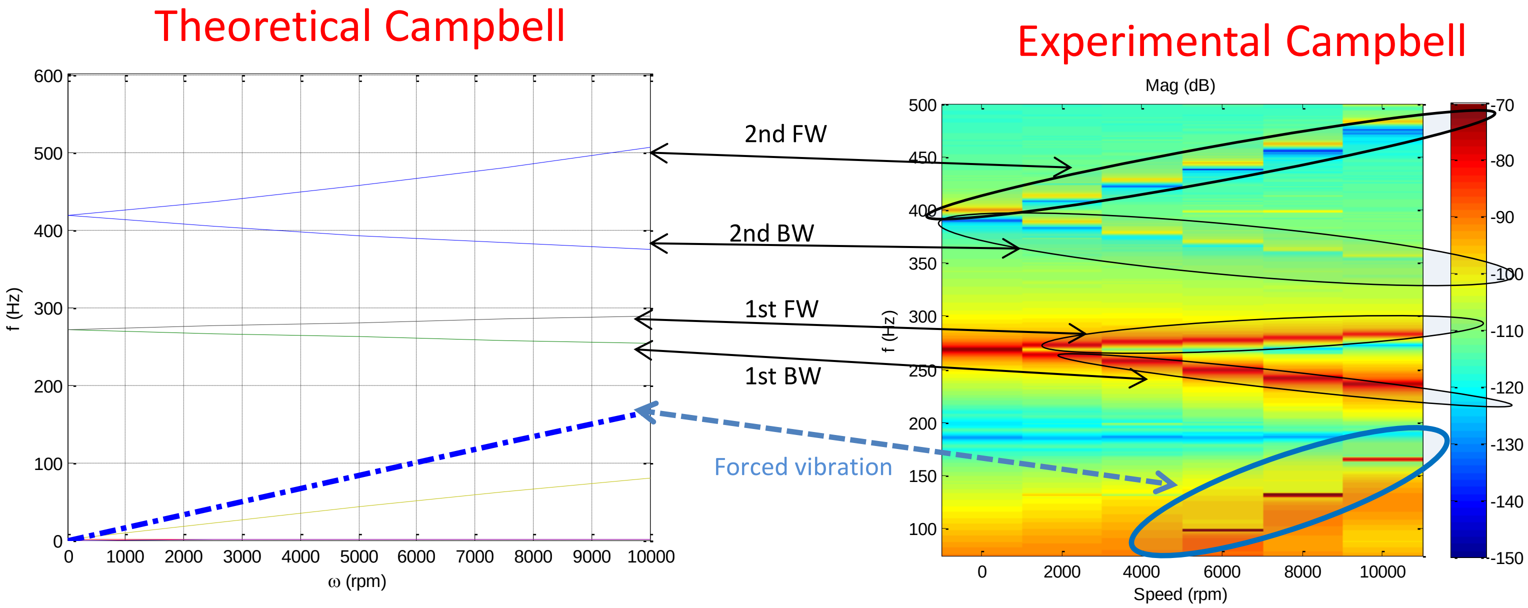
- Continuous monitoring
  - Maximum adquiring frequency: 1 value per second
  - Unlimited number of parameters: temperatures, currents, positions,...
- Event based monitoring
  - Up to 15 signals per capture
  - High frequency capture: 20KHz maximum
  - Up to 10^6 values captured
- Identification tests
  - User commanded
  - It is possible to make programmed tests or event based tests





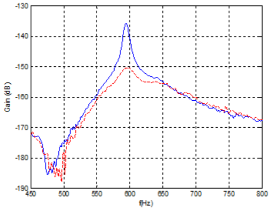


- Forward and backward natural frequencies campbell diagram
  - Controller adjustment to systems dynamic behaviour

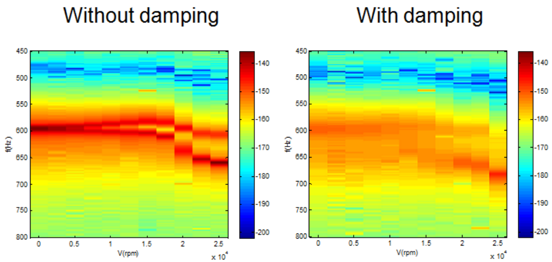


Control algorithms

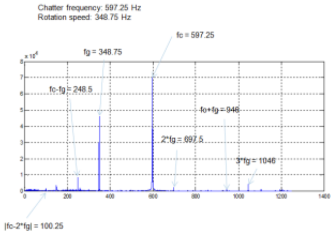
- Orbit rotation (2004)
  - Unbalance forces are not transmitted to the external structure
- 3 plane balancing (2010)
- High frequencies damping algorithm (2012)
  - Flexible modes are dampen.
  - Demonstrated in a machining application



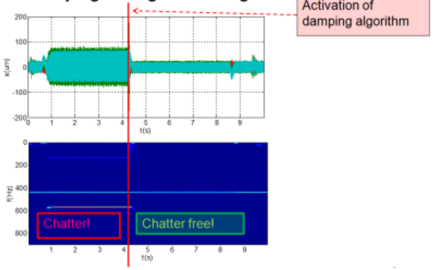
Position against perturbation force FRF, without (blue) and with (red) damping



Evolution of the response of the first mode against perturbation, in function of spindle speed, without (left) and with (right) damping algorithm (Real 5F spindle result).



Activation of damping during machining.

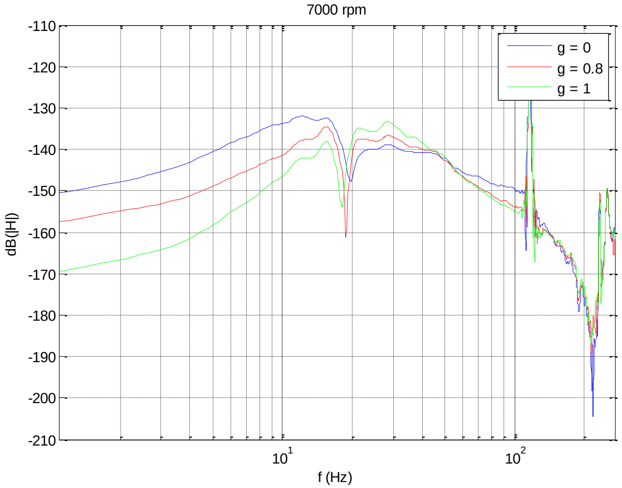


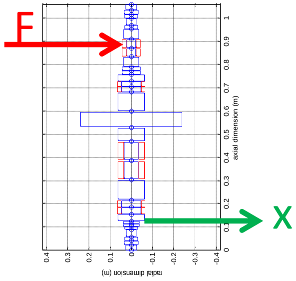
	Without damping	With damping	With ACL.
Depth of cut	5mm	15mm	15mm
Width of cut	10mm	10mm	10mm
Feed-rate	3.5m/min	6m/min	7.5m/min
Chip-flow	175cm³/min	900cm³/min	1125cm³/min

- MIMO controller (2014)
  - High increase of stability:
    - Flexible shafts with high inertia
    - Rotors with high giroscopic effects
  - Low frequency response against perturbations is highly increased.
  - Demonstrated in flywheel applications
  - Based on rotordynamic model. Simple commissioning

Crossed transfer function with different MIMO gains

X(s)/F(s)





Material:

Aluminum

Coatings:

- Theoretical calculations.

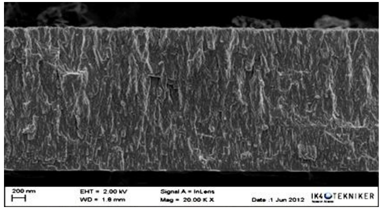
Neutron absorbance depend on thickness, density and microstructure of the coating

- B_4C by HIPIMS (High Power Impulse Magnetron Sputtering)

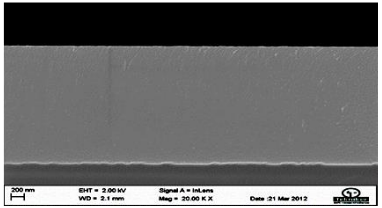
HIPIMS magnetron sputtering produce the most compact layers.

Selecting the suitable deposition parameters for producing effective absorbed layers

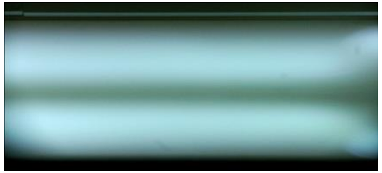
- B_4C by magnetron sputtering
- High Boron content layers by Plasma Spraying technologies



DC magnetron



HIPIMS



WORKING TEAM EXPERTISE

- **ICMA** (Aragón Materials Science Institute)-Theoretical calculations, simulations and microstructural characterization. (Dr. Javier Campo group).
- **IK4-TEKNIKER** –Coatings producer

Physical Deposition Unit has 25 years of experience working in PVD, designing and manufacturing our equipment's and coatings

IK4-TEKNIKER FACILITIES:

8 PVD SYSTEMS

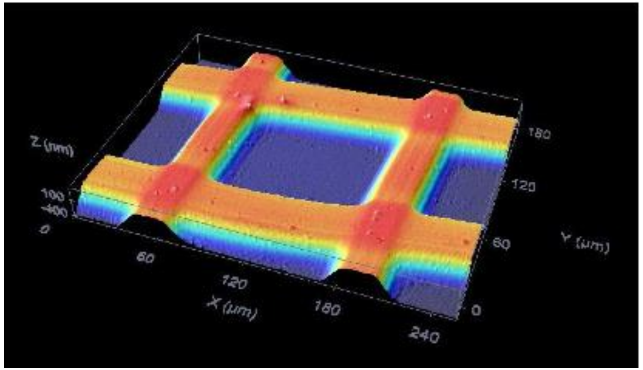
- Lab scale deposition chambers
- Industrial scale deposition chambers

CHARACTERISATION LAB

- Tribometers for different configurations (10 equipment's)
- FE-SEM, XRD and GDOES for composition and microstructural samples characterization

FACILITIES @ icma (CSIC-UZ)

Instituto de Ciencia
de Materiales de Aragón



- Surface Characterization and coatings Service (AFM, MFM, SNOM, Nanoindentador, etc…)
- Diffraction Service
  - http://sai.unizar.es/difraccion/dotacion.html
- Electron Microscopy Service (TEM, FESEM, etc…)
  - http://sai.unizar.es/microscop-mat/dotacion.html
  - http://ina.unizar.es/lma/services.html

Methodology:

1. Theoretical calculations, simulations and coatings design (ICMA)

2. Coatings deposition

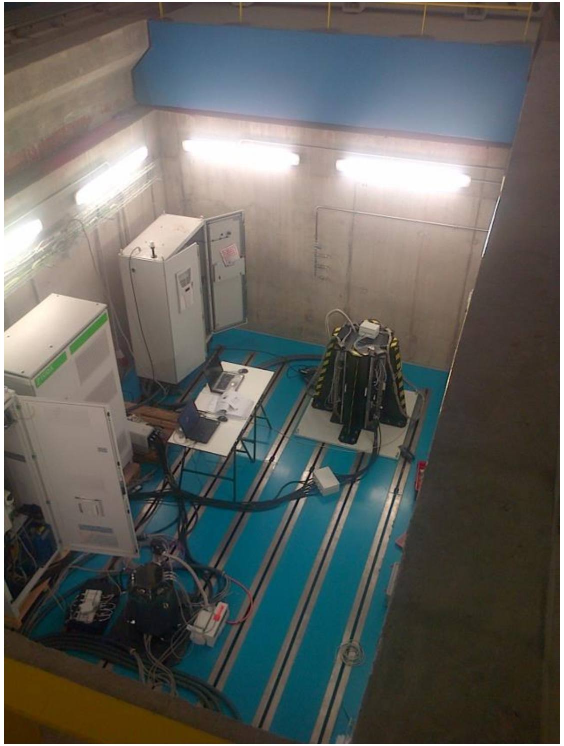
3. Microstructural characterization (ICMA)

4. Tribo-Mechanical tests (foto de nuestro chopper)

5. Neutron absorbance tests

(posibilidad de emplear el CRG D1B en el ILL operado por el ICMA para toda España)

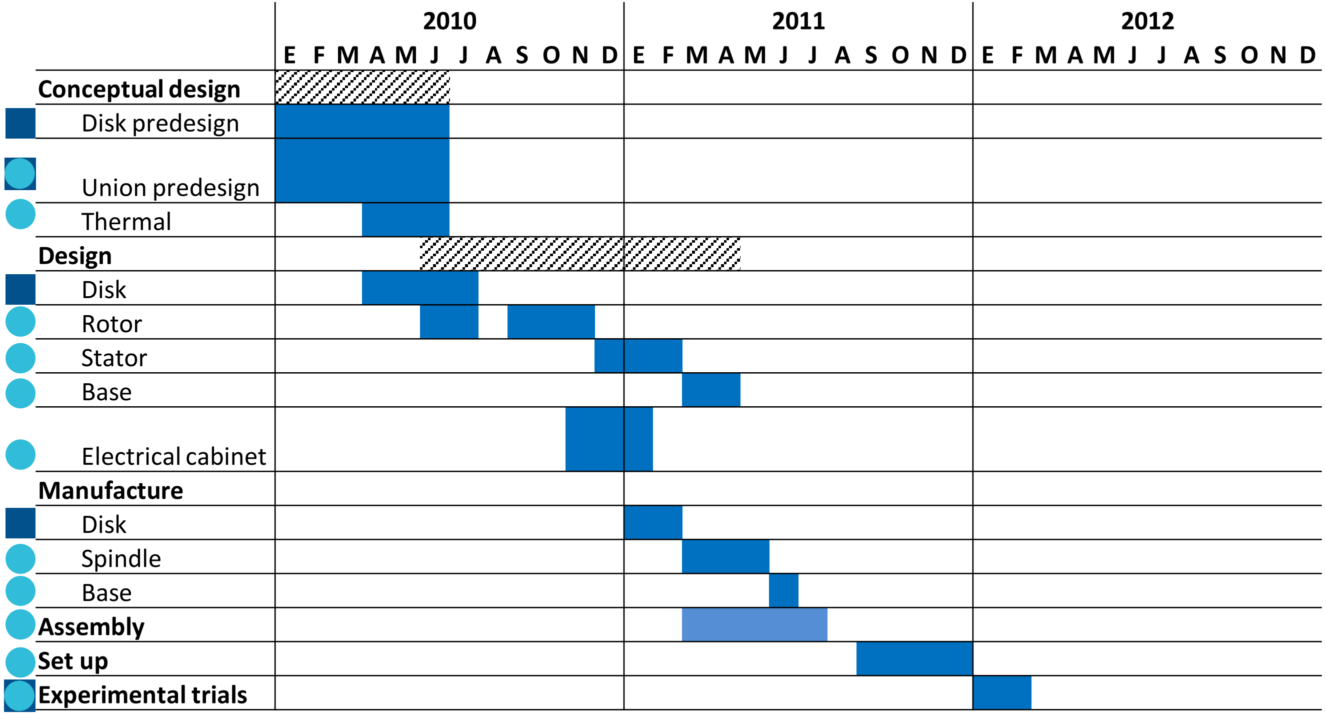
- BUNKER
  - 7 m length, 4 m width and 4 m height
  - Up to 200 kVA of electrical power
  - Ethernet, pressurized air and water cooling
  - 1m thickness reinforced concrete walls



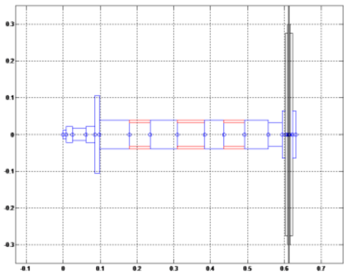
- High speed chopper development collaboration project.

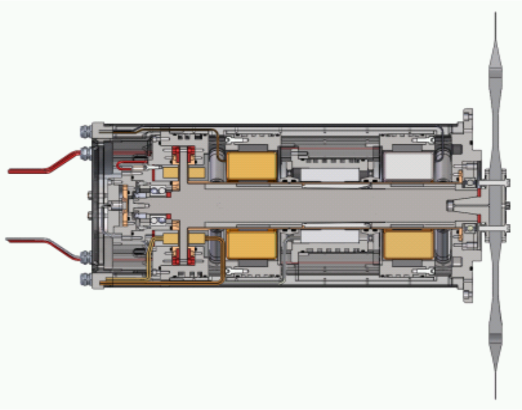
AERnnova

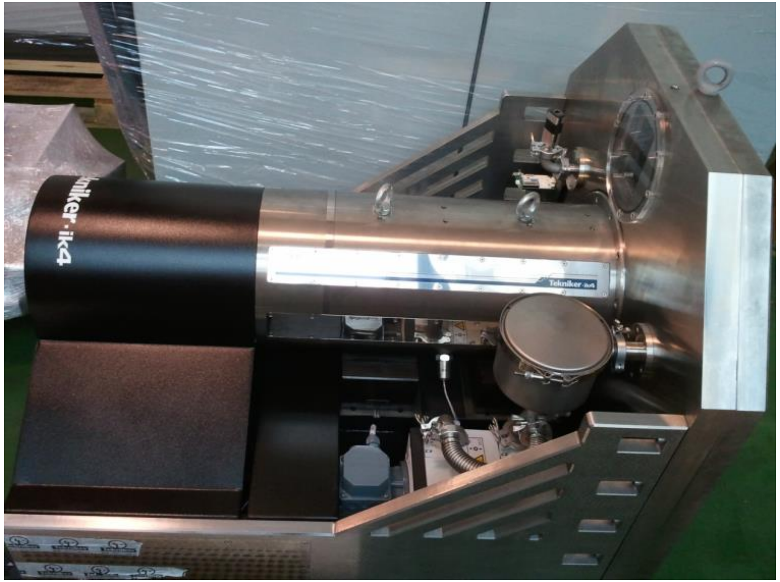
IK4 TEKNIKER Research Alliance



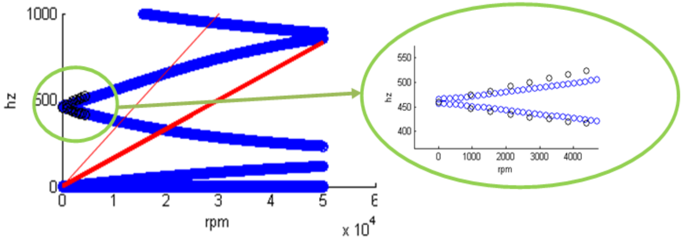
- High speed chopper development collaboration project. 2009-2012
  - 24000 rpm
  - 700 mm diameter
  - Design and manufacture:

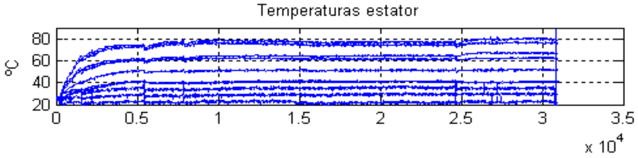


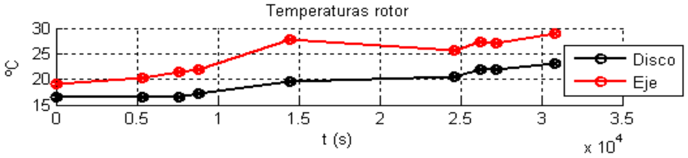


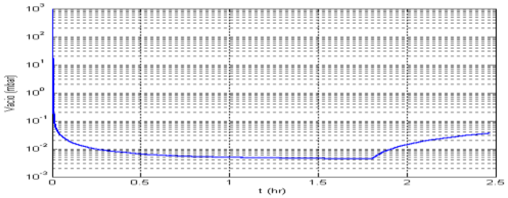


- High speed chopper development collaboration project. 2009-2012
  - Experimental trials:
    - Validation of rotordynamic calculations (up to 6000 rpm)
    - Temperatures
    - Vacuum









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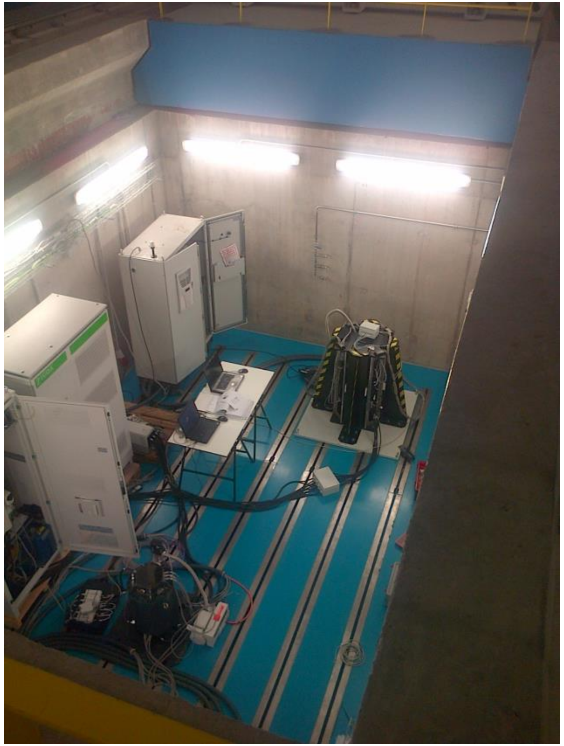

Eskerrik asko

Gracias

Thank you