Innovative Dynamical Modeling for Safer and More Accurate Robotic Handling in maintenance

Developed by CEA List, a novel remote handling dynamical modeling method addresses challenges in tokamak maintenance. Focused on precise control of flexible systems, CEA's solution aims to enhance robotic trajectory accuracy and reduce risks associated with heavy load manipulation. The method, tested on a robotic joint mock-up, utilizes a super-element approach for efficient engineering software calculations. Offering improved precision and adaptability, it holds potential applications in various industries, including space, transportation, metal, and construction.

Description of the technology

Maintenance tasks within a tokamak, following nuclear plasma operation, are hazardous for humans due to intense radiation. Robotic operation with remote handling is the solution, but challenges arise with heavy load manipulation, risking structural damage and reduced trajectory precision

Traditionally, trajectory modeling for remote-handled robots involves linearly modeling structural deformation, which proves insufficient for ITER due to precision limitations. In this context, a new remote handling dynamical modelling method has been investigated by CEA, with the objective to control with precision complex flexibles systems and prevent uncontrolled or under-evaluated errors.

To study this new approach, test were made on a single axis mock-up of robotic joint, supplied by a highly flexible structure. A mathematical modelling of it was realized to set all the variables, and a more simplified model was used as the reference model for the results interpretations. Here are the parametric values :

Physical parameters	Symbol	Value
Rod length	L	3m
Pipe wall thickness	eW	$3{,}25\times10^{-3}$ m
Section area	A	$5{,}92\times10^{-5}$ m^2
Density	ρ	$7{,}85\times10^{3}$ kg/m^3
Young modulus	E	210×10^{9} N/m^2
Second moment of area	I	$2{,}37\times10^{-7}$ m^4
Payload mass	Me	14,1 kg

All physical properties (beam length, value of the lumped mass, etc.) and materials characteristics used for the computation are deduced from measurements made on the experimental assembly.

The engineering software was used with a super-element method instead of a large finite element method to gain calculation time. The principle of this method is to decrease the size of the problem to solve by replacing different regions of the structure by their equivalent stiffness and mass properties. These equivalent properties are evaluated in prior fast computations, called super-elements creations.

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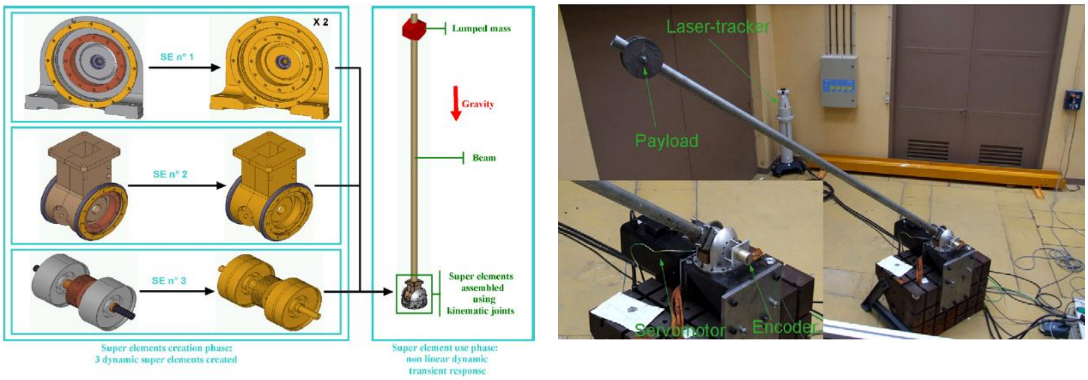

Fig. 1 & 2 : Description of the finite element model and picture of the experimental assembly.

A comparison was made to compare results of the physical experiment and the modelling.

As expected, deflection of the articulation due to elasticity of the reducer of the hinge joint is one of the major positioning errors. It was also proved that oscillations of the control scheme have a non-negligible impact on the positioning error and on dynamical behavior of the system.

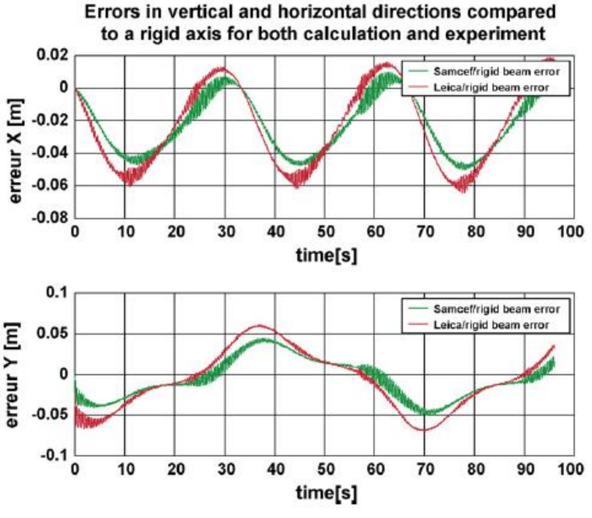

Fig. 3 : Vertical and horizontal errors for both model and measurements compared to rigid position.

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TECHNOLOGY TRANSFER PROGRAMME

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Innovation and advantages of the offer

The solution developed offers several advantages, such as better precision of handling heavy loads, reducing the risks related to the handling, and better following of trajectory by robots. It presents advantages compared to others method used is this domain, which lead to to poor positioning accuracy.

It has shown better results and is easily adaptable to different structures, loads and environment.

Non-fusion Applications

The method enhances remote handling of heavy loads across industries, including space, transportation (automotive, train, aeronautics), metal, and construction, with easy adaptability and cost-effective testing.

EUROfusion Heritage

This know-how was developed to gain precision while handling heavy loads in fusion tokamaks. Its part of the LIST Interactive Robotics Unit’s project related to fusion nuclear technologies.

The objective is to optimize processes for future applications in ITER project.

Indeed, when the test phase with non-nuclear plasmas will be done and radioactive components will be injected in, it will no be possible for human to enter in the tokamak anymore.

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