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Tokamak Magnetic Control Simulation: Applications for JT60-SA and ISTTOK Operation.

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ABSTRACT

The characterisation of the interactions

Keywords: Plasma-surface interactions, Liquid-metals, Tin, Deuterium retention, Spectroscopy

RESUMO

A caracterização das interações entre plasmas magneticamente

Palavras-chave: Plasma, metais liquidos, estanho, retenção de deutério, espectroscopia

SOMMARIO

Il soggetto del presente lavoro di tesi è la caratterizzazione dell'interazione tra la superficie di metallo liquido

Parole chiave:Interazione plasma-parete, Metalli liquidi, Stagno, Ritenzione del Deuterio, Spettroscopia

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LIST OF ABBREVIATIONS

@TODO: Review variable lists as writing the thesis

- AC - Alternating Current
- ADC - Analog to Digital Converter
- DAC - Digital to Analog Converter
- DC - Direct Current
- GUI - Graphical User Interface
- HV - High Voltage
- IO - Input Output
- IST - Instituto Superior Técnico

LIST OF VARIABLES

@TODO: Review variable lists as writing the thesis

VARIABLES:

- k - Boltzmann constant
- V_b - breakdown voltage
- j_{sat}^{+} - current density
- n - density of the plasma
- $E_{breakdown}$ - electrical breakdown field
- E - electrical field
- e - electron charge
- V_f - floating potential
- γ - flow constant
- d - gap distance
- i_{sat}^{+} - ion saturation current
- c_s - ion sound speed
- m - mass
- Γ - particle flux density
- ϵ_0 permittivity of vacuum
- V_p - plasma potential
- p - pressure
- V_s - probe voltage
- v_{se} - speed at the sheath edge
- A_s - surface of the probe
- T - temperature
- α - Townsend parameter

INDEXES:

- e - electron
- i - ion
- l - left
- lw - left wall
- r - right
- rw - right wall
- se - sheath edge
- sf - sheath floating

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INTRODUCTION

1.1 CONTEXTUALIZATION

The development of humanity has been closely related to energy and to the manners of harnessing it in its many forms. @TODO: possibly include graph with energy growth predictions

1.1.1 *Fusion Energy*

Not all the reactions of nuclear fusion are of interest to energy production. The mass of a nucleus is not the sum of the masses of the protons and neutrons that constitute it, i.e. $m \neq Zm_p + (A - Z)m_n$. Where Z is the atomic number, A is the mass number, m_p and m_n are respectively the free masses of proton and neutron. The difference corresponds to a binding energy E_B, which is the energy that should be supplied to a nucleus to decompose it in its nucleons. $E_B = (m - Zm_p + (A - Z)m_n)c^2$. To produce energy, the reactions of particular interest are those whose rest energy of the resulting nucleus is lower than the rest energy of the reacting nuclei. In such cases, a quantity of energy is released resulting from the difference in binding energy between the final and initial states. Image 1.1 shows the normalisation of the binding energy of the nucleon mass as a function of the mass numbers of elements. The steep increase for the light elements motivates the choice of reagents where nuclear fusion is favourable.

Figure 1.1.: Average binding energy (in MeV) per nucleon as function of the atomic mass number (A) for most common isotopes. The sudden increase of binding energy in the low atomic mass side manifests itself as a release of energy in the balance of a fusion reaction.

Table 1.1.: Comparison of the energy density from different power sources

Energy Density [MJ/kg]	
Fusion	335000
Fission	87600
Coal	27.8
Hydroelectric	4.9×10^{-4}

Upon deciding the underlying mechanism by energy will be produced the following subject to address if the choice of fusion reaction. There are a plethora of energy-producing fusion reactions between the low atomic mass nuclei, and some of most relevant are detailed below, on table 1.2:

Table 1.2.: Relevant nuclear reactions

Designation	Reaction	Released energy (MeV)
Deuterium - Deuterium	${}^2_1H + {}^2_1H \rightarrow {}^3_2He + {}^1_0n$	3.27
	${}^2_1H + {}^2_1H \rightarrow {}^3_1H + {}^1_1H$	4.04
Deuterium - Tritium	${}^2_1H + {}^3_1H \rightarrow {}^4_2He + {}^1_0n$	17.59
Deuterium - Helium-3	${}^2_1H + {}^3_2H \rightarrow {}^4_2He + {}^1_1H$	11.33
Tritium - Tritium	${}^3_1H + {}^3_1H \rightarrow {}^4_2He + 2\,{}^1_0n$	18.35

Since there are several possibilities with different advantages however not all of them have the same probability of occurrence. Each of these reactions will have a reaction rate or cross-section which is dependent on the conditions of the reagents, particularly their energy. Figure 1.2 show the cross-section of several fusion reactions. It becomes clear from that figure that for a large energy interval the fusion reaction that holds most potential is the Deuterium-Tritium fusion, or D-T.

Figure 1.2.: Cross-section of several fusion reactions as function of temperature. This figure illustrates how, from several reactions, the most promising for using on a fusion reactor is the deuterium with tritium. The cross-section has a peak at ≈100 keV. @TODO: from 'The physics of inertial fusion' by Atzeni and Meyer-ter-Vehn, Oxford Science Publications

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LIQUID METALS AS PLASMA FACING COMPONENTS

2.1 INTRO

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OVERVIEW OF SPECTROSCOPY

In its pure form it has the following definition:

$$G(x;\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \tag{3.1}$$

where μ is the expected value, the central wavelength, and σ is the standard deviation. The FWHM can be expressed explicitly in terms of the curve's standard deviation:

$$FWHM = 2\sqrt{2\ln(2)}\sigma \tag{3.2}$$

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TIN, LITHIUM AND LITHIUM-TIN ALLOYS

@TODO: cfac results should come in a different chapter. these should be in the same order as the contextualisation chapter!!!!!

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LIQUID METAL SAMPLES EXPOSURE UNDER ISTTOK PLASMAS

5.1 BLA BLA

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FTU

6.1 Collaboration in the experimental campaigns of Cooled Lithium Limiter (CLL) and Tin Liquid Limiter (TLL) held in FTU

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DEMONSTRATIONS