CDTN

CENTRO DE DESENVOLVIMENTO
DA TECNOLOGIA NUCLEAR

COMISSÃO NACIONAL DE ENERGIA NUCLEAR
CENTRO DE DESENVOLVIMENTO DA TECNOLOGIA NUCLEAR
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIA E TECNOLOGIA DAS RADIAÇÕES,
MINERAIS E MATERIAS

Tese ou Dissertação

TITLE MUST BE WRITTEN IN ENGLISH

NAME OF THE AUTHOR

BELO HORIZONTE/MG
2024

NAME OF THE AUTHOR

TITLE MUST BE WRITTEN IN ENGLISH

Tese ou Dissertação apresentada ao Programa de Pós-Graduação em Ciência e Tecnologia das Radiações, Minerais e Materiais do Centro de Desenvolvimento da Tecnologia Nuclear, como requisito parcial para obtenção do título de Mestre ou Doutor em Ciência e Tecnologia das Radiações, Minerais e Materiais.

Área de Concentração: INSERIR ÁREA DE CONCENTRAÇÃO

Supervisor:	Prof. Dr(a). Nome do(a) orientador(a)
Co-supervisor:	Prof. Dr(a). Nome do(a) coorientador(a)

Programa de Pós-Graduação em Ciência e Tecnologia das Radiações, Minerais e Materiais

---

A presente dissertação de mestrado ou tese de doutorado, intitulada "--" de autoria de ---, foi defendida e aprovada em -- de --------- de -------- pela Banca Examinadora abaixo assinada.

Belo Horizonte, -- de ------ de ----.

Prof. Dr(a). Nome do(a) orientador(a) – Orientador(a) – CDTN

Prof. Dr(a). Nome do(a) coorientador(a) – Coorientador(a) – Instituição

Prof. Dr. Membro da banca – Instituição

Prof. Dr. Membro da banca- Instituição

Prof. Dr. Membro da banca - Instituição

"O começo de todas as ciências é o espanto de as coisas serem o que são."

(Aristóteles)

Acknowledgment

Please add your acknowledgment right here

Please add your acknowledgment right here

Please add your acknowledgment right here

Please add your acknowledgment right here

Please add your acknowledgment right here

Please add your acknowledgment right here

Resumo

Este é o resumo em português.

Palavras-chave: Palavra-chave 1. Palavra-chave 2. Palavra-chave 3. Palavra-chave 4. Palavra-chave 5.

Abstract

This is the English abstract.

Keywords: Keyword 1. Keyword 2. Keyword 3. Keyword 4. Keyword 5.

List of Figures

List of Tables

Abbreviations

CNEN	Comissão Nacional de Energia Nuclear
RMB	Reator Multipropósito Brasileiro
IAEA	International Atomic Energy Agency
MEF	Método dos Elementos Finitos
FEA	Finite Element Analysis
PU	Poliuretano

List of Symbols

Γ Letra grega Gama

λ Comprimento de onda

$\in$ Pertence

Summary

1 INTRODUCTION

This Template aims to facilitate the editing of PPG-CDTN thesis and dissertations in the traditional format of academic documents and facilitate the approval process. The LaTex template is divided into several files and directories containing the document content. The student must fill in each file with their content, following the instructions presented in this document.

The student begins by editing the file *capa.tex*, found in the folder *01-elementos-pre-textuais*. Do not change formatting parameters, just place the requested content, according to the instructions found in the document itself. All documents in this template present detailed function comments to improve understanding and avoid errors.

The approval sheet is in PDF format. The file must be included in the *01-elementos-pre-textual* directory. For it to be included in the document, change the name of the file to be imported in the file *Aprovado.tex* found in the folder *01-elementos-pre-textuais*.

This chapter must include the supporting elements of the research. The introduction content must be written within the *introducao.tex* file present within the *02-elementos-textuais*. Figures, tables, abbreviations acronyms, symbols, etc. can be inserted in this section. The figures and tables will be automatically displayed in the figure and table lists, respectively. However, abbreviations and acronyms, as well as symbols used in the text, must be inserted manually according to the order in which they are presented. To do this, use the "list- siglas.tex" and "lista-simbolos.tex" files present in the folder "01-elementos-pre-textual".

Figures are inserted using the "*begin{figure}*" command. For the compiler to add the figure to the text, you must first upload the file containing the figure. The compiler supports extensions like *.png, .svg, .pfd*. Please, provide an individual "label" for each figure using the command *label{An example figure 1}* and use the *autoref{rotulo da figura 1}* command to call it in the text.

As an example, Figure 1 is presented below. Note that a brief presentation description of the figure is inserted using the command *caption{Descrição da figura}* within the environment "*begin{figure}*".

Figure 1 – An example figure.
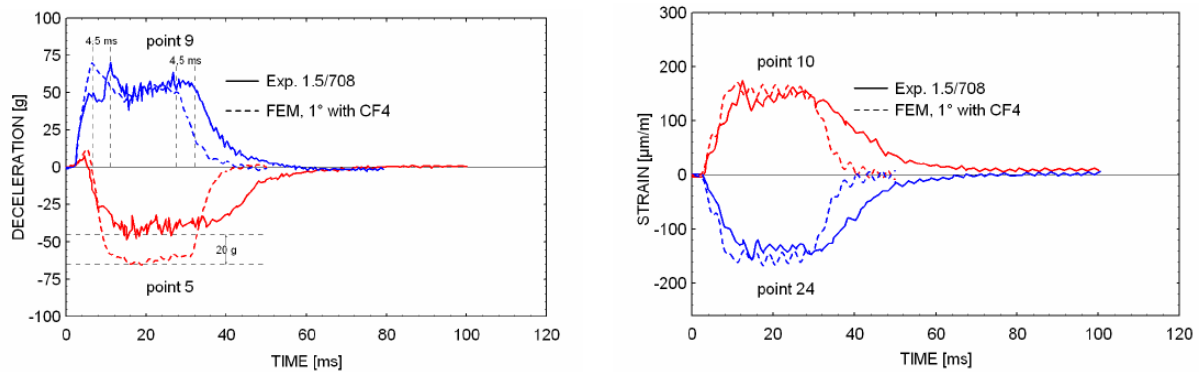
FONTE: QIAO ET AL. (2007)

Tables are inserted using the command "\begin{table}". An example table is shown below. Remember to add a brief description of the table presentation. Please, provide an individual "label" for each table using the command \label{table label 1} and use the command \autoref{table label 1} to call it in the text. This way the compiler will create a hyperlink.

As an example, Table 1 is presented below. Note that a brief presentation description of the table is inserted using the command \caption{An example of table 1} within the environment "\begin{table}".

Table 1 – An example of table.

Faixa de ângulos	Orientação
$0° < \theta < 15°$	Vertical
$15° < \theta < 75°$	Em ângulo
$75° < \theta < 90°$	Horizontal

Source: Author.

Use the commands "\cite" or "\citeonline" to reference works in your bibliography. Using the command "\cite", the implemented reference model is called simple mention, as seen below:

CNEN is developing the Brazilian Multipurpose Reactor project, the RMB, which is a radioisotope research and production reactor. The Reactor will have a capacity of 30 MW of thermal power and will be an open pool-type reactor that will use low-enriched uranium as the main fuel.

It is also possible to make literal citations of the reference text using $\backslash begin\{citacao\}$, as shown below.

> CNEN is developing the Brazilian Multipurpose Reactor project, the RMB, which is a radioisotope research and production reactor. The Reactor will have a capacity of 30 MW of thermal power and will be an open pool-type reactor that will use low-enriched uranium as the main fuel.

On the other hand, using the command "$\backslash citeonline$", it is possible to cite integrated text, as shown below:

Lee et al. (2005) carried out comparative studies between two classic finite element software programs, Abaqus and LS-Dyna, to verify whether the responses obtained such as tensions, deformations, accelerations, and energies are equivalent. The hull model in question contained the outer cylinder, resin shielding, inner cylinder, lead shielding, and the fuel element positioning basket.

1.1 Objectivies

1.1.1 General objectives

Insert the general objective of the Thesis or Dissertation.

1.1.2 Specific objectives

The specific objectives of this Thesis or Dissertation are:

a) Specific objectives 1;
b) Specific objectives 2;
c) Specific objectives 3;
d) Specific objectives 4.

2 LITERATURE REVIEW

This chapter should address the elements of literature review relevant to the development of the Thesis or Dissertation. The content of the review must be written within the file *revisao-literatura.tex* present within the folder *02-elementos-textuais*. If necessary, organize the text into sections and subsections using the *section{}* and *subsection{}* commands. Provide an individual "label" for each section and subsection using the command *label{section or subsection label}* and use the command *autoref{section label or subsection}* to call it in the text. This way the compiler will create a hyperlink. Below, as an example, we will present the Section 2.1: Normative Base and the Subsection 2.1.1: *Drop Tests* - Numerical Approach.

2.1   Normative Base

The CNEN NN 5.01 (CNEN, 2021) standard contains the resolution that deals with the transport of radioactive materials on public roads as well as radioprotection and safety requirements to guarantee an adequate level of control of possible exposure of people, goods and the environment to ionizing radiation. The standard also includes, among others:

    a) specifications on radioactive materials for transport;
    b) selection of the type of packaging;
    c) specification of design requirements and packaging acceptance tests;
    d) provisions relevant to the transport itself.

2.1.1   *Drop Tests* - Numerical Approach

Approximately 20 million containers of different types and sizes containing nuclear fuels are transported every year around the world (LIU et al., 2018).

Safety and protection against radiation caused by possible accidents are critical aspects when transporting these containers. Numerical simulations using the finite element method are used in the design phase of transport hulls to first determine the most critical orientation during the drop test (*drop test*), which generally greatly reduces the costs of experimental tests without penalizing the degree of project safety.

3 MATERIALS AND METHODS

The methodology must address the elements used to obtain the results presented in the Thesis or Dissertation. The content of the methodology must be written within the file *metodologia.tex* present within the folder *02-elementos-textuais*. To insert equations, use the command "*begin{equation}*" to start the LATEX equation writing environment. Provide an individual "label" for each equation using the *label{equation label}* command, and use the *autoref{equation label}* command to call it in the text. This way, the compiler will create a hyperlink, in addition to automatically enumerating the equations according to the order in which they are presented in the text. Below, as an example, Equation 1 and Equation 2 are presented:

$$X(s) = \int\limits_{t=-\infty}^{\infty} x(t) \, \mathrm{e}^{-st} \, dt \tag{1}$$

$$F(u,v) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m,n) \exp\left[-j2\pi\left(\frac{um}{M} + \frac{vn}{N}\right)\right] \tag{2}$$

The symbols present in the equation must be listed in the list of symbols in the order in which they are presented in the text. It is also possible to organize ideas in the form of items or list them sequentially. To start the structure of separation into items, use the command "*begin{itemize}*" and add each item using the command *item*. The result is exemplified below:

- The Hull will be subjected to a sequence of impacts in different orientations in accordance with guidelines present in the standards (NRC, 2014) and (CNEN, 2021);
- Vertical impacts will be carried out in two directions (upper shock absorber and lower shock absorber), horizontally and at an angle against a rigid surface;
- Puncture impact consists of a fall from a height of 1 m against a steel bar large enough to inflict structural damage on the fuel element containment cylinders and the top cover closing valve.

To start the enumerated separation structure, use the command "*begin{enumerate}*" and add each item using the command *item*. The result is exemplified below:

1. The Hull will be subjected to a sequence of impacts in different orientations in accordance with guidelines present in the standards (NRC, 2014) and (CNEN, 2021);
2. Vertical impacts will be carried out in two directions (upper shock absorber and lower shock absorber), horizontally and at an angle against a rigid surface;

3. Puncture impact consists of a fall from a height of 1 m against a steel bar large enough to inflict structural damage on the fuel element containment cylinders and the top cover closing valve.

To start the separation structure in alphabetical order, use the command "$\backslash begin\{alineas\}$" and add each item using the command $\backslash item$. The result is exemplified below:

a) The Hull will be subjected to a sequence of impacts in different orientations in accordance with guidelines present in the standards (NRC, 2014) and (CNEN, 2021);

b) Vertical impacts will be carried out in two directions (upper shock absorber and lower shock absorber), horizontally and at an angle against a rigid surface;

c) Puncture impact consists of a fall from a height of 1 m against a steel bar large enough to inflict structural damage on the fuel element containment cylinders and the top cover closing valve.
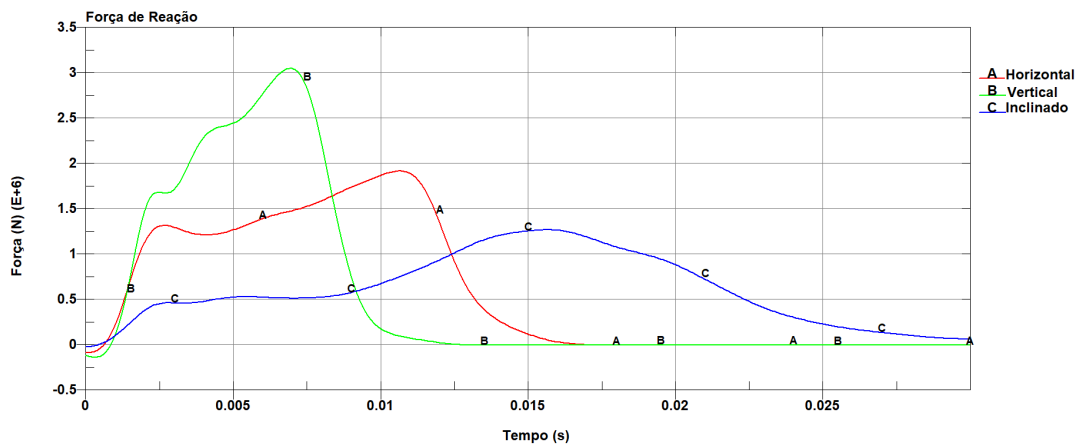
4 RESULTS

This chapter should address the results obtained to be presented in the Thesis or Dissertation. The content must be written within the file *resultados.tex* present within the folder *02-elementos-textuais*. Below are examples involving the textual elements discussed combined.

4.1 Analysis of Acting Loadings

4.1.1 Vertical drop

As demonstrated in Figure 2, the vertical orientation had the highest peak force value compared to the others. In this way, it is expected that through action/reaction, the internal structures of the hull will experience greater values of tension. In the vertical drop the peak force was 3050 kN, in the horizontal 1920 kN, and in the angle 1290 kN. This observation is consistent with what was observed in experimental tests carried out on a similar hull (SALIBA et al., 2011).

Figure 2 – An example figure.

Source: Author.

Table 2 shows in $G's$ the values of the pulses reached.

Table 2 – An example table.

Ponto	Horizontal	Vertical	Inclinado
Superior (A)	173,3	267,1	119,3
Central (B)	175,3	266,1	118,2
Inferior (C)	179,4	263,0	123,3

Source: Author.

5 CONCLUSIONS

This chapter should address the conclusions obtained to be presented in the Thesis or Dissertation. The content must be written within the *conclusao.tex* file present within the *02-elementos-textuais*.

5.1 Future Works

As a suggestion for future work, the following points can be addressed:

- future work 1;
- future work 2;
- future work 3.

Bibliography

CNEN. Norma cnen nn 5.01 - regulamento para o transporte seguro de materiais radioativos. In: **DOU - CNEN 271/21**. [S.l.: s.n.], 2021.

LEE, Y.-S.; RYU, C.-H.; KIM, H.-S.; CHOI, Y.-J. A study on the free drop impact of a cask using commercial FEA codes. **Nuclear Engineering and Design**, Elsevier BV, v. 235, n. 20, p. 2219–2226, set. 2005.

LIU, Q.; ZHU, S.-P.; YU, Z.-Y.; DING, R. A coupled thermal-drop impact analysis-based safety assessment of radioactive material cask. **International Journal of Structural Integrity**, Emerald, v. 9, n. 2, p. 185–195, abr. 2018. Disponível em: <https://doi.org/10.1108/ijsi-05-2017-0028>.

NRC. Nureg-2125 spent fuel transportation risk assessment, final report. In: **Nuclear Regulatory Comission**. [S.l.: s.n.], 2014.

SALIBA, R.; MOURAO, R. P.; QUINTANA, F.; NOVARA, O.; SILVA, L. L. da; MIRANDA, C.; NETO, M. M. Analysis and design of spent fuel transport cask impact limiters. **Packaging, Transport, Storage & Security of Radioactive Material**, Taylor & Francis, v. 22, n. 4, p. 172–178, 2011.

Appendix

APPENDIX A – Name of the Appendix A

Remember that the difference between an appendix and annex concerns the authorship of the text and/or material placed there.

If the supplementary or complementary material or text is your authorship, then it must be placed as an appendix. However, if the authorship is by third parties, then the material or text must be placed as an attachment.

Organize the appendices so that each one contains a single type of content. This makes reading and understanding easier for the reader of the work. To create a new appendix, use the command *chapter{appendix name}* and remember to change the "label" of the new appendix created. The content of the attachment must be written within the file *appendices.tex* present within the folder *03-elementos-pos-textuais*.

If your dissertation or thesis project does not have an attachment, simply comment the include "*{\ include./03-elementos-pos-textual/apendices}*" in the main file "*Template. tex*", adding "%" to the beginning of the line.

Annex

ANNEX A – Name of the Annex A

Remember that the difference between an appendix and annex concerns the authorship of the text and/or material placed there.

If the supplementary or complementary material or text is your authorship, then it must be placed as an appendix. However, if the authorship is by third parties, then the material or text must be placed as an attachment.

Organize the annexes so that each one contains a single type of content. This makes reading and understanding easier for the reader of the work. To create a new annex, use the command *chapter{Annex name}* and remember to change the "label" of the new annex created. The content of the annex must be written within the file *anexos.tex* present within the folder *03-elementos-pos-textual*.

If your dissertation or thesis project does not have an attachment, simply comment the include "*{* include./03-elementos-pos-textual/anexos}" in the main file "*Template. tex*", adding "%" to the beginning of the line.