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Process Optimisation for the Production of Solid Rocket Motors

Bachelor Thesis
to achieve the university degree of
Bachelor of Science
Mechanical Engineering

submitted to

Graz University of Technology

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Client
Student Association Aerospace Team Graz

Graz, March 2025

Abstract

The objective of this thesis was to optimise the production process of Rocket Candy-based propellant for a solid rocket engine as part of the AVES II rocket project at the Aerospace Team Graz (ASTG). The initial manufacturing process exhibited deficiencies in safety, efficiency, repeatability, and the quality of the final propellant grains. These issues were addressed as far as financially and organisationally feasible within the association.
The study aimed to improve the manufacturing process to achieve accurate and repeatable process times, consistent quality, and enhanced safety within the limited resources available. It also examined the key factors influencing process efficiency, product quality, and safety, with a particular focus on factors affecting density and, consequently, the overall performance and reliability of the propellant.
To explore relevant material behaviours, manufacturing constraints, and the feasibility of new production methods, extensive literature research was conducted, and numerous experiments were performed. While significant optimisations were implemented, certain ideal process improvements remained constrained by budgetary and equipment limitations.
This work presents alternative manufacturing approaches and proposes a concept that best meets the defined requirements. It also details the key functionalities of the newly developed tools. The optimised process was successfully tested, resulting in propellants with consistent performance, which contributed to successful hot-fire campaigns and a strong performance at the European Rocketry Challenge.

Affirmation

I hereby affirm that this Bachelor thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text. This work has not been submitted for any other degree or professional qualification except as specified, nor has it been published.

Graz, March 27, 2025

Georg Witzlinger

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1. Introduction

This thesis describes the development of an optimised production process for manufacturing solid rocket motors based on Rocket Candy (RC)-propellant. This first chapter provides an overview of the circumstances that led to this work, followed by a review of the state of the art within the Aerospace Team Graz (ASTG), from which the objectives of the study are derived.

1.1. Motivation and goal

The Aerospace Team Graz is a student association dedicated to designing and developing experimental rockets for international rocketry competitions while conducting aerospace research. It was founded to provide members with the space and tools needed to gain practical experience alongside their theoretical education at universities in Graz. As a founding member of ASTG in 2019, I sought to combine my academic studies with my passion for rocketry in this work.
A rocket's propulsion system is crucial for generating sufficient thrust to achieve acceleration and can be classified based on the aggregate state of the oxidiser and fuel. Liquid propulsion systems use both components in liquid form, requiring fluid lines, valves, and control mechanisms, making them the most complex and expensive. In contrast, solid propulsion systems combine the oxidiser and fuel in solid form within the combustion chamber, offering a simpler and more cost-effective solution but lacking the ability to be switched off once ignited. Hybrid propulsion systems integrate elements of both, using either a solid fuel with a liquid oxidiser or vice versa. This approach retains controllability while remaining more affordable than fully liquid systems.
During the COVID-19 pandemic and in preparation for the European Rocketry Challenge in October 2021, procuring solid rocket motors became difficult due to supply shortages. With limited resources available for building its first competition rocket, AVES, the association decided to develop its own solid propellant. This propellant was composed of RC, primarily consisting of potassium nitrate (KNO_3) as the oxidiser and sorbitol as the fuel.

The aim of this thesis is to optimise the production process for developing a new solid rocket motor. This propulsion system is intended for integration into AVES II, the association's next competition rocket, in an application for the European Rocketry Challenge in October 2022. The key objectives are to enhance repeatability, quality, and safety while reducing process time. Identifying factors that influence these aspects is essential, with particular attention given to propellant density, which fell short of the desired level in the previous project.
This work explores available manufacturing methods and proposes a concept that best meets the defined requirements. Based on this, an appropriate design will be developed and manufactured.