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قال تعالى:

- (الرَّحْمَنُ (1) عَلَّمَ الْقُرْآنَ (2) خَلَقَ الْإِنْسَانَ
(3) عَلَّمَهُ الْبَيَانَ (4) الشَّمْسُ وَالْقَمَرُ بِحُسْبَانٍ
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صدق الله العظيم

الآية (1-6) سورة الرحمن

DEDICATION

This Ph.D thesis is dedicated to:

The sake of Allah, my Creator and my Master,

My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life,

My home land Sudan, the warmest womb;

The Sudan University of Science and Technology; my second magnificent home;

My great parents, who never giving of themselves in countless ways,

My dearest wife, who leads me through the valley of darkness with light of hope and support,

My beloved brothers and sisters; whom stands by me when things look bleak,

My beloved kids: Mohammed, Abubaker, Omer and Rawda, whom I can't force myself to stop loving.

To all my family, the symbol of love and giving,

My friends who encourage and support me,

All the people in my life who touch my heart,

I dedicate this research

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In the Name of Allah, the Most Merciful, the Most Compassionate all praise be to Allah, the Lord of the worlds; and prayers and peace be upon Mohamed His servant and messenger.

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ABSTRACT

Solid Rocket Motors (SRM) manufacturing and design were expensive. In the design to develop the solid propellant rocket motors, the use of numerical tools able to simulate, predict and reconstruct the behavior of a given motor in all operative conditions is particularly important in order to decrease the planning and costs to avoid made destructive test.

The study is devoted to present an approach to the numerical simulation of a given Solid Propellant Rocket Motor (SPRM) internal ballistics, 122 mm, during the quasi steady state by means of a commercial tool (ANSYS FLUENT). The main goal of the work is to study and simulate charged motor for long range (20~40km) rocket (122mm) motor internal ballistics (thrust & pressure).

The internal ballistics model constructed in the study is a 2-D axisymmetric model, based on several assumptions that there is no contribution of the erosive burning and dynamic burning in the burning rate model. The results of the internal ballistics simulation are compared with that obtained from the experimental ground firing test station for three models with original. The validation of the results allows concluding that the assumptions made in the construction of the model are reasonable. Good agreement observed between theoretical, analytical and experimental results.

In the study some of the conventional 2-D grain burn backs are analyzed and thrust - pressure time histories are predicted by plotting some graphs in different temperature ranges (20, 35, 50) °C. These graphs are validated by comparing the ground static firing test data obtained by Ballistic Test Motor. ANSYS FLUENT simulation can improve to investigating other solid rocket motors which used in missile or rockets or any other type of ammunitions which is high cost to investigate with experimental ground firing test station. The study allow make use of computers to model the test of SRM that eliminate cost of SRM research.

مستخلص الدراسة

تعتبر المحركات الصاروخية ذات الوقود الصلب عالية الكلفة المالية من حيث التصميم والتصنيع. لتطوير هذا النوع من المحركات يتم استخدام برامج رقمية قادرة على عمل المحاكاة ، التنبؤ ، التوقع وإعادة البناء السلوكي للمحرك في جميع ظروف التشغيل والذي يمثل جزءاً مهماً وأساسياً للمساعدة في تقليل الكلفة المخططة لتفادي الإختبارات الإتلافية .

هذه الدراسة تمت بغرض تقديم منهجية من خلال المحاكاة الرقمية للبايستية الداخلية للمحرك الصاروخي الذي يعمل بالوقود الصلب ، للمنتج الصاروخي 122 ملم ، خلال مرحلة إستقرار المحرك بعد مرحلة الإشعال باستخدام برنامج رقمي تجارى (ANSYS FLUENT) . الهدف الرئيسي من هذا البحث دراسة البايستية الداخلية (الدفع والضغط) من خلال دراسة ومحاكاة محرك صاروخي للمنتج 122 ملم بعيد المدى (20~40 كلم) مشحون بوقود صلب .

النموذج المستخدم لدراسة البايستية الداخلية مبنى ومصمم من بعدين بمحور ينصف شكل المحرك وبناء على عدد من الإفتراضات ، بحيث لا توجد مساهمة للإحتراق الناتج من الإحتكاك أو الإحتراق الديناميكي في معدل الإحتراق للنموذج . من خلال البحث تم عمل مقارنة لنتائج البايستية الداخلية المستهدفة الناتجة من المحاكاة مع نتائج الإختبارات العملية بمحطة الإختبارات الأرضية الساكنة (النظري والعملى) لعدد ثلاثة محركات كنماذج والنتائج الأصلية للمحرك ، وبناء على ذلك تم التحقق من نتائج النماذج المعده. من خلال التحقق والتي مكنت من الوصول لخلاصة أن الافتراضات التي بنيت عليها الدراسة مقبولة إلى حد كبير و أن هنالك مقاربة كبيرة في النتائج بين النظري والتحليلي والعملى.

تم دراسة عدد من التحولات للوقود ذات البعدين كما تم تحليلها بالتركيز على مخططات الدفع والضغط مع الزمن خلال درجات حرارة مختلفة $(20,35,50) ^\circ\text{C}$. هذه المخططات تم التحقق منها بمقارنة نتائجها مع النتائج العملية للنموذج في محطة الإختبارات الأرضية الساكنة .من خلال موثوقية النتائج يمكن إستخدام المحاكاة عبر برنامج ANSYS FLUENT للتحسين والتحقق من نتائج محركات لمنتجات أخرى تحت نفس الظروف والتي تستخدم في الصواريخ مختلفة الأحجام أو أى نوع آخر من أنواع الذخائر ذات الكلفة المالية العالية عند إجراء إختبارات المحطة الأرضية الساكنة لها (الإختبار الإتلافي). تم الإستفادة من البحث بحيث يتم حساب البايستية الداخلية للمحرك بإستخدام الحاسوب عوضاً عن الإختبارات الإتلافية مما ساهم مساهمة كبيرة في تقليل القيمة والكلفة المالية للمنتج.

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LIST OF SYMBOLS

Symbol	Definition	Unit
u	Gas velocity	m/sec
a	Burn rate coefficient	m/s
C	Effective exhaust velocity	m/s
F	Thrust	N
C_F	Thrust Coefficient	
c_p	Specific heat	J/kg k
g	Standard acceleration of gravity	m/s^2
D	Diameter	m
c*	Characteristic velocity	m/sec
I_{sp}	Specific impulse	sec
I₀	Total impulse	Ns
m	Mass flow rate	kg/s
n	Burning rate exponent	m/s
p	Pressure	MPa
q	Heat flux	J/kg
R	Universal gas constant	J/kgk
T_b	Burning rate	s
t	Time	s
A	Area	m^2
γ	Ratio of specific heats	
ρ	Gas density	kg/m^3
ε	Nozzle expansion ratio	
μ	Gas viscosity	Ns/m^2

ABBREVIATIONS

CAD	Computer Aided Design
SRM	Solid Rocket Motor
CFD	Computational Fluid Dynamics
MIC	Military Industrial Corporation
AP	Ammonium Perchlorate
SPRM	Solid Propellant Rocket Motor
IT	Ignition Transient
LPRM	Liquid Propellant Rocket Motor
TNT	Trinitrotoluene (C ₇ H ₅ N ₃ O ₆)
USD	United State Dollar
QSS	Quasi Steady State
TO	Tail Off
SPIT	Solid Propellant rocket motor Ignition Transient
BLT	Boundary Layer Transition
k	Turbulent kinetic energy
ε	Dissipation rate of k
UDF	User Define Function
SST	Shear Stress Transport

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