





TEH 2026

12th INTERNATIONAL SCIENTIFIC CONFERENCE
ON DEFENSIVE TECHNOLOGIES

PROCEEDINGS

TOPICS

AERODYNAMICS AND FLIGHT DYNAMICS
AIRCRAFT
WEAPON SYSTEMS AND COMBAT VEHICLES
AMMUNITION AND ENERGETIC MATERIALS
INTEGRATED SENSOR SYSTEMS AND ROBOTIC SYSTEMS
TELECOMMUNICATION AND INFORMATION SYSTEMS
MATERIALS AND TECHNOLOGIES
QUALITY, STANDARDIZATION, METROLOGY, MAINTENANCE AND EXPLOITATION

OTEH

DEFENSIVE TECHNOLOGIES

OTEH 2026

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PREFACE

Military Technical Institute, the first and the largest military scientific-research institution in the Republic of Serbia with over 77 years long tradition, has been traditionally organizing the OTEH scientific conference, devoted to defense technologies. The Conference is supported by the Ministry of Defense and it takes place every second year.

Its aim is to gather scientists and engineers, researchers and designers, manufactures and university professors in order to exchange ideas and to develop new relationships.

The 12th International Scientific Conference OTEH 2026 is scheduled as follows: lecture on the occasion of "Miomir Vukobratović", given by Aleksandar Rodić, PhD Eng, and two plenary lectures: given by representatives of DRS RADA Technologies, and presented by Velibor Ilić, PhD Eng "Artificial Intelligence from Perception to Autonomous Action: Applications, Opportunities and Challenges" .

The papers which will be presented at the Conference have been classified into the following topics:
− Aerodynamics and Flight Dynamics
− Aircraft
− Weapon Systems and Combat Vehicles
− Ammunition and Energetic Materials
− Integrated Sensor Systems and Robotic Systems
− Telecommunication and Information Systems
− Materials and Technologies
− Quality, Standardization, Metrology, Maintenance and Exploitation.

The Proceedings contain 160 reviewed papers which have been submitted by the authors from 13 different countries. I would also like to emphasize that we have 15 papers with authors from abroad. The quality of papers accepted for publication achieved very high standard. I expect stimulated discussion on many topics that will be presented online, during two days of the Conference.

On behalf of the organizer I would like to thank all the authors and participants from abroad, as well as from Serbia, for their contribution and efforts which made this Conference possible and successful.

I would also like to thank the Ministry of Science, Technological Development and Innovations of the Republic of Serbia for its financial support.

Finally, dear guests and participants of the Conference, I would like to wish you a pleasant and successful work during the Conference. I am looking forward to see you again at the Conference. All the best and stay healthy.

Serbia, Tara, October, 2026

Col. Aleksandar Kari PhD Eng
President of the Scientific Committee
OTEH 2026

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INTERNAL BALLISTICS-BASED DESIGN AND STRUCTURAL ANALYSIS OF A 30×165 mm CANNON BARREL

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Abstract: *This paper deals with the analysis and optimization of parameters influencing the internal ballistics and barrel design of the 30×165 mm automatic cannon. Internal ballistic calculations were performed using a mathematical model based on the Drozdov method, with the aim of determining the influence of various parameters on projectile muzzle velocity and maximum powder gas pressure inside the barrel. The analysis was first carried out using reference internal ballistic parameters, after which selected parameters were varied within a limited range in order to examine their influence on system performance. By individual and combined variation of the parameters, their mutual dependence and impact on the operating characteristics of the weapon system were determined. The primary objective was to obtain higher projectile muzzle velocity while maintaining the maximum pressure within allowable limits. Based on the obtained optimal parameters, the barrel geometry was calculated. In the final stage of the research, structural verification of the designed barrel was performed using the finite element method in Simcenter Femap. The barrel model was subjected to loading conditions corresponding to the calculated internal ballistic forces, enabling analysis of stress distribution, deformation, and structural integrity under operating conditions.*

Keywords: *Internal ballistics, barrel design, Drozdov method, FEM analysis.*

1. INTRODUCTION

The design of artillery gun barrels requires the simultaneous consideration of internal ballistic performance and structural integrity. During firing, the barrel is subjected to rapidly varying pressure loads generated by the combustion of the propellant, producing complex stress and deformation states. Therefore, reliable barrel design requires both accurate prediction of the internal ballistic parameters and evaluation of the structural response under transient loading.

Internal ballistic calculations provide the pressure distribution, projectile velocity and projectile position throughout the firing process. These parameters can be used as input for finite element analysis, enabling a detailed assessment of the barrel stress and deformation during projectile travel. Such an approach allows the direct connection between the internal ballistic solution and the structural analysis of the weapon system.

In this study, an internal ballistic model of a 30×165 mm automatic cannon cartridge was used to determine the pressure distribution along the barrel. The obtained pressure curves were converted into a sequence of loading conditions and applied to an axisymmetric finite element model of the barrel developed in Simcenter Femap/Nastran. The structural response was evaluated by monitoring the maximum equivalent stress and total displacement throughout the firing cycle.

Furthermore, the structural response obtained for the optimized propellant configuration was compared with that of the initial configuration. The comparison enables the assessment of how the optimization of internal ballistic parameters influences the stress state and deformation of the barrel, providing a basis for further improvement of barrel design and material selection.

The proposed methodology provides an efficient procedure for transferring internal ballistic results into finite element load cases and can be applied during the structural design and verification of gun barrels.

2. INTERNAL BALLISTICS CALCULATION

The structural analysis presented in this paper is based on the results of an internal ballistic calculation performed for a 30×165 mm automatic cannon cartridge. The internal ballistic model was developed using the Drozdov method [1]. The calculation provides the temporal evolution of the chamber pressure, projectile velocity and projectile position, which are subsequently used as input data for the finite element analysis.

The initial calculation was performed using the nominal ballistic parameters of the selected ammunition. Input

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parameters for calulation are summarized in Table 1.

Table 1. Nominal input parameters

Label	Value	Unit
Powder chamber volume- W_0	0.000311	m
Barrel bore cross-sectional area- S_c	0.000738	m^2
Total projectile barrel travel- X_u	2.16	m
Forcing pressure- p_0	30e6	Pa
Fictitiousness coefficient- φ	1.169	/
Projectile mass- m	0.435	kg
Propellant charge mass- m_b	0.195	kg
Propellant density- ρ_b	1600	$\frac{kg}{m^3}$
Covolume of propellant gases-α	0.00103675	$\frac{m^3}{kg}$
Specific heat ratio- θ	0.269	/
Propellant grain thickness- r_0	0.000335	m
Shape coefficient- κ_1	1.24179	/
Shape coefficient- λ_1	-0.19471	/
Specific work of propellant gases- fb	926712.491	$\frac{J}{kg}$
Propellant burning rate- u_{z0}	6.66e-10	$\frac{m}{sPa}$

The results of the IB calculations indicate a maximum chamber pressure of 313.69 MPa and a muzzle velocity of 1008.95 m/s.

Graphical results of IB calculation are shown in images below.

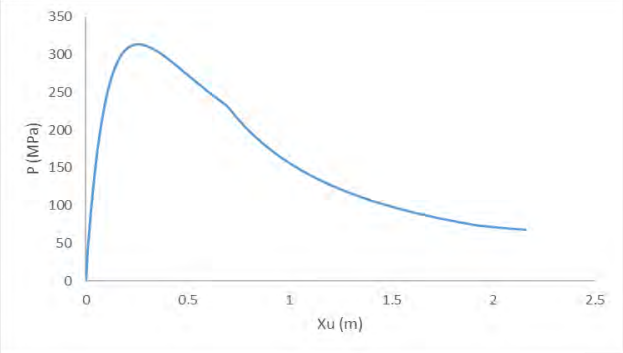


Figure 1. Pressure-travel curve.

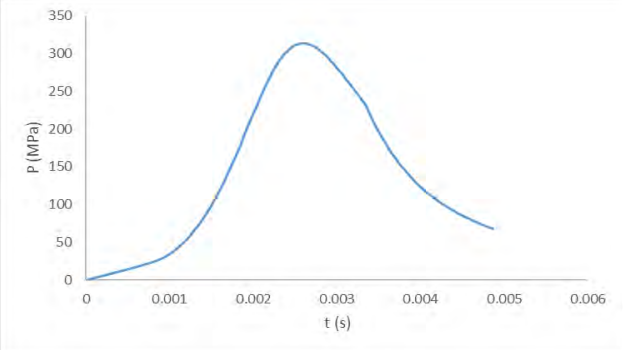


Figure 2. Pressure-time curve.

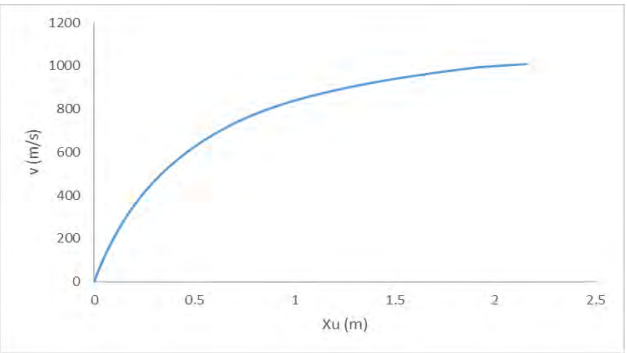


Figure 3. Velocity-travel curve.

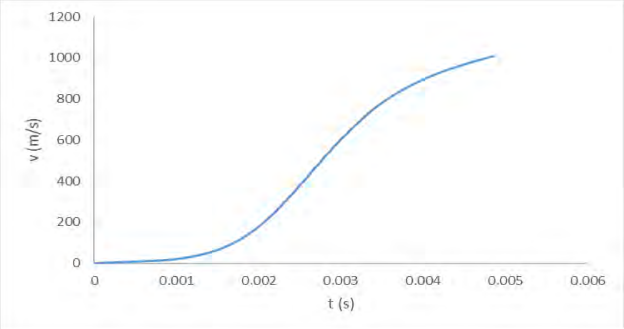


Figure 4. Velocity-time curve.

The initial ballistic solution served as the reference configuration for the subsequent optimization process.

2.1. Selection of the optimized IB configuration

The influence of the most significant internal ballistic parameters on the muzzle velocity and maximum chamber pressure was investigated by varying each parameter individually within predefined limits. [2] The objective of the analysis was to identify the parameters whose variation produces a favorable increase in projectile velocity without causing an excessive increase in the maximum pressure. [3]

Only the parameters that demonstrated a positive influence on the desired ballistic performance were selected for further optimization. Parameters with negligible or unfavorable influence were excluded from the final configuration.

The selected parameters together with their influence on the muzzle velocity and maximum pressure are presented in Table 2.

Table 2. Influence of changed parameters.

Parameter	Parameter change (%)	Velocity change (%)	Pressure change (%)
m	-5%	+1,64%	-5,03%
r_0	-5%	+1,72%	+10,92%
m_b	+2,5%	+1,85%	+6,37%
m_b	+5%	+4,63%	+16,72%
u_{z0}	+5%	+1,62%	+10,2%

α	+5%	+0,83%	+3,22%
f_b	+2,5%	+1,67%	+4,99%
f_b	+5%	+3,31%	+10,11%

Based on the observed trends, an optimized combination of internal ballistic parameters was defined. Newly selected parameter changes are: m-5%; m_b+2.5%; α+5%; f_b+2,5%. The selected parameter values represent a compromise between increased projectile velocity and acceptable structural loading of the barrel. This optimized configuration was adopted as the basis for the subsequent structural analysis. [4]

Graphical results of IB calculation are shown in images below.

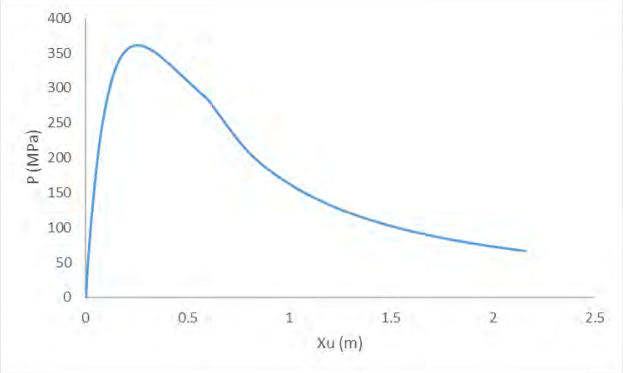


Figure 5. Pressure-travel curve.

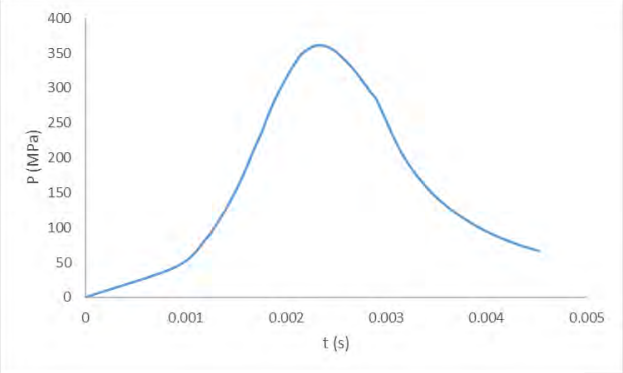


Figure 6. Pressure-time curve.

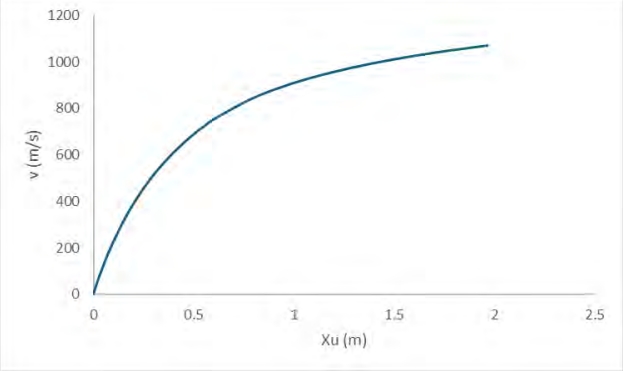


Figure 7. Velocity-travel curve.

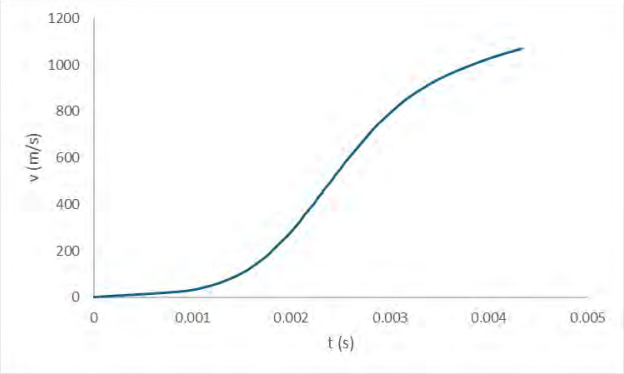


Figure 8. Velocity-time curve.

A comparison between the initial and optimized internal ballistic configurations is presented in Table 3.

Table 3. Comparison of the ballistic configurations.

	Maximum pressure (MPa)	Muzzle velocity (m/s)
Nominal conifig.	313.69	1008.95
Optimized config.	361.88	1090.49
Relative change	+15.36%	+8.08%

3. FINITE ELEMENT MODEL OF THE BARREL

The structural response of the barrel was evaluated using the finite element method based on the pressure distribution obtained from the internal ballistic analysis. The complete procedure included the development of the barrel geometry, generation of the finite element model, definition of material properties and boundary conditions, and application of the pressure loading corresponding to different projectile positions during the firing process.

3.1. Barrel geometry

The barrel geometry was generated using the KODCEV software package based on the optimized internal ballistic solution. The software calculates the required barrel profile from the specified ballistic loading conditions and material characteristics, providing the inner and outer barrel contours required for structural analysis. The barrel was dimensioned according to the Huber-Mises-Hencky (von Mises) criterion, where the elastic strength limit is defined by internal pressure at which the equivalent stress reaches the yield strength of the material. [5]

The calculated barrel profile was exported as a set of coordinate points describing the barrel cross-section. These coordinates were imported into the FEA environment, where the two-dimensional axisymmetric geometry of the barrel was reconstructed. Since the loading and geometry are rotationally symmetric, an axisymmetric representation was adopted in order to reduce the computational cost while preserving the accuracy of the structural analysis.

Due to space limitations, profiles of the chamber, the

forcing cone and the initial section of the projectile guide are represented in figure 9.

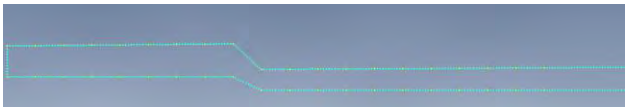


Figure 9. Profiles of the chamber, the forcing cone and the initial section of the projectile guide.

3.2 Finite element model

The finite element model was developed in Simcenter Femap**.** The reconstructed barrel profile was meshed using two-dimensional axisymmetric solid elements. The final mesh consisted of a combination of quadrilateral and triangular elements, with a characteristic element size of approximately 2 mm. This element size provided sufficient spatial resolution along the barrel profile while maintaining reasonable computational efficiency. The resulting finite element model contained a total of 5719 nodes and 4671 elements.

Linear elastic material properties corresponding to the selected barrel steel were assigned to the model. The material was assumed to be homogeneous and isotropic throughout the analysis.

The rear end of the barrel was constrained to represent its attachment to the breech mechanism. This boundary condition prevented rigid body motion while allowing the structural response of the barrel to be evaluated under the applied internal pressure loading.

The completed finite element model together with the applied boundary conditions is presented in Figure 10.

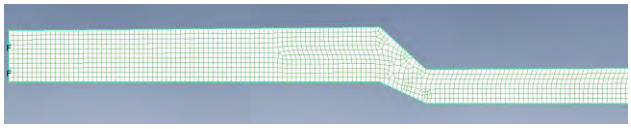


Figure 10. Finite element model with the applied boundary conditions.

3.3. Pressure loading

The pressure loading applied in the finite element model was derived directly from the optimized internal ballistic calculation. The pressure acting inside the barrel changes continuously as the projectile travels along the bore. Therefore, instead of applying a single uniform pressure, the loading was represented by a sequence of pressure distributions corresponding to successive projectile positions.

The pressure history obtained from the internal ballistic calculation was discretized into 40 loading steps, each representing a characteristic projectile position inside the barrel. For every loading step, the pressure was applied only to the portion of the barrel occupied by the propellant gases, while the remaining part of the barrel remained unloaded. This procedure reproduces the actual movement of the pressure front during the firing process.
To automate the preparation of the finite element model, custom BASIC scripts were developed within Simcenter Femap. The scripts automatically generated the pressure functions, created the corresponding Load Sets and assigned the pressure distributions to the appropriate barrel segments. The use of custom automation scripts enabled an efficient transfer of internal ballistic results into the finite element model, substantially reducing the time required for model preparation and minimizing the possibility of human error. [6]

Example of the sequence of pressure loading conditions applied during the analysis is schematically illustrated in Figure 11.

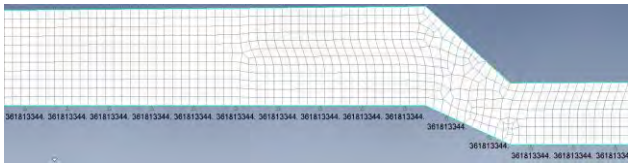


Figure 11. Example of the sequence of pressure loading conditions.

3.4. Numerical analysis

Following the definition of the finite element model and loading conditions, a MultiSet analysis was performed using Simcenter Nastran. Each loading step corresponded to one projectile position, allowing the evolution of the stress and deformation fields to be monitored throughout the firing process.

For every load case, the maximum equivalent (von Mises) stress and total displacement were extracted. These quantities were subsequently used to compare the structural response of the initial and optimized internal ballistic configurations. Also, an element and node ID of located maximum stress and displacement were also extracted.

The obtained results are presented and discussed in the following section.

4. RESULTS AND DISCUSSION

The structural response of the barrel was evaluated throughout the complete firing cycle using the sequential pressure loading obtained from the nominal and optimized internal ballistic calculation. For each loading step, the maximum equivalent (von Mises) stress and total displacement were extracted and analyzed as functions of both projectile position and time.

The variation of the maximum equivalent stress with projectile position and firing time is presented in Figures 12 and 13, respectively.

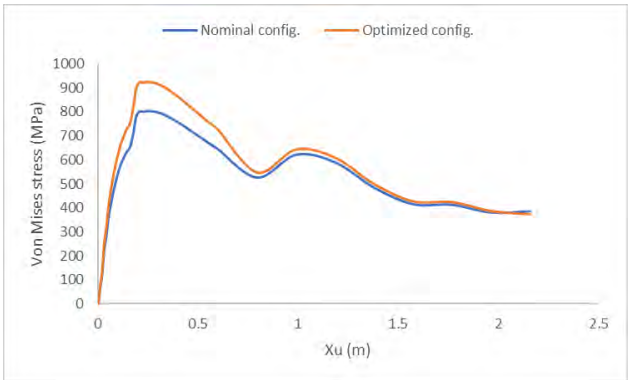


Figure 12. Von Mises stress-travel curve.

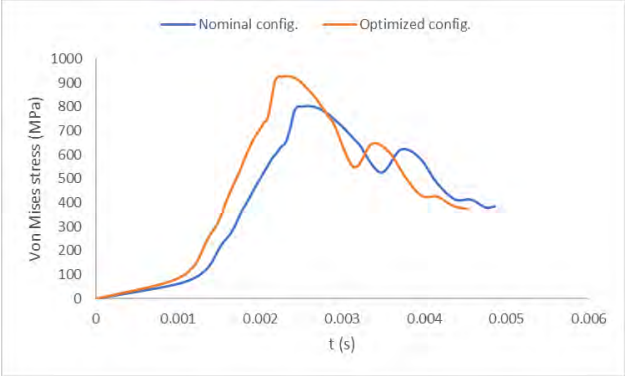


Figure 13. Von Mises stress-time curve.

Both figures demonstrate that the equivalent stress rapidly increases during the initial stage of projectile motion, reaches its maximum shortly after the pressure peak, and gradually decreases as the projectile approaches the muzzle. This behavior follows the evolution of the internal pressure generated during the firing process.

The variation of the total barrel displacement with projectile position and firing time is shown in Figures 14 and 15.

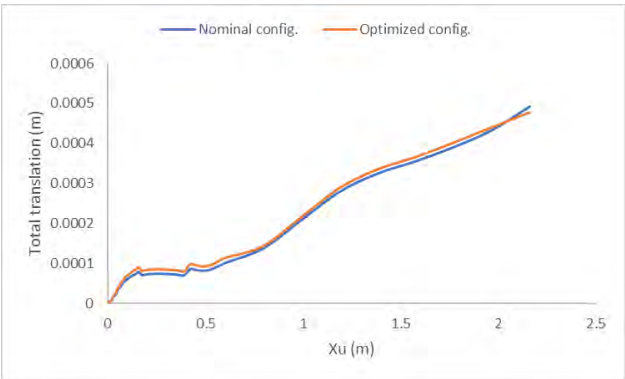


Figure 14. Total translation-travel curve.

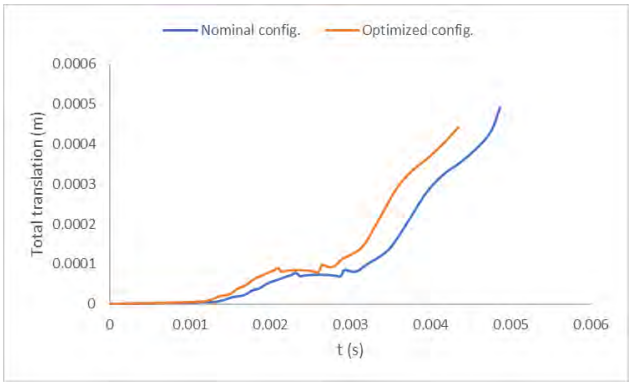


Figure 15. Total translation-time curve.

Unlike the equivalent stress, the total displacement exhibits a gradual increase during projectile travel, reaching its maximum near the muzzle. This behavior is expected since the loaded length of the barrel continuously increases as the projectile advances, resulting in progressively larger elastic deformation of the structure.

To evaluate the influence of the internal ballistic optimization, the maximum equivalent stresses obtained for the initial and optimized configurations were compared. The comparison is presented in table 4.

Table 4. Comparison of the maximum equivalent stress.

Configuration	Maximum equivalent stress (MPa)
Nominal	803.11
Optimized	926.75

The optimized internal ballistic configuration resulted in a increase of the maximum equivalent stress while simultaneously increasing the muzzle velocity. This indicates that the selected combination of ballistic parameters improves ballistic performance but decreases structural loading conditions of the barrel.

Although the calculated equivalent stresses reach relatively high values, the duration of the loading is extremely short. Therefore, the maximum equivalent stress was not used as the sole criterion for material selection based on the yield strength. Instead, the obtained stress distribution was primarily used to identify the most highly loaded regions of the barrel and to evaluate possible design improvements.

The numerical results indicates one characteristic region in which the maximum equivalent stresses repeatedly occurs during the firing cycle. The region is located near the transition between the chamber and the projectile guiding section. The repeated occurrence of stress maxima in this region suggests that further structural optimization could be achieved by modifying local geometric features, such as transition radii or wall thickness distribution. This region is shown in Figure 16.

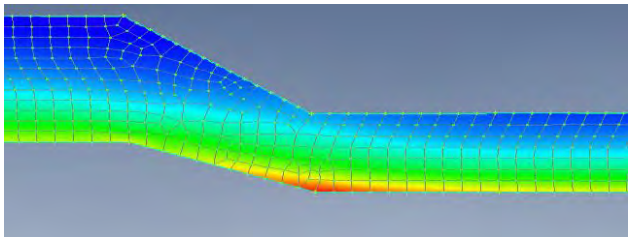


Figure 16. Repeated maximum stress occuring region.

From the manufacturing point of view, the obtained stress levels also indicate that additional strengthening methods may be considered in the most highly loaded portions of the barrel. Depending on the selected material and production technology, suitable solutions include local surface strengthening of the projectile guiding section, strengthening of a limited wall thickness, or the application of an autofrettage process in order to improve the fatigue resistance and operational life of the barrel.

The displacement results may also be useful during the design of the complete weapon system. Appropriate stiffening elements or barrel support arrangements may therefore be introduced to reduce deflection and improve the overall structural rigidity of the weapon.

Overall, the presented methodology demonstrates that coupling internal ballistic calculations with finite element analysis provides not only an assessment of barrel stresses and deformations but also valuable information for structural optimization and manufacturing process selection.

5. CONCLUSION

A methodology for the coupled internal ballistic and finite element analysis of a 30×165 mm automatic cannon barrel has been presented. The pressure distribution obtained from the internal ballistic calculation was transferred into a sequence of finite element loading conditions, enabling the structural response of the barrel to be evaluated throughout the firing cycle.

The parametric optimization of the internal ballistic model resulted in an increase in muzzle velocity, while the optimized pressure history provided realistic loading conditions for the finite element analysis.

The numerical analysis identified the evolution of equivalent stresses and barrel displacements and the most highly loaded regions. These results can be used to identify locations where additional strengthening methods, such as local surface treatment or autofrettage**,** may improve barrel service life.

The presented methodology demonstrates that coupling internal ballistic calculations with finite element analysis provides an efficient approach for the structural assessment and optimization of gun barrels, offering practical guidance for their design and further development.

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