Examining Thin-Walled Steel Structures under blast loading conditions

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Abstract:

This research paper explores the impact of blast loading on thin-walled steel structures, with a specific emphasis on blast-resistant doors and the influence of stiffeners and plate curvature. The study employs numerical simulations to assess the performance of various stiffener shapes and plate curvatures under blast conditions. The findings underscore the importance of design considerations and provide insights for improving the blast resistance of such structures.

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1. Introduction

Blast-resistant structures are essential for safeguarding personnel and assets against explosive events. Understanding the behavior of thin-walled steel structures under blast loading is critical for effective design and mitigation strategies. This section provides an overview of the significance of blast-resistant structures and introduces the objectives of the research.

A comprehensive understanding of blast phenomena, structural dynamics, and blast aerodynamics is crucial for designing blast-resistant structures. This section discusses previous research on blast-resistant doors, the importance of stiffened plates, and the advantages of curved steel plates in withstanding blast loads.

Design Considerations for Blast Resistant Structures

Structural dynamics and blast aerodynamics play pivotal roles in the design process of blast-resistant structures. This section outlines key considerations in designing structures to withstand blast loading, including the challenges involved and the use of numerical techniques for analysis.

2. Review of literature

The field of steel structure design and examination has a long history, documented in technical literature such as textbooks, handbooks, and scientific journals. Initially, contributions were experimental, followed by theoretical investigations yielding simple solutions. However, as civil engineering challenges grew more complex over time, closed-form solutions became impractical. Designers turned to experiments, which were costly and time-consuming. In the absence of closed-form solutions, numerical methods emerged as a viable alternative, albeit requiring significant computational resources. The practical implementation of numerical methods became feasible with advancements in computer science, leading to increased research interest worldwide. This review focuses on research papers exploring the analysis of steel structures under explosive blast loads, highlighting the role of numerical methods in addressing complex engineering problems.

T. Ngo, et al. in their study on structures exposed to blast loads, presented an outline with regard to design & analysis of various structural elements and their dynamic response to blast loads. This study also includes design methodologies for severe loads like an impact of shock waves due bomb blast or a projectile.

Ming-Wei Hsieh et al. (2008) studied the effect of blast load on a stiffened door structure by varying height and thickness of the stiffener. The door is designed to provide maximum protection to its occupants and contents, and the damage is limited to the extent specified in TM5- 1300. To achieve this, they conducted a number of transient analyses to determine the blast response of the doors.

A.Khadid etal. (2007) investigated the dynamic response of stiffened plates that are fully fixed and exposed to blast loads. They incorporated a variety of stiffener geometry, and studied the consequence of grid size, strain rate sensitivity and time duration. In this paper, they employed FEM and FDM (central difference method) to solve non-linear equations of motion.

R. Rajendran et al. (2009) studied the effect of different blast loads on plates which are the one of the basic elements of various structures. These structures may be land based which may be subjected to air blast during combat environment or terrorist attack, while marine structures may be subjected air blast or under-water explosion by the attack of a torpedo or a mine or a depth-charge and an effect of on-board explosive devices on aircraft structure. Further-more, the effect of gas-explosion on off-shore installations and industries is also studied.

3. Methodology and Analysis

This research employs the ABAQUS software to analyze the structural response of stiffened steel plates subjected to blast and impulse loads. The methodology is structured to systematically investigate the blast load resistance of panels reinforced with T, I, and HAT sections. Special attention is dedicated to assessing mid-point displacement and strain energy absorption to comprehensively evaluate the performance of stiffened steel plates under blast loading conditions. The finite element analysis is conducted utilizing S4R shell elements to represent the computational domain, while beam elements are utilized to model stiffeners. The following steps outline the methodology employed in this research:

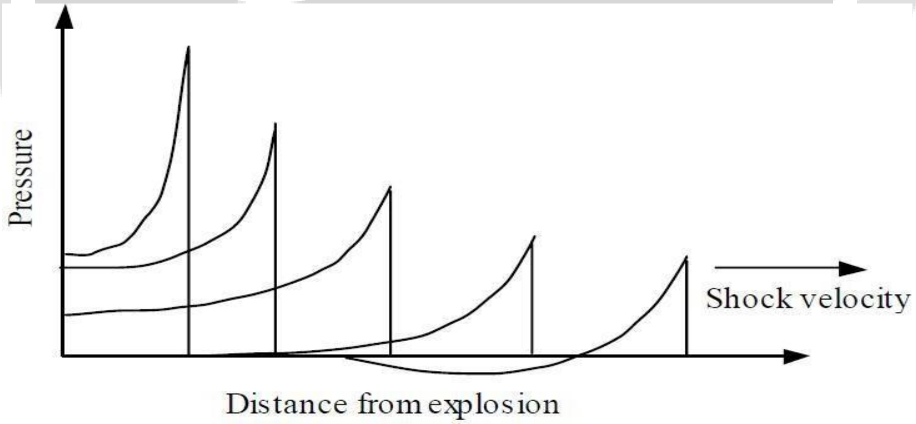

Fig3.1:Propagation of Blast Wave

Investigation Details

This section presents the specific details of the investigation, including the range of blast loads considered and the variations in stiffener shapes and plate curvatures. Transient simulation studies are described, highlighting the dynamic response of stiffened plates under blast loading.

4. Results and Discussion

The results of the numerical simulations are presented and discussed in this section. Analysis of stress distribution, displacement, and strain energy absorption provides insights into the performance of different stiffener shapes and plate curvatures under blast loading conditions.

Table 4.1: Buckling load of circular plate with T - stiffener underdifferent modes for various R/T ratio.

R/T	Buckling Load (kN)					
	Mode-1	Mode-2	Mode-3	Mode-4	Mode-5	Mode-6
200	31.798	40.140	68.706	69.884	85.864	95.466
210	28.214	35.164	60.198	61.538	75.854	83.714
220	25.206	31.010	53.096	54.532	67.464	73.838
230	22.690	27.556	47.190	48.672	60.456	65.570
240	20.596	24.696	42.302	43.794	54.626	58.684
250	18.8638	22.344	38.284	39.756	49.808	52.988

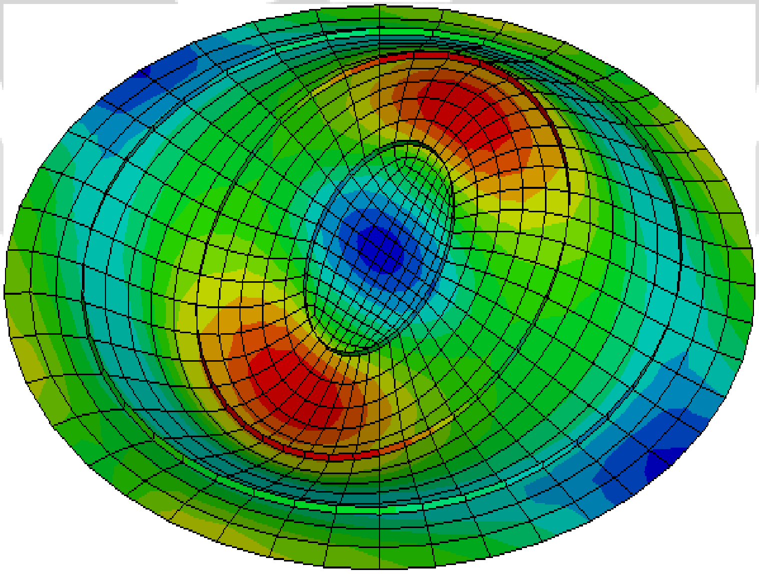

Fig 4.4: Deformed shape of circular plate with T-Shape stiffener

5. Conclusion

The conclusion summarizes the key findings of the research and their implications for the design of blast-resistant structures. Recommendations for future studies are provided, highlighting areas for further exploration and refinement of design methodologies.

6. References

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