Equivalent Design of Stiffened Panel based on Load Characteristics

LI juncheng[1,2], HUANG fenglei1*, LU yonggang[2], YU chunxiang[2], CHEN hua[3]

1.State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, Beijing 100081, China
2.Institute of Systems Engineering, China Academy of Engineering Physics, Mianyang, Sichuan,621999, China
3.Troops 96901, Beijing 100081, China
E-mail: huangfl@bit.edu.cn.

Abstract

In order to use a cheaper and homogeneous steel plate to replace the real stiffened panel in warhead tests, we numerically simulated and analyzed the deformation and failure characteristics of the stiffened panel as well as the force characteristics of the projectile in the warhead-target interaction. Based on the energy equivalence method, we first used the acceleration curve of the warhead in actual target penetration process as the reference for equivalent design and replaced it using a three-layered homogeneous steel plate. To visually assess their equivalence, we introduced Pearson correlation coefficient in statistical analysis to reflect their correlation. The results showed that the equivalent design method based on load characteristics make both consistent not only in the kinetic energy loss but also in the warhead's target-piercing acceleration process, thus realizing the equivalence from process to final state.

Stiffened panel structure model

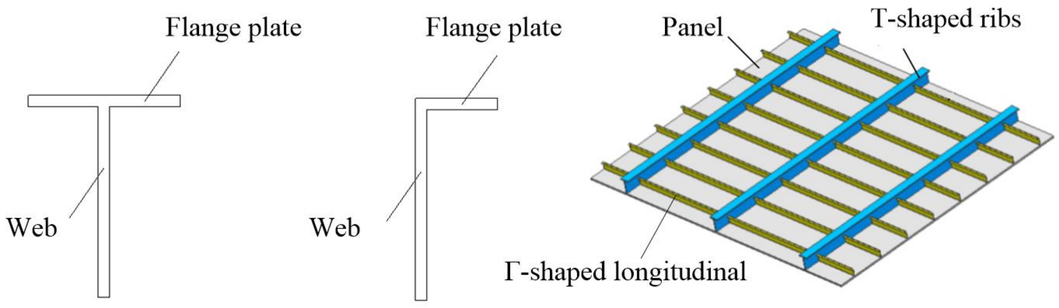

Figure 1. Diagram of stiffened plate

The stiffened panel of the deck consists of equal-thickness steel plate (panel) with thickness of 30 mm, inter-rib spacing of 2000 mm, and inter-longitudinal spacing of 600 mm , T-shaped ribs with flange plate width of 160 mm, thickness of 16.7 mm; web depth of 240 mm, and Γ-shaped longitudinal made of a 40 mm wide and 6.7 mm thick flange plate and a 133 mm deep and 6.7 mm thick web

Analytical model and numeric simulation

➢ Stiffened panel

Stiffened panel is made of 921A steel

Table 1. Johnson-cook parameters of 921A steel

ρ/（kg/m³）	E/GPa	v	A/MPa	B/MPa	C	n	m
7800	205	0.28	760	500	0.014	0.53	1.13
C_p/（J/（kg · K））	T_r	T_m	D_1	D_2	D_3	D_4	D_5
400.9	294	1765	1.13	0	0	0	0

➢ projectile

Table 2 Projectile material parameters

ρ/（kg/m³）	E/Gpa	v	σ_y/Mpa	E_p /Mpa	P	ε_{eff}^{p}
7800	210	0.3	1400	1215	4.47	0.6

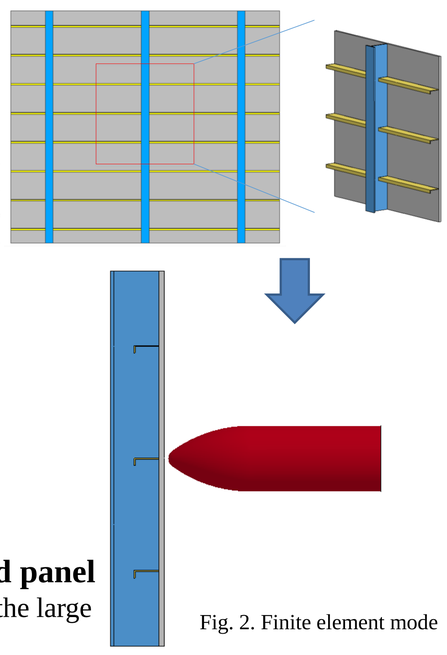

Fig. 2. Finite element mode

➢ Deformation and failure features of stiffened panel

- The overall plastic deformation and failure as well as the large bending of its rib beam structure.
- Load curve is characteristic of low amplitude, long pulse width and multiple peaks.

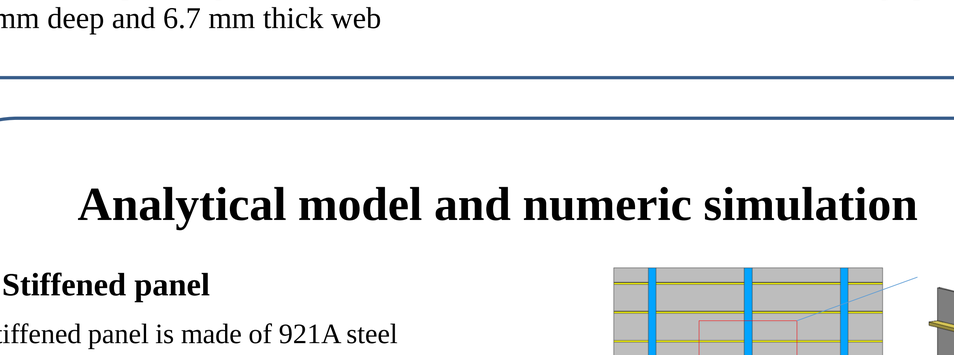

Fig.3. Warhead's target-penetrating process

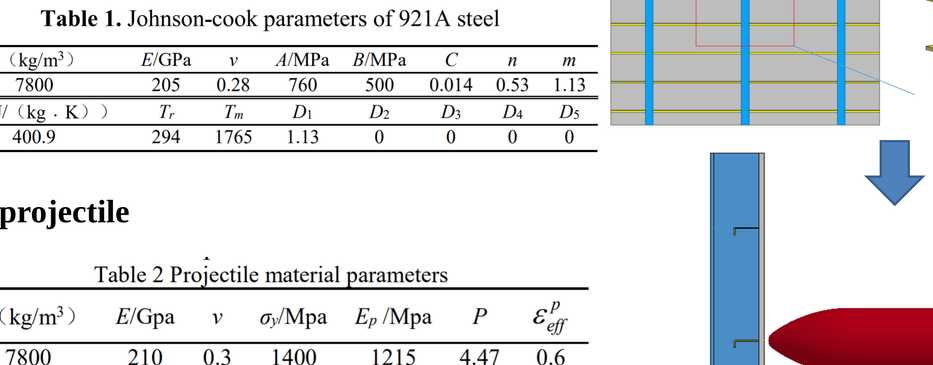

Fig. 4. The time history curve of the projectile(acceleration and velocity)

Equivalent design based on energy method

➢ Equivalent to a single-layer, 60 mm thick homogeneous ship steel plate using the energy method.

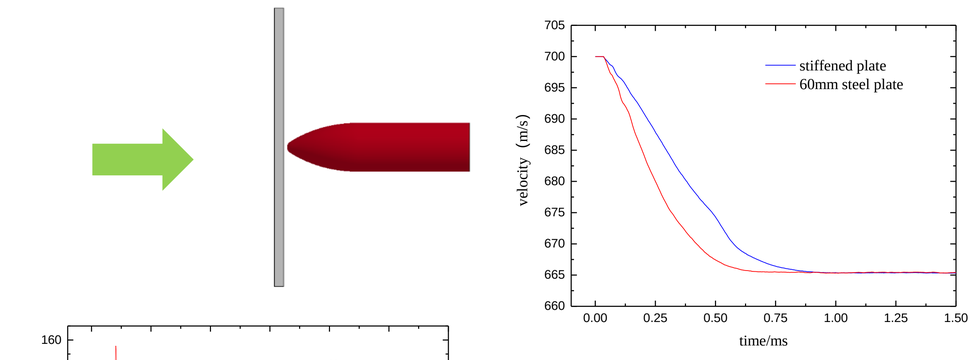

Fig.5. Comparison of the velocity curves

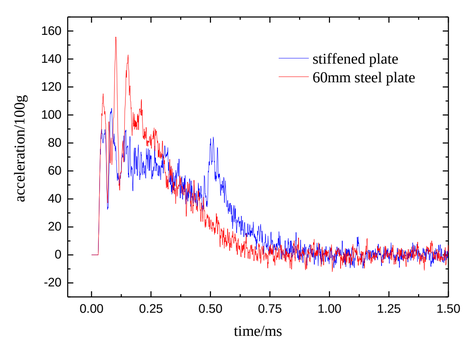

Fig.6. Comparison of the acceleration curves

The final residual speed of the warhead penetrating the two kinds of targets is the same, while the force characteristics and speed change processes are significantly different.

Equivalent design based on load characteristics

➢ According to the acceleration varying features of the warhead in its actual target penetration process to realize similar speed variation trend and value.

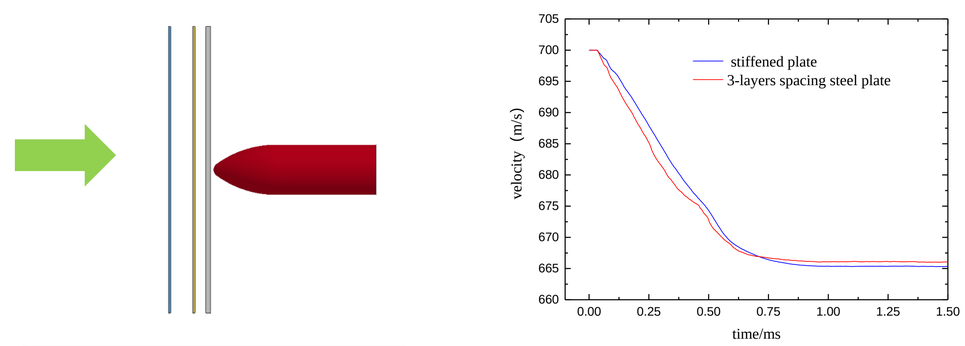

Fig.7. Comparison of the velocity curves

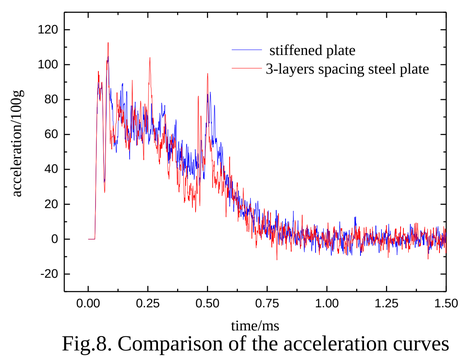

Fig.8. Comparison of the acceleration curves

The residual speed of the warhead after penetrating the equivalent 3-layer target is 666.1 m/s and that after penetrating the stiffened panel is 665.3, with a difference of only 0.12%, indicating that both have same ability to absorb the kinetic energy from the warhead. Moreover, both of them have a good similarity in acceleration peak, duration, and overall changing trend.

Table 3 Correlation analysis results

Target type	Initial speed (m/s)	Residual speed (m/s)	Acc. Peak (g)	Corr. Index r	
				velocity curve	acceleration curve
Stiffened panel	700	665.3	10500	1	1
60-mm steel plate	700	665.4	15600	0.9648	0.7895
3 layered spacing steel plate	700	666.1	11400	0.9963	0.8843

The stiffened panel is equivalent to the 3-layer target plate with correlation index of the speed changing curves of the warhead during penetrating these two targets being 0.9963, and the correlation index of their acceleration curves being 0.8843, indicating that the equivalent design is more reasonable.

Conclusion

➢ The stiffened panel structure utilizes its overall plastic deformation and failure as well as the large bending of its rib beam structure to consume the velocity of the projectile. Compared with the single-layer, homogeneous steel target, the warhead's load curve is characteristic of low amplitude, long pulse width and multiple peaks.

➢ The equivalent design based on load characteristics uses the warhead-target interaction process as the design reference and can more truly simulate the force environment of the warhead. Compared with the equivalent design based on the energy method that only considers the target-piercing speed loss, the former is more reasonable.

Acknowledgement

The reported research is financially supported by the Natural Science Foundation of China under Grant No.11572299. The financial contributions are gratefully acknowledged.