ANALYTICAL SIMULATION OF SHOCK TESTS ON POLYUREA COATED COMPOSITE PANELS

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Understanding and predicting the material and structural responses that result from blast and high velocity impacts are essential for designing survivable systems for both military and civilian structures. Blast and impact produce intense impulse loading, high rates of strains and high pressures, and sometimes associated with intense fire that result in large-scale inelastic deformation, massive fracturing, and high temperature that may change the physical and mechanical properties of the materials. The ability to predict the combined effects of blast, impact and the resulting shock, penetration and their interaction as they propagate and disperse though the structures are essential to design survivable systems as well as in assessing vulnerability of existing structures. Even in areas away from direct impact or blasts, the people and the equipment must be protected from stress waves that are propagating through the material and degrading their functionality.

To mitigate blast a number of concepts are being experimented. One such experiment that is being conducted by US Navy is coating of structural member by super elastomer such as polyurea (PU). This paper tries to address through mechanics how the PU contributes to the shock mitigation.

E-Glass/Vinyl ester composite panels processed by vacuum assisted resin transfer molding [1] were coated with polyurea in different arrangements. These panels were tested [2] under various shock levels at the University of Rhode Island using shock tube. Total thickness of the composite and the PU is maintained constant while developing the panel layer arrangements. Table 1 describes the panel configuration, location of PU layers and the panel designation. Table 2 summarizes the peak shock pressure, duration, and visible damages observed in each case. This data clearly demonstrates that PU coated composite panels took double the shock pressure than the bare composite panel and even then they have not fractured.

Table 1. Details of various PU/FRP sandwich configuration

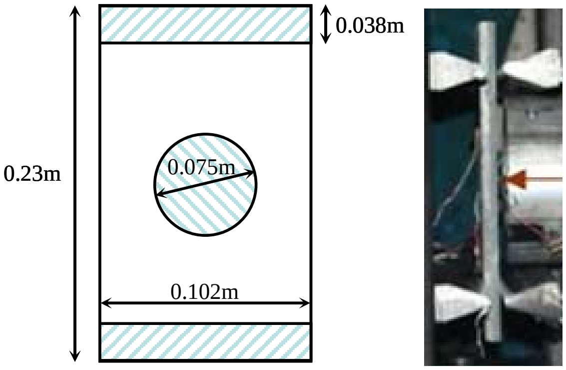
Test case	Sample	Description
Base line	F1SN-3 F1SN-5	1/4-in Woven roving E-Glass/Vinyl ester composite
PU/FRP	F1SF-2 F1SF-3	1/4-in PU coated on 1/4-in Gl/VE composite panel
FRP/PU	F1SB-1 F1SB-5	1/4-in Gl/VE composite back face coated with 1/4-in PU
FRP/PU/FRP	F2SFS-2 F2SFS-4 F2SFS-1 F2SFS-3	1/4-in PU interleaved between 1/8-in Gl/VE composite panels
PU/FRP/PU	F1SFB-3 F1SFB-4	1/4-in Gl/VE composite coated on front and back face by 1/8-in PU

To understand this superior shock mitigation property of PU a detailed impulse loading analysis of the test panels are being conducted. The test specimen used was a rectangular panel of length 0.23m and width 0.102m and the two opposite ends were simply supported at 0.038m from the edges leaving 0.154m as the unsupported span. The other two edges were unsupported. The test specimen and test conditions are shown in Figure 1. The material properties given in reference [1] are used for composites. The polyurea is considered as a rate-sensitive, elastic-plastic material with stiffening by increasing strain and strain rates as described by an elastic-plastic-hydrodynamic model with Gruneisen equation of state. The material constitutive model was developed by Nemat-Nasser [3].

Table 2. Shock test details for various PU/FRP sandwich configuration

Test samples	**Peak shock pressure MPa**	**Duration, ms**	**Visible damage**
Base line			
F1SN-3	0.62	4.9	Completely failed
F1SN-5	0.45	4.1	Minimal deformation Intense transverse cracks and delaminations in front layers
PU/FRP			
F1SF-2	0.62	---	Completely failed
F1SF-3	0.75	---	No deformation No visible damage
FRP/PU			
F1SB-1	0.77	---	Minimal deformation Intense transverse cracks and delaminations in front layers
F1SB-2	---	5.1	No deformation No visible damage
F1SB-3	---	4.9	Minimal deformation Fiber breakage in back layer
F1SB-5	1.18	---	Extensive delaminations and fiber breakage Separation between PU and FRP layer
FRP/PU/FRP			
F2SFS-2	0.62	---	No deformation No visible damage
F2SFS-4	0.75	2.4	
F2SFS-1	1.03	2.5	
F2SFS-3	1.18	2.2	
PU/FRP/PU			
F1SFB3	1.18	---	Minimal deformation Wrinkling of PU layer accompanied by through width delamination
F1SFB4	1.18	---	Minimal deformation Wrinkling of PU layer

LS-Dyna explicit dynamic finite element code was used to model the problem. Since dynamic problems are always sensitive to modeling, a typical problem solved in reference [4] was analyzed and verified. The experimental shock loadings are applied to predict the deflection, strain and stress responses. These results are being compared with experimental data. The full paper will explain how the PU mechanics enhances the shock mitigation.



a. Specimen
b. Simply supported boundary

Fig. 1: Test specimen and support conditions

References

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