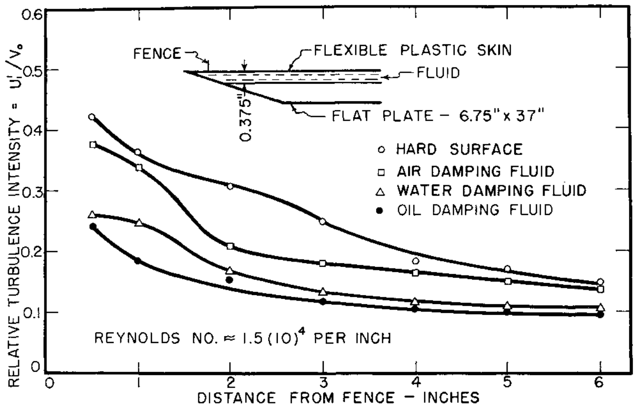

Fig. 3 Variation of relative turbulence intensity.

they lead one to speculate, using Von Karman's similarity hypothesis,[8] that perhaps the skin friction also was reduced. However, it is realized that the tests were not conducted in a natural turbulent boundary layer but rather in a mixture of a fence wake plus a boundary layer.

Therefore, future tests are being planned that will measure the relative turbulence intensities, Reynolds stresses, and skin friction coefficients in natural turbulent boundary layers on flabby skin flat plates. Care will be taken to determine the effect of magnitude and direction of skin tension, skin mass and depth, and viscosity of damping fluid.

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Small Arms Fire Effects on Aluminum Honeycomb Panels

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Introduction

ALUMINUM honeycomb paneling is extensively used on aircraft, missiles, and ground support equipment. The widespread usage is, in large measure, based on the ability of the panel to carry great loads with lightweight structures. Present technology produces paneling which, in normal service, has longer life expectancy than the rated life of the aircraft or missile on which it is employed. However, in combat conditions, such paneling is exposed to small arms fire, which can degrade the structural value of the material. It is an object of this study to measure the effects of certain conventional ammunition on several pieces of aluminum honeycomb paneling.

Discussion

A great variety of aluminum honeycomb paneling is manufactured, and an exhaustive study of small arms fire effects would require testing of many different types of such paneling with several types of ammunition. The scope of the present study is restricted to testing a series of 3-in. by 12-in. by 0.54-in. panels with three different kinds of ammunition. The test panels used in this study had aluminum honeycombs 0.5 in. thick with 0.25-in. cells and was made of 0.004N-5052H-39. The honeycomb was sheathed on both sides with 0.020-2024-T3. The skins were bonded to the cores with FM-1000 adhesive cured at 335°–355°F under 20–34 psi for 1 hr. A total of 57 test panels were used in the study. Eighteen of the test panels were exposed to .22 calibre rifle fire. Eighteen other panels were exposed to .30-'06 calibre rifle fire. A final 18-test panels were exposed to .30 calibre carbine fire. Three remaining panels were used as control specimens in the compression-shear test program. Commercial .22 calibre long rifle high speed rim fire ammunition, military .30-'06 calibre ammunition, and military .30 calibre carbine ammunition were employed in the test program. The .22 calibre ammunition and the .30-'06 ammunition were fired from bolt action rifles. The .30 calibre carbine ammunition was fired from a semiautomatic rifle. The .22 calibre long rifle ammunition has an estimated muzzle velocity of 1335 fps, the .30-'06 ammunition 2700 fps, and the .30 carbine 1970 fps. All 54 test firings were conducted with a fixed muzzle-to-specimen distance of 19 in.

Three bullet impact angles of 90°, 60°, and 30° were used in the firing program. Bullet paths through the specimens were in the direction of the 3 in. width. Bullet entry and exit locations were selected to prevent edge-tearing of the specimens. Each test firing condition was repeated in triplicate.

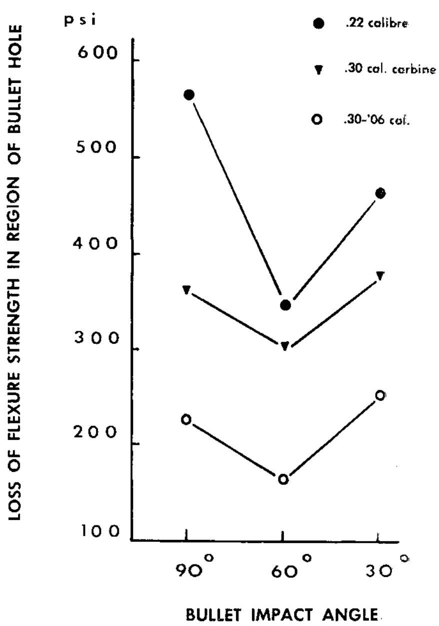

Fig. 1 Loss of flexure strength in regions of bullet holes vs bullet impact angles.

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Test panels and control panels were subjected to compression shear measurements (i.e., sandwich flexure) and to rolling drum peel measurements in accordance with the testing methods of conventional practice. Table 1 describes the experimental program and the test results. Each of the test results shown is an average of the three separate panels used for each test condition.

Compression-shear testing was accomplished by the 2-point loading method, and the failure level of the bullet-pierced specimens was compared with the failure level of unpierced specimens.[1] This comparison is shown in Fig. 1, where the losses of strength are plotted vs bullet impact angles. Least loss of strength was caused by the .30-'06 bullets. More damage was caused by the .30 calibre carbine bullets than the .30-'06 bullets, and the .22 long rifle solid bullets caused the greatest reductions in strength. In this series, there is an inverse relation between the muzzle velocities of the test bullets and the reductions of strength in the test panels. The slowest bullet, the .22 long rifle, was the most damaging of the projectiles in the test program. The .30-'06 bullets had the greatest muzzle velocities of the tested projectiles, and they caused the least damage. The .30 calibre carbine bullets, traveling at velocities greater than the .22 and slower than the .30-'06, caused intermediate reductions of strength.

Table 1 Test program and results

Test condition	Calibre	Impact angle		Test results, psi
Compression shear				
A	.22	90°		1715
B	.22	60°		1935
C	.22	30°		1815
D	.30-'06	90°		2055
E	.30-'06	60°		2120
F	.30-'06	30°		2025
G	.30 Carb.	90°		1923
H	.30 Carb.	60°		1973
I	.30 Carb.	30°		1900
J	...	...		2280
			Average, in.-lb	Minimum, in.-lb
Rolling drum peel				
K	.22	90°	97	47
L	.22	60°	76	30
M	.22	30°	93	39
N	.30-'06	90°	81	43
O	.30-'06	60°	76	51
P	.30-'06	30°	87	47
Q	.30 Carb.	90°	59	37
R	.30 Carb.	60°	85	54
S	.30 Carb.	30°	70	49

A surprising result of the tests was the minor influence of bullet calibre on the losses of strength. Bullets of .30 calibre have approximately 80% greater cross-sectional areas than do the .22 calibre bullets. The holes caused by the .30 calibre bullets were larger than the holes caused by the .22 calibre bullets. There was no evidence to indicate that any of the bullets fired in this test program tumbled or broke during their flights through the test panels. Visual examination of all the bullet holes failed to show any damages arising from the cartridge gases. All the bullet holes were bright and clean. Holes caused by the .22 calibre bullets were of smaller diameter than the holes produced by .30 calibre bullets, but the .22 calibre bullet holes showed greater degrees of lifting and tearing of the exit skins than did the .30 calibre holes. Panel exit skins pierced by the .30 calibre bullets were markedly smoother and more uniform than the exit skins of the .22 calibre firings.

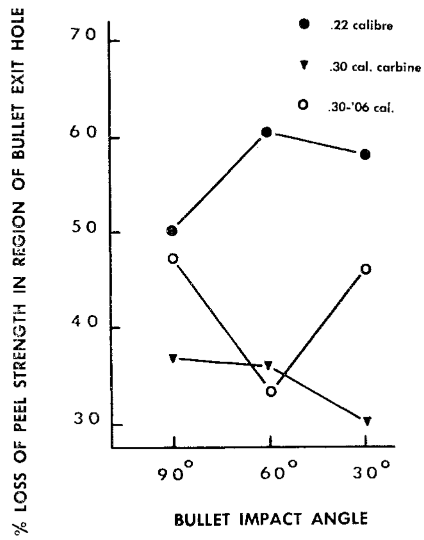

Fig. 2 Percent losses of peel strengths in regions of bullet exit holes vs bullet impact angles.

Another unexpected result of the compression-shear tests, i.e., the sandwich flexure tests, is the nonlinear loss of panel strength with respect to bullet impact angle. Bullets penetrating specimens at 30° impact angles involve greater volumes of the specimens than do bullets penetrating at 60°. Bullets penetrating specimens at 90° involve the smallest specimen volumes. Yet, the results of the compression-shear tests indicated that the loss of strength was not a simple function of the angle of bullet impact. In the three series used in this study, .22 calibre, .30 calibre carbine, and .30-'06 calibre, those bullets impacting at 60° consistently caused lower losses of panel strengths than did the same calibre bullets striking at 90° and at 30°. No care was exercised to direct the test bullets to penetrate the test panels in a fixed position relative to a single individual honeycomb core cell. All test panels were considered to be monolithic in structure. Each test condition was repeated in triplicate, and the individual test results for a single test firing condition were quite alike. Within the bounds of experimental error, the assumption of a monolithic structure was valid. Further, visual examination of the honeycombs of the peeled specimens showed the bullet damages to be highly confined to the vicinity of the bullet path. There was no visual evidence of damage propagation through the honeycomb structures by gas pressurization or by secondary projectiles.

Rolling drum peel tests were performed on 27 specimens. In all cases, the peel testing was performed using the skins through which the bullets passed out of the specimens. These exit skins had varying degrees of distortion caused by the bullets that passed through them. Projecting torn edges were bandsawed-off the skins prior to testing. Test autographs indicated losses of peel strengths in the areas of the bullet exit holes. Information contained in Table 1 for each condition was derived by averaging the peel strengths of the individual test panels in their virgin undisturbed portions to obtain an average value for each test panel. In the region of the bullet hole, the autograph's minimum value was noted. Then, the three test panels, which represented a single firing condition, were averaged, and the results were noted in the lower portion of Table 1. In that table, the term "Average" refers to the mean value of the average of the three specimen panels of the firing series, and the term "Minimum" refers to the mean of the minimum values for the same three panels in the region of the bullet hole. Figure 2 plots the percent losses of peel strengths in the regions of the bullet exit holes for each of the test conditions vs the bullet impact angles. As in the compression-shear tests, the .22 calibre long rifle bullets did more measurable damage than did the .30 calibre carbine bullets and the .30-'06 calibre bullets. The authors did not have a supportable interpretation for the results of the .30 calibre bullet tests. Although considerable care was taken to circumvent interference of the deformed skins with the rolling drum, it is possible that skin configurations gave rise to the .30 calibre results shown in Fig. 2. It is also within the realm of possibility that unobserved muzzle blast effects may have produced the results shown. In any case, it appears that the slow moving .22 calibre bullets inflicted the greatest losses of peel strength.

Conclusions

Bullet perforations of aluminum honeycomb sandwiches measurably reduce the load-bearing and the peel-strength properties of that paneling. This study records the measured effects of three series of bullet perforation tests on a single type of sandwich material. In the test firing series of this study, it was noted that the bullet damages to the test panels were highly localized. They were closely confined to the immediate vicinities of the bullet paths and were not propagated through honeycomb structures. Skin unbonding also was confined to the immediate locales of the bullet entry and exit sites. No extensive unbonding of the skins was observed.

A consistent result from this study was the damage causing superiority of the .22 calibre long rifle solid bullets. The .22 calibre bullets had the lowest velocity of the three types of bullets used on the program. On the basis of the test results, the calibre of the bullet was of lesser importance than the velocity of the projectile. A parallel situation exists in the field of blasting. In commercial blasting, the velocity of the explosive is related to the blast effect in a given material. For aluminum sandwich panels, energy partition from bullet to panel is related to the rate of energy transfer. Later work in this field may reveal that the damage effects also are related to the types of honeycombs, skins, and adhesives, as well as to the bullet impact velocities and bullet impact angles.

Reference

[1] MIL-A-25463(ASG).