Defence Science Journal, Vol 48, No January 1998, pp. 115-118

SHORT COMMUNICATION

Differential Ballistic Response of Aramid-Glass Fibre Laminates to Soft and Hard Shots

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ABSTRACT

Ballistic performance of all-glass, all-aramid and aramid-glass fibre-reinforced phenolic resin composite laminates has been evaluated against 0.30 in. calibre soft ball and hard armour piercing (AP) bullets. It is observed that mass effectiveness of glass fibre phenolic composites against impacts by AP bullets can be improved by aramid fibre reinforcement in the back of laminate. The performance of aramid phenolic composites against ball ammunition can be improved by hybridisation with glass fibre reinforcement at the front.

1. INTRODUCTION

Fibre-reinforced plastic composites are extensively used as armour materials. Glass and aramid fibres are the common reinforcements used in making such ballistic resistant composites[1]. High strength polyethene fibres are also being increasingly used. Combinations of fibres, like glass with nylon[2] and aramid with graphite[3] are also known. Aramid fibres have lower density than glass fibres but have excellent ballistic resistance on impact of a projectile due to longitudinal fibrillation. Costwise glass fibres are much less expensive than aramid fibres. This paper describes changes in ballistic resistance of hybrid laminates comprising a common phenolic resin matrix with varying volume fractions of glass and aramid fibre reinforcements.

2. MATERIALS & METHODS

Woven glass roving fabric of E-type glass (360 g/m^2) and aramid fabric (480 g/m^2) were obtained from Unnati Corp., Ahmedabad and Jay Synth Dyechem Industries, Mumbai, respectively. Phenolic resin was obtained from Indian Plastics Industries, Mumbai and polyvinyl butyral from Synthetic Polymers Ltd, Ahmedabad. Solvents, such as ethyl alcohol were distilled before use.

For preparation of prepregs, the reinforcing fabrics were cut to convenient sizes and kept for 4 hr at 100 °C. They were later coated with solutions of modified phenolic resin and allowed to

Received 26 May 1997, revised 12 September 1997

dry in air at room temperature for 48 hr. The tack-treated fabric plies were then kept in an air oven at 120 °C, just enough to lower the tack to adequate levels.

Treated-aramid fabric and treated-glass fabric (30 cm . 30 cm) were used for making the composite. Aramid fabric were laid one over the other on teflon-coated glass cloth and the layers of glass fabric were laid over them to obtain the desired weight ratios. The alignment of the fabric was adjusted, so that all warps were parallel. After building up the required thickness, the stacked plies were kept between two mild steel plates and placed between two pre-heated platens of a hydraulic press. The laminates were moulded at 160 °C under pressure. Postcuring was also done at 160 °C for 12 hr to release the residual strains in the laminates. The final thickness of the laminates was 50 mm.

Tests for ballistic resistance were carried out by firing soft (lead;ball) or armour piercing (steel;AP) ammunition from a 0.30 in. calibre rifle from a distance of 10 m on targets made from laminates of defined test composition, backed with a standard glass fibre-reinforced phenolic resin laminate clamped together to a firing stand. In all tests, glass was the striking face. A schematic of the firing arrangement is shown in Fig. 1. Velocity of the impacting projectiles was uniform, around 800 m/s as measured with a 'Drello' electronic velocity measuring equipment. From the values of depth of penetration of the bullets and density of a particular laminate tested and those of a standard all-glass laminate, mass effectiveness coefficient (MEC) was calculated as

$$\text{MEC} = D_b\,\rho_b \quad (D_c\,\rho_c + D_b\,\rho_b)$$

where

D_b is the depth of penetration of ammunition and ρ_b is the density for the standard material. D_c is the depth of penetration of ammunition and ρ_c is the average density of the test composite.

3. RESULTS & DISCUSSION

Ballistic resistance of the composites has been evaluated against two kinds of projectiles, viz., armour piercing and ball ammunitions with glass as the striking face. Normalised values with respect to the performance of all-glass composite as unity are given in Table 1. It shows that the increasing percentage of aramid in the hybrid composite resulted in higher MEC values against the non-deforming AP bullets. On the other hand, effectiveness against ball ammunition steadily decreased with increase in aramid fibre

Table 1. Normalised mass effectiveness coefficient of glass-aramid fibre phenolic resin composites impacted with 0.30 in. calibre bullets at ~800 m/s

Fibre reinforcement glass-aramid weight ratio	Bullet	
	Armour piercing	Ball
100:0	1.00	1.00
80:20	1.03	0.74
50:50	1.20	0.82
34:66	1.32	
0:100	1.41	0.66

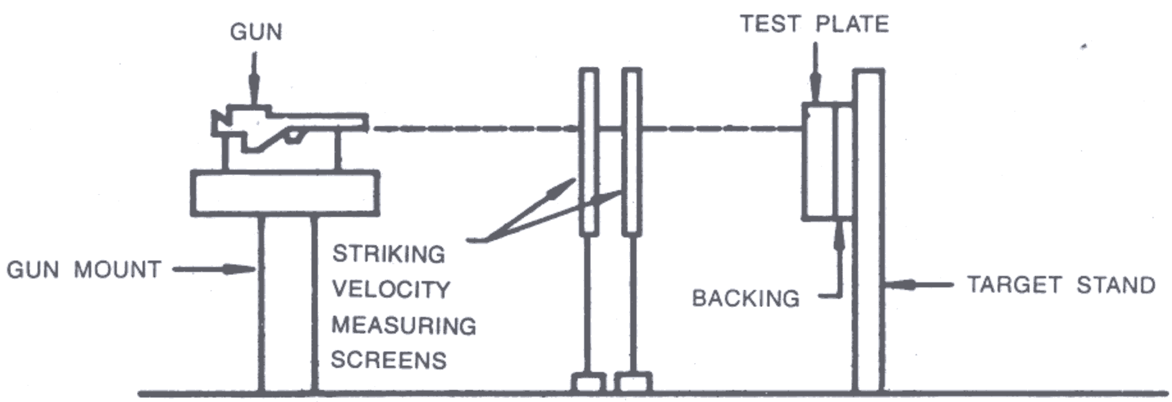

Figure 1. Firing arrangement

reinforcement. This differential response can be related to the nature of deformation in the shot during impact. The hard shot (AP) remains intact during collision but the soft shot (ball) deforms. AP shots which do not break or deform require that the armour absorbs all the energy by itself leading to low efficiency of the armour. This can be done more effectively by the softer and tougher aramid when compared to glass composite and hence efficiency increases as the percentage of Kevlar increases. In the case of ball ammunition, increased hardness of the armour laminate can cause increased deformation of the shot. This not only leads to greater energy absorption by the soft shot on itself but also increases the impact area. This together lead to increased efficiency with increased percentage of glass laminate and hence the observed increased efficiency with increased percentage of the glass fabric.

4. CONCLUSION

Against ball ammunition, mass effectiveness of aramid-phenolic resin composite can be improved by hybridisation with glass fibre-reinforced phenolic resin matrix as the striking face. Against AP ammunition, mass effectiveness of glass fibre reinforced phenolic composite can be improved by backing with aramid fibre reinforced composite.

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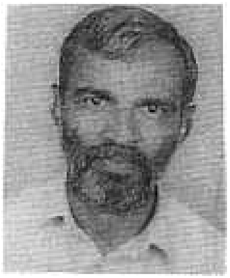
Contributors



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