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PREDICTING THE BALLISTIC STRENGHT OF COMPOSITE LAMINATES SUBJECTED TO A PERPENDICULAR IMPACT BY A SOLID PROJECTILE

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Abstract

In the paper, the attempt was made to assess the applicability of the full factorial experimental design in predicting the ballistic strength of nylon fiber/ phenolic composite laminates when subjected to a perpendicular impact by a solid projectile. In the study we used a number of ballistic composites (20 cm x 20 cm) with different areal weight (thickness) and fiber/resin ratio. The composites were made with an open mold high pressure, high-temperature compression of prepreg layers made of plain woven ballistic nylon fabric and polyvinyl butyral modified phenolic resin of the resole type. The preparation of the composite experimental samples was conducted in accordance with the full factorial experimental design. The areal weight of the composites was taken to be the first factor and the second was the fiber/resin ratio. The influence of each individual factor to the response function was established, as well as the influence of the interaction of the two factors. We found out that the estimated first-degree regression equation with the interaction gave a very good approximation of the experimental results of the ballistic strength of composites within the study domain.
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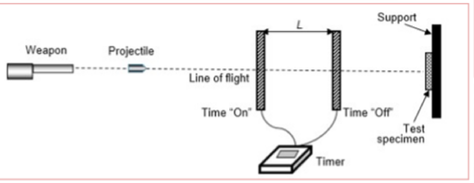
Experimental procedure

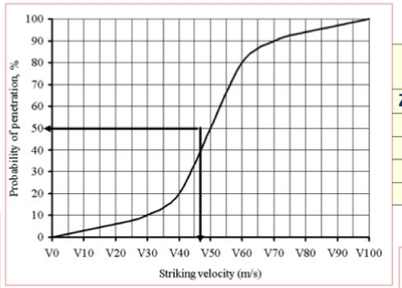
Main properties of the nylon fabric

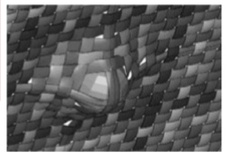
Property	Unit	Value
Type of nylon	/	6,6
Weave	/	plain (1x1)
Thread count (warp x weft)	/	15 x 15
Areal density	g/m^2	265±8
Yarn linear density	tex	120
Thickness	mm	0,40
Fabric tensile strength (warp x weft)	N/5cm	4200 x 4200



Ballistic test setup

Probability of penetration vs. striking velocity

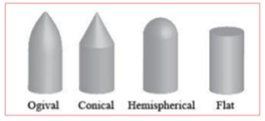




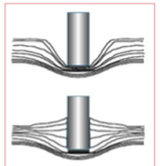
The V50 velocity decreases in the following order of the projectile geometry: hemispherical, flat, ogival, and conical. But, the effect of projectile geometry decreases with the thickness of the laminate.

2^2 full factorial experimental design (FFED) by using of two parameters and two levels of variation

	Areal weight, kg/m^2	Fiber/resin ratio, (wt. %)
Zero (Basic) level, $x_i = 0$	5,5	65/35
Interval of variation	3,5	15/15
High level, $x_i = +1$	9	80/20
Lower level, $x_i = -1$	2	50/50
Code	x_1	x_2



Projectiles with different geometries



Cutting actions with flat-tip projectile

Results and discussion

Experimental matrix with results

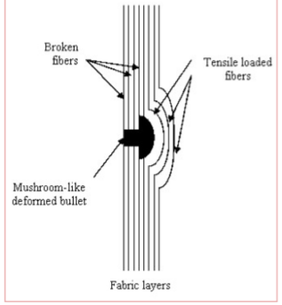
Trials	x_1	x_2	x_1x_2	Nylon composite V50, (m/s)
1	-1	-1	+1	218,4
2	1	-1	-1	441,9
3	-1	1	-1	199,1
4	1	1	+1	405,0
-1 Level	2 kg/	20%	-	-
+1 Level	9 kg/m^2	50%	-	-

By implementing the 2^2 full factorial experimental design we found out that the response function in coded variables, y_k, is:

$$y_k = 316{,}10 + 107{,}35x_1 - 14{,}05x_2 - 4{,}40x_1x_2 \quad \ldots\ldots\ldots\ldots (1)$$

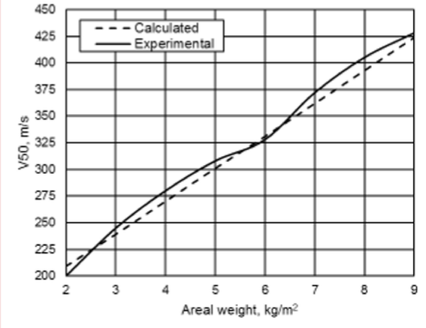
and in engineering or natural variables, y_n :

$$y_n = 164{,}0571 + 33{,}6048x_1 - 0{,}4757x_2 - 0.0838x_1x_2 \quad \ldots (2)$$



Cross-section of the composite at the bullet penetration point

Theoretical vs. experimental values of V50



- *A very good agreement was found between experimental and calculated values.*
- *It was observed that if the study domain is precisely established (narrow enough), the full factorial experimental design can be employed in order to give good approximation of the response i.e. V50 value.*
- *V50 is directly proportional to the areal weight of the composites and inversely proportional to the resin content.*
- *The areal weight is a more dominant factor than the resin content.*