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Impact properties of multilayered materials

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ABSTRACT

The possibilities of multilayered materials as high impact resistance materials are considered with reference to safety in transportation.

The mechanism of fracture of the different layers of the material produces an enhancement of the impact resistance behavior and, as a consequence, a lower quantity of material is needed with the corresponding saving in weight of the transport vehicle.

The reinforcing material of this multilayered composite are steel sheets. The sheets, two or more, are dipped in molten zinc and pressed together during the withdrawal. The still molten zinc outside of the surface of the sheets, i.e., between the different sheets, solidifies and all the sheets with the solidified zinc forms the composite where the zinc is as a glue.

The adherence of this composite is very good because of the metallurgical bond between the steel sheets and the zinc. Also, the composite presents a very good behavior from the point of view of the corrosion resistance because the cathodic protection of zinc. That means the material may be safely used during the whole life time of the vehicle or equipment.

Some tests concerning the impact resistance and the corrosion resistance are presented and discussed. Applications in vehicles, containers and highway guard rails are considered the most promising.

1.- INTRODUCTION

In previous work (1-3) we describe the production process and different results obtained with the test performed with a metal laminated composite material made of zinc matrix and steel reinforcing sheets have been discussed elsewhere (1-3). Some considerations about the advantage of this composite in terms of low cost production and low price of materials used in their fabrication were considered in previous paper. In the present paper we will present some results obtained with the drop weight test machine in comparison with the same resistance transverse surface of steel.

2.- EXPERIMENTAL

The composition of the different steel used are presented in Table 1. All of them are plain carbon steel and their mean composition is presented in the bottom line of the table.

Thickness, mm	% C	% Si	% Mn	% P	% S
0.5	0.07	0.05	0.33	-	-
0.5	0.065	0.05	0.33	0.017	0.026
1.0	0.055	0.03	0.22	0.008	0.016
1.0	0.055	0.03	0.25	-	-
1.0	0.057	0.03	0.23	0.008	0.017
1.5	0.045	0.04	0.24	0.012	0.013
1.5	0.073	0.04	0.037	-	-
2.0	0.045	0.03	0.24	-	-
2.5	0.026	0.03	0.25	0.005	0.013
3.0	0.050	0.03	0.23	0.012	0.018
Mean value	0.054	0.03	0.25	0.011	0.017

TABLE 1.- Composition of steels

The drop weight test consists in the free fall of a mass from different heights; in consequence the energy of impact, and the velocity of impact change proportional to the height and to the sq. root of the height respectively.

This weight has an triangular prismatic impactor and the ariste with different radius, 5 and 3 mm, impact transversal to the main

axis of a tensile test sample clamped horizontally. The scheme of the machine is presented in Fig. 1.

3.- RESULTS AND DISCUSSION

Fig. 2 represents the minimum impact energy of the mass needed to produce 100 % fracture of the tested samples and the maximum energy that withstand all the samples without fracture when we use the 5 mm radius head (Fig. 2.a). In fig. 2.c are presented the equivalent results when the 3 mm radius head is used.

If we compare the results of both materials we may appreciate, as can be expected, the lower the radius of the head the lower energy needed to fracture because of the stress concentration in the impact zone is higher.

Fig. 2. represents the equivalent values in the case of composite samples with the 5 mm radius impact head and Fig. 2. corresponds to the results obtained testing composite samples with the 3 mm radius head.

Again we obtain better resistance in the case of higher radius impact head.

If we compare all the data presented in Fig. 2 there is a clear benefit in favor of composite material. The main aspect we may consider in this comparison is that there is a increase in energy consumption when we test composite samples with more than one reinforced sheet. Nevertheless if we consider the same situation with the monolithic single samples we got the same energy consumption in the case of 0.5 mm, 1.0 mm and 1.5 mm thickness. The equivalent situation with the composite is two reinforcing sheets 0.5 mm and 3 reinforcing sheets 0.5 mm. When we go to thicker single samples or to composites with more reinforcing sheets the energy needed increase as can be expected.

a) $r=5$ mm monolithic

b) $r=5$ mm composite

c) $r=3$ mm monolithic

d) $r=3$ mm composite

a) $r=5$ mm monolithic b) $r=5$ mm composite c) $r=3$ mm monolithic d) $r=3$ mm composite

The explanation to this facts could be the height of the steps in energy we use during the test. This height is only 0.1 m, i. e., 29 J and, in relative terms to the energy needed to produce the fracture of the single samples, it means almost 25 % of total energy because we got the 100 % fracture of samples with 0.47 m height. If the differences in the energy needed to produce this fracture lays in between it appears that the energy needed to produce the fracture of those samples is independent of the thickness and certainly this is not true.

In any case, we must take in consideration the case of single samples. When the impact energy is enough high to initiate a crack in the sample, the stress at the tip of the crack is enough high to produce a fast growing and the sample cracks at the plane of fracture.

Quite different is the situation in the case of composite samples. First of all the energy needed to produce the fracture of a bilaminar samples is quite higher than in the case of the single monolithic of equivalent steel thickness (1.0 mm). The main explanation lays on the behavior of their structure as a crack arrester structure, i. e., a structure where the crack initiated in the first reinforcing sheet is arrested when it reach the zinc matrix.

As a consequence of this increase in the energy consumption, the step of 0.1 m height is enough low in absolute and relative terms in the case of composite samples and a distinct behavior of the bilaminar and trilaminar composite samples is observed.

Another interesting aspect of the data presented in Fig. 2.c is that of the cross of the lines corresponding to the 2.5 mm thickness sample. If we observe the composition of this steel in Table 1 it has much lower content in carbon so their mechanical properties may be lower than those of the other steels. In any case the difference in energy corresponds only to a height step of 0.1 m and is, relatively insignificant.

In Fig. 3 a we represent the results in terms of Energy vs. thickness of steel in the case of tests with monolithic samples and in Fig. 3.b with composite samples, both with the head with 5 mm radius. In Fig. 3.c and d we represent the equivalent results obtained with the head of 3 mm radius on monolithic and composite samples. In both cases the data corresponding to the maximum energy applied with 0 % fracture and to the minimum energy to obtain 100 % fracture are presented.

The shape of the curves are equivalent. The single samples presents the horizontal line till 1.5 mm thickness of steel and then a continuous growing with the exception of 2.5 mm thickness in the case of 5 mm radius. The composite figures, Fig. 3.b and 3.c show a continuous growing in energy facing the thickness.

a) $r = 5$ mm monolithic

b) $r = 5$ mm composite

c) $r = 3$ mm monolithic

d) $r = 3$ mm composite

Fig. 4.a represents the specific consumption in energy in terms of Energy/transversal section of steel vs. steel thickness with the 5 mm radius head for monolithic and Fig. 4.b for composite samples, and in figures 4.b and 4.d the corresponding results with the 3 mm head radius.

We appreciate there is a confluence of both curves 0 % fracture and 100 fracture as the thickness of the steel increases. Also can be seen the higher performance of the composite material with reference to the single monolithic steel samples in both tests with 3 and 5 mm radius head.

4.- CONCLUSIONS

There is a clear benefit of this composite, in comparison with the same amount of monolithic steel material in terms of increase in energy absorption without fracture. That means we have the opportunity to use this material in applications where the risk of impact is relatively high, as in cars, trucks, etc., and also in guard rails.

This advantage may be used maintaining the same weight with a clear increase in safety, because the higher impact resistance of the material or maintaining the same level of safety, i. e., energy absorption of the material but with a lower weight of the composite in comparison with the single monolithic material.

Also, we may also to use this composite made with plain carbon steel for non composite high resistance low alloyed steel applications because of the low price in terms of equal impact resistance.

This better behavior of the composite material includes not only the impact resistance but also the better corrosion resistance. This is an aspect of high interest for cars because the goals of higher cosmetic and structural corrosion resistance of the cars. The higher recyclability of both materials, steel and zinc, is another aspect to be considered as an additional benefit of the application of this kind of multilaminar composite.

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