THE ACOUSTIC EMISSION TECHNIQUE APPLIED TO TEST PIPES OF GFRP DESTINATED TO TRANSPORT CHEMICALS

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ABSTRACT:

The object of this study was the validation of the acoustic emission technique as a non destructive test applied to GFRP, which were used to transport corrosive liquids. For this purpose, different tubes were made, by filament winding. Then, the tubes were exposed at different corrosive liquids at 50ºC and, finally, they were tested at compression and, simultaneously, by acoustic emission technique. The validity of the data obtained by A.E was checked by microscopy technique. In order to study the effect of the several variables, at the same time, it was carried out an experimental design. The fundamental variables considered in the design were: the using corrosive medium, the postcured method of the samples, the concentration of the corrosive medium, and the exposure time. The results showed that the most significant factor was the corrosive medium using by to attack the tubes.

INTRODUCTION

There are many non destructive test (1). All of them have in common the static character, that is to say, they are able to detect existing damages of the material but not those which it is suffering at that time. These methods offer the possibility of detecting cracks and breakages which existed in the sample before the inspection.

The difference between acoustic emision (A.E.) and another non destructive techniques is the active character of the former. The A.E test is able to detect a failure process of the composite under load while those are taking place (2-6) and in some cases to locate fracture locus (7,8). Recently, we have tried a work in which the emission acoustic technique has been applicated to the study of fracture in a composite material with vinylester matrix (9). The technique presents as an aditional adventage that is the possibility of making inspections without stopping the normal performance of the structure to be analyzed.

The interest of the technique is to test big structures. In this field, one failure provokes great economic losses and in some cases human damages. The great adventage of the A.E. technique is that it monitors the total structure during mechanical loading, in contrast to the other technique where a small part of the structure is treated at a time, and some part may escape attention.

EXPERIMENTAL

The experimental work was carried out on four pipes made by winding polyester A-bisphenol resin (Atlac 382/05) impregnated glass fibres (2400 tex, Vetrotex Saint Gobain with P122 ensimage) around a cylindrical chromed aluminium mandrel (102 mm diameter). The outer diameter of the completed pipe was aproximately 107 mm. The nominal fibre content was 77% by weight.

Each pipe was cut in five segment, one of them was used as a reference. The sixteen segment were exposed in different conditions as chemicals medium, concentration of chemicals or exposition time. Only eight specimens were postcured at a 100ºC during 2h. The work temperature was 50ºC. The contact with the corrosive medium was only by inner face.

The chosen liquid to fill the tubes and their concentrations are shown in Table 1.

Table 1.- Experimental conditions

Corrosive medium	Factors	Condition 1	Condition 2
HCl	Concentration	0,20 M	0,40 M
HCl	Exposure Time	1 month	2,5 months
HCl	Postcured	No	Yes
NaClO	Concentration	6,0%	12,0%
NaClO	Exposure Time	1 month	2,5 months
NaClO	Postcured	No	Yes

In order to reduce the number of experiments it was introduced an experimental desing which let us study the maximum number of variables using the minimum number of posible experiments.

Once the exposure has finished, the specimens were cut in rings, approximately 30 mm wide and after that they were polished.

Those samples will be tested by acoustic emision and compression at the same time. During the compression test, A.E. monitored and all noises generated were recorded.

The compression test was carried out using the mechanical testing Universal Machine Ibertest mod. Elib 50W. The samples were compressed at a rate of 1mm/min.

The acoustic response was monitored using a Locan AT acoustic emission unit supply from Physical Acoustics Corporation. Two AE sensors (PAC R 15 I) were coupled to the outer surface of the sample with a high viscosity vacuum grease. The transducer frecuency response was centered at 150 kHz with output passing through a 40 dB preamplifier and a 100 to 300 kHz band pass filter (PAC 1220 A) before being processed. Two A.E. channels were assigned, one of them (channel 3) a 40 dB threshold and a 25 dB gain and the other one (channel 4) a 55 dB and a 10 dB gain.

Acoustic parameters recorded include signal amplitude duration, energy and counts.

RESULTS AND DISCUSSION

The microscopy technique allows to evaluate the extent of attack on inner surface of the pipe by corrosive medium, that is to say, the penetration degree of the mediums in the samples. This method is cuantitative.

Refering to A.E., this technique allows to determine at which grade of deflection of the tube starts the initial damages. We have defined two moments in the fracture process of the composite: beginning and fracture propagation. We understand the beginning as the moment of deflection at which the first symptoms of fracture are noticed, that is to say, we receive signals that do not imply serious damages in the structure but that are a clue that the real initial damages are near. It would be convenient to review the structure at that moment in order to find out if there is some area weaker than the rest.

The propagation happens at the same time at the moment when the fractures begin to be considered as such. Although initially the fractures are not produced in continue way, this deflection shows that from this moment on, if the structure is not repaired or the load is increased, the damages will start to increase with time. This deflection shows us how far the tube can be loaded without producing great damages. From that value on, damages that the tube may suffer can be irreversible. Apart of carrying out the study fixing these two values of deflection, an experimental design was applied to study one all the factors together to see the influence that each of them has on the corrosion.

One also tried to mathematically modelize the acoustic emission. The obtained result are very promising.

MICROSCOPY INSPECTION

The obtained values though the measurement of the extent of attack of pipe wall show that the attack of NaClO is more aggressive than that of the hydrochloric acid. The data obtained are shown in Table 2.

Table 2.- Corrosion depth (in mm)

Medium	HCl	HCl	HCl	HCl	NaClO	NaClO	NaClO	NaClO
t.expos.	1 month	1 month	2,5 month	2,5 month	1 month	1 month	2,5 month	2,5 month
Concent	0,20 M	0,40 M	0,20 M	0,40 M	6,0%	12,0%	6,0%	12,0%
No post*	0,128	0,11	0,23	0,185	0,152	0,264	0,22	0,375
Post**	0,092	0,104	0,23	0,185	0,116	0,128	0,185	0,38

* Post = Postcured sample ** No post = Non postcured sample

ACOUSTIC EMISSION

The acoustic emission study was carried out with the data taken from the graphics of the acoustic emission equipment.

The data value of beginning and propagation of acoustic emission corresponding to virgin tubes are 4,63% and 9,02% respectively.

For the tubes that are been exposed in corrosive liquids the data are shown in the Table 3 and 4. The underlined values are the samples corresponding to tube no. 1. This tube, as it was seen when the acoustic emission study was carried out, is defective. This tube is worse impregnated and its fracture behaviour is different from the rest of the tubes, appearing the beginning and propagation of damages prior to the rest of the tubes.

Table 3.- Deformation percentage (%) corresponding to beginning of Acoustic Emission

1 month	HCl	HCl	NaClO	NaClO
Concentration	0,20 M	0,40 M	6,0%	12,0%
Non postcured	4,73	0,93	0,98	1,47
Postcured	4,23	4,98	1,47	3,32
2,5 months	HCl	HCl	NaClO	NaClO
Concentration	0,20 M	0,40 M	6,0%	12,0%
Non postcured	4,06	4,46	1,63	0,98
Postcured	1,96	5,67	1,40	1,63

Table 4.- Deformation percentage (%) corresponding to propagation of Acoustic Emission.

1 month	HCl	HCl	NaClO	NaClO
Concentration	0,20 M	0,40 M	6,0%	12,0%
Non postcured	6,32	6,86	2,23	2,02
Postcured	6,43	6,94	2,65	4,05
2,5 months	HCl	HCl	NaClO	NaClO
Concentration	0,20 M	0,40 M	6,0%	12,0%
Non postcured	6,66	8,33	1,58	0,97
Postcured	7,75	10,0	2,55	1,64

Seeing these results and as it was appreciated in microscopy, the sodium hypochlorite is more aggressive than the hydrochloric acid. In the case of hydrochloric acid, the beginning and propagation damages are behind in respect to sodium hypochlorite. Moreover, the fracture velocity is lower in the case of hydrochloric acid than in that of the sodium hypochlorite. The acoustic emission graphics show this fact clearly.

Considering the rest of factors such as postcured, concentration or exposure time, the results are more confusing. The difference between both mediums remains, but the effect of the rest of conditions is not clear. The effect of postcured is not appreciated in first stages of fracture, that is to say in the beginning. However, it is remarkable in the propagation stage.

Considering the effect of concentration and time, it can be said that each medium has a different behaviour. Whereas in the case of hydrochloric acid, neither exposure time nor concentration generate differences in fracture schedules, in the case of sodium hypochlorite these factors do have an influence. In this case, deflection corresponding to beginning of fracture as to the beginning of propagation decreases when the exposure time is increased.

That difference between both mediums is due to different degrees of attack that each one produces on the samples. The hydrochloric acid, under our working conditions, is a less aggressive medium and with time does not increase his attack.

On the contrary, the effect of sodium hypochlorite increases with the time. The longer the exposure time, the bigger the effects of corrosion. This means that the damage appears earlier. The conclusions are different when the postcured is analysed. While during the stages of beginning of fracture this factor does not have a relevant effect on neither of the two mediums, it gains importance during the propagation of fractures with regard to the non postcured tubes.

With the purpose of considering all the factors together, a statistic study of them was carried out. This analysis was carried out at different moments during the fracture process.

The obtained values show that the most significant factors are the corrosive medium used and a lower rate of postcuring inside the propagation stage. The rest of the factors have a negligible importance.

After this study the data analysis was considered from the point of view of the used and

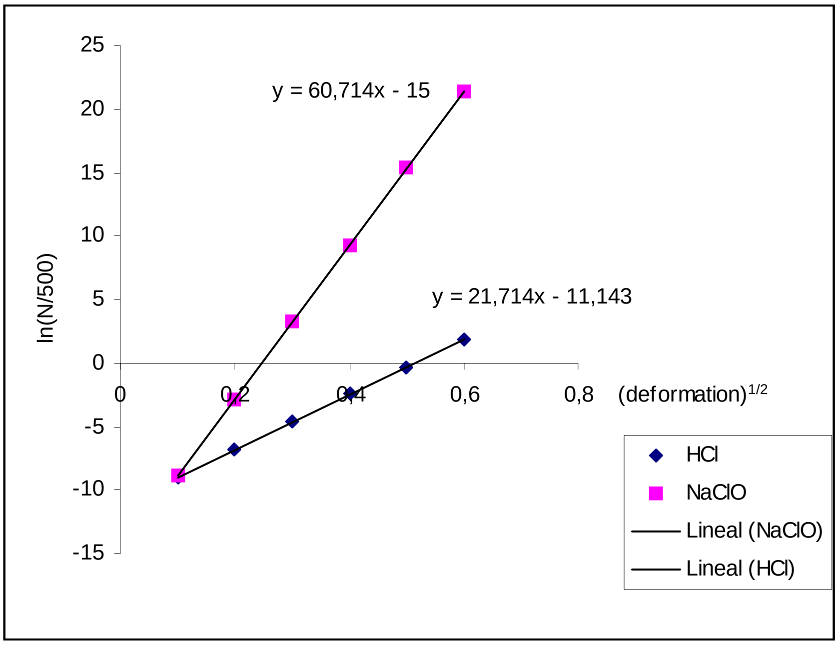

Figure 1.- Non postcured samples exposed during 2,5 months

CONCLUSIONS

The acoustic emission is a useful technique in controlling the state of a tube exposed to corrosive mediums, being possible to know tube conditions at every moment. Moreover the A.E. technique allows to differentiate between the aggresivity that differents mediums show on certain composite. From this conclusion we can deduce the possibility of solving the deterioration that the tubes present before the damages are irreversible.

The sensitivity of the technique is such that allows to evaluate differences originated during the manufacturing stage, as it can be the superficial finishing off.

This technique is a tool that can be complemented with other non destructive techniques, such as the microscopy.

The sodium hypochlorite is a much more aggressive medium for the analyzed tubes than the hydrochloric acid.

In the case of the corrosive medium was hydrochloric acid, the study show how the different conditions used as exposure time, concentration of the chemical, and postcured treatment are not differentiable. However, the sodium hypochlorite due to more aggressive attack that exert on the tubes gives rise to differences on the tube state when we change the exposure conditions.

By the mathematical result obtained, this kind of structures follow a schedule of fracture with can fit a proposed model.

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