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The evaluation of castor oil effect on stress-cracking resistance of polyethylene sheets by means of a practical device

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Summary

The occurrence of stress cracking failure in polyethylene films caused by a chemical was checked by means of a device, such as a "big jack" support. In this work, castor oil was used as the reagent and polyethylene films of different origins were tested. The samples used were cut out of polymer films just like those used in stress-strain study, i. e., dogbones. The stress applied in testing was caused by the dislocation of the "big jack" parallel plates. The test was run at room temperature and at 60°C, in presence and in absence of castor oil. Tendency of failure is favored by presence of stress when the specimen is in contact with castor oil. Higher temperatures enhance the tendency of failure.

Introduction

Polymeric materials can be used in a wide variety of applications, ranging from packaging to engineering materials. In some of these applications, such materials have to work in contact with certain environments and are subjected to complex stress conditions. Considering this fact, environmental stress cracking (ESC) resistance has been an important subject of study and plays an important role in the selection of materials for a certain application.

It was found that besides the applied load in service, ESC may also occur when the material presents a certain degree of residual or internal stresses remaining from the industrial process.

The interaction of load or strain with chemical resistance has a profound effect on many plastics, hence any information obtained about such behaviour can be of use in regard to the vulnerability of a plastic when in contact with a particular agent. The effect of the active environment is to change the material properties, causing cracks to appear at lower stresses, or in shorter times, than in the absence of the active environment.

One who wishes to work with thermoplastics in a given environment needs to take into account particular questions, such as:

- What is the reason for ESC.

- How to identify which agent may cause such failure in a material.
- What can be done to prevent this problem.
- How to suit the available ESC tests to evaluate the susceptibility of polymers to this failure.

Unfortunately, in the absence of standard methods, a great many variations of methods are in practice, which leads to difficulty in comparing materials and finding data to match a particular end-use. Time, temperature, and stress or strain level interact to produce complex patterns of environmental stress attack. A short test at one temperature and one stress level is no guarantee that the test reagent will not cause failure at other more severe conditions. Therefore, tests that cover a range of stress and strain levels over a considerable time can be more reliable. Failure is time-dependent for all plastics regardless of the presence of an agressive environment. Therefore, since most environmental stress-crack resistance tests are inherently time-dependent, it is necessary to run control tests usually in the absence of the environment, so that the effect of the agent can be perceived.

The difficulty in comparing the results of ESC evaluation is even more evident when one takes into account that two basic types of tests are available: Those based on a constant load, and those based on a constant strain. Depending upon the type of test applied, the results can be completely different for the same specimen. This is due to the difficulty to isolate the yield stress as a parameter independent of the failure resistance of the plastic.

Although some molecular mechanisms for ESC have been suggested (1), the exact mechanism for all classes of polymers is not completely understood. It is reasonable to correlate the possibility of stress failure of a polymer with the difference between the solubility parameters of the liquid (environmental stress cracking agent) and polymer. Hence, as this difference increases, the critical stress also increases (2). In fact, the ESC agent does not attack the polymer chemically as a solvent, but instead brings about failure which would not occur in a reasonable period of time under the same stress conditions and the absence of the environment. When no stresses are present, these agents may not have any readily discernible effect on the polymer.

Soni and Geil (3) have shown by stress-strain measurements in polyethylene samples that the strain at break of LDPE is always lower in the presence of stress cracking agents as compared to that in their absence, and that this effect becomes more pronounced with increasing temperature.

Baker (4) established that the cracking could be correlated with the orientation of the film. In PET fibres, some residual or internal stress may remain. When such fibres come into contact with solvent, relaxation occurs, which would cause stress cracking without application of any load. So, there are a number of end-use tests that require immersion of a plastic in the stress cracking agent to determine whether residual molding stresses are sufficient to craze it (5).

It was found from earlier studies (6) that polyethylenes containing relatively few tie molecules are more susceptible to ESC. On the other hand, materials with more tie molecules are more resistant to this type of failure. Hence, the more crystalline the material, the lower its ESC resistance, due to the fewer number of tie molecules.

A review of methods for the testing and study of environmental stress failure in thermoplastics has been suggested (7). There are no standard method for measuring the environmental stress-crack resistance applicable to all plastics, despite that this is an important property in the selection of plastics for many applications. Considering this, a practical device for the evaluation of chemical stress-cracking resistance of plastics sheets and films is suggested in this paper.

Experimental

Specimens 0,32 mm thick were cut of nine polyethylene bags. Melting and crystallization temperatures were determined over the range of 60 to 160°C by differential scanning calorimetry using a Perkin Elmer DSC-2 equipment.

The specimens used in ESC tests were cut out of the films just like those used in stress-strain studies, i. e., a dogbone specimen. The specimens, which were initially 16 cm long, were stretched up to the maximum of 45% of the original length by using a *"big jack"*. This device is provided of two parallel plates separated by an articulated system, which permits the control of the distance between plates by adjusting the central screw, as seen in Figure 1. The specimens were fixed between the plates by means of two holes in the extremities. Stress cracking resistance of samples was evaluated in presence and absence of castor oil. The test was conducted by fixing two specimens (A and B) of the same sample in the *"big jack"* and stretching them up to 37.5% of their original length. Specimen B was put in contact with castor oil during the test, while specimen A was tested without the presence of castor oil. The test was initially carried out at ambient temperature (30°C) for 24 hours (condition I); subsequently, the assembly was put into an oven (60°C), the elongation was kept constant and the test proceeded for 24 hours (condition II). When no rupture was observed at this point, the elongation was raised to 45% and the assembly was kept outside the oven for 24 hours (condition III). Finally, in case of no rupture, the assembly was put into the oven once more (60°C) and monitored every subsequent 24 hours, for 3 days (condition IV).

Results and discussion

The melting and crystallization temperatures of the nine polyethylene samples are show in Table 1. It can be seen that the values are practically the same for all samples, ranging from 107 to 110°C for melting temperature (T_m) and from 94 to 96°C for crystallization temperature (T_c).

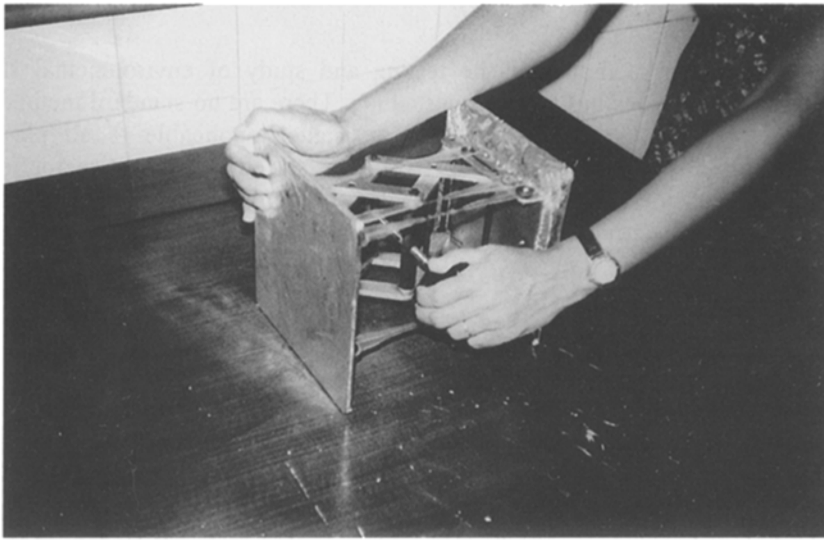

Figure 1: Assembly suggested for ESC studies of polymer sheets

Table 1

Melting and crystallization temperatures of PE samples

Sample	T_m (°C)	T_c (°C)
IMA-01	109	95
IMA-02	108	94
IMA-03	107	94
IMA-04	110	95
IMA-05	109	96
IMA-06	110	96
IMA-07	107	94
IMA-08	107	94
IMA-09	108	94

The results of ESC evaluation of the samples is shown in Table 2. It is clear that tendency of rupture is higher at temperatures above ambient and when the specimen is in contact with castor oil. Except for sample IMA-06, all others have shown resistance to failure in the absence of castor oil, no matter the test condition (I, II, III or IV). On the other hand, when in contact with castor oil, only samples IMA-01, IMA-04 and IMA-05 have shown resistance to failure. In cases in which specimen B (with castor oil) has failed, it was observed that after the end of the test, when specimen A (without castor oil) was put in contact with oil, rupture could be observed after a few hours at 60°C. It means that castor oil has a pronounced effect of the behaviour of polyethylene sheets submitted to a certain degree of stress at temperatures above ambient.

Table 2

Environmental stress cracking resistance of polyethylene films

Samples[(a)]		Test conditions[(b)] I	II	III	IV
IMA-01	A	(+)	(+)	(+)	( )
	B	(+)	(+)	(+)	(-)
IMA-02	A	(+)	(+)	(+)	(+)
	B	(-)	—	—	—
IMA-03	A	(+)	(+)	(+)	(+)
	B	(-)	—	—	—
IMA-04	A	(+)	(+)	(+)	(+)
	B	(+)	(+)	(+)	(+)
IMA-05	A	(+)	(+)	(+)	(+)
	B	(+)	(+)	(+)	(+)
IMA-06	A	(-)	—	—	—
	B	(-)	—	—	—
IMA-07	A	(+)	(+)	(+)	(+)
	B	(-)	—	—	—
IMA-08	A	(+)	(+)	(+)	(+)
	B	(+)	(-)	—	—
IMA-09	A	(+)	(+)	(+)	(+)
	B	(+)	(+)	(+)	(-)

(a): A and B refer, respectivelly, to the absence and presence of castor oil on the specimen during the test;

(b): I: ambient temperature, 24 hours, stretched 37,5% — II: 60°C, 24 hours, stretched 37,5%

III: ambient temperature, 24 hours, stretched 45% — IV: 60°C, 72 hours, stretched 45%

(+) means that specimen has not ruptured and (-) means the occurrence of rupture. Specimens were sequentially submitted to conditions I, II, III and IV.

Conclusions

The aim of this work is to bring about a method for ESC evaluation of polymer sheets by using castor oil as the active agent. The method can be easily applied in common laboratories and we have seen that the informations obtained can be useful when one wants to know about the vulnerability of a polymer which has to be used in contact with reagents and submitted to a certain degree of stress. The method is not intended for getting accurate measures of stress level, instead, it is carried out by submitting the specimen to a constant elongation at different temperatures. The informations so obtained can be useful in determining the susceptibility of the specimens to fail over an entire range of selected temperatures. It was found that castor oil influences the stress cracking resistance of polyethylene over the test conditions employed. This effect is more pronounced when the test is carried out at higher temperatures.

Acknowledgments

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