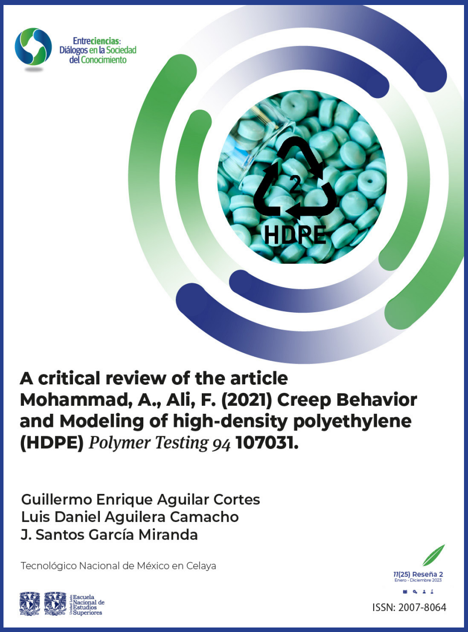
Entreciencias: Diálogos en la Sociedad del Conocimiento

Entreciencias: Diálogos en la Sociedad del Conocimiento
Año 11, Número 25, Reseña 2: 1-3. Enero - Diciembre 2023
e-ISSN: 2007-8064

http://revistas.unam.mx/index.php/entreciencias



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DOI: 10.22201/enesl.20078064e.2023.25.85703
e25.85703

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Fecha de recepción: 18 de mayo de 2023.
Fecha de aceptación: 1 de junio de 2023.
Fecha de publicación: 9 de junio de 2023.

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A critical review of the article

Mohammad, A., Ali, F. (2021) Creep Behavior and Modeling of high-density polyethylene (HDPE) *Polymer Testing 94* 107031. DOI:10.1016/j.polymertesting.2020.107031

The study of polymers has become increasingly important due to its wide use in our daily lives. The analysis of their properties, and the prediction of their useful life are often unknown due to their behavior when different loads are applied to them. In most cases in the design with polymers, large safety factors are used to guarantee greater durability, however, due to their viscoelastic and viscoplastic nature, these polymers can fail before the expected time, so knowing as many properties as possible will allow a better understanding of its behavior. One of these little-understood properties in materials and especially polymers is Creep, which is a creep failure mode when a constant load is applied to the material and it continues to deform over time.

Mohammad Amjadi and Ali Fatemi's research is the most extensive recent work on the subject of creep behavior. This work deals with different methods to predict the creep behavior of high-density polyethylene using tensile creep tests. The study's relevance lies in using methods to predict the long-term behavior of the material using temperature variations. The experimental study included virgin, regrind, and laminated high-density polyethylene (HDPE) with compression molding and blow molding processing techniques to investigate the effects of material and processing techniques on compressive strength.

For the samples tested virgin HDPE and crushed HDPE, rectangular plates of 2 and 4 mm thickness and dimensions of 200 × 200 mm were compressed or blow molded. Creep tests were performed with a closed-loop servo-hydraulic testing machine controlled by a digital controller. An extensometer was used to measure strain. The tension was generated with a pair of pneumatic grips with a capacity of 5 kN and an adjustable pressure system. They also used a lever arm testing machine with dead weights to perform long-term creep tests at room temperature. Some of the tests carried out with the servohydraulic testing machine were repeated with the lever arm machine to verify the repeatability of the results. These tensile creep tests were carried out with the ASTM D2990 standard, in which they carried out short tests from 3 hours to 3 days and long tests of up to 180 days. The authors obtained high-density polyethylene (HDPE) by the lamination and blown method, in addition to virgin samples. They observed that increasing the temperature significantly reduces the yield stress. This is because molecular mobilization is increased, which causes more deformation at elevated temperatures. The chosen temperatures were 23, 53, and 82 °C, based on the service temperature range for application in the design of automotive fuel tanks. They also performed room temperature tests to assess the accuracy of extrapolating results from short-term creep tests to long-term creep tests. They used various empirical power-law models to describe the nonlinear creep deformation behavior of polymeric materials, such as the Findley power-law model. They also used Norton's power law to relate the minimum creep rate to strain. In doing so, they determined that there is no significant difference in minimum creep rate between virgin, milled, and laminated HDPE materials with different processing techniques. To predict the time to rupture, they used the Monkman-Grant relationship, which is another creep model, which is related to the minimum creep rate.

Finally, they performed short-term tests at elevated temperatures and/or low-stress levels to predict long-term creep behavior. The time-temperature superposition (TTS) technique was used to predict the creep behavior; however, this method is most effective for polymers with linear viscoelastic behavior, and because HDPE has nonlinear viscoelastic behavior, it may not give accurate results. They used this technique with three temperatures of 23, 53, and 82 °C.

In conclusion, they showed that the prediction of the creep curves is more in line with the experimental data when the temperature is 23 °C. And at these temperatures, the TTS method is better than Findley's power law model. However, the use of the TTS model has the limitation of temperature, so it would not be very accurate when increasing the temperature. Both the TTS and Monkman methods are within the dispersion bands of ±2 % that they used as the error factor of the experimental

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data. So these two methods can predict the time to rupture by creep in tension. The TTS is more effective in the long term and the Monkman model generates a better prediction until rupture regardless of temperature. They also concluded that there was no significant difference in creep behavior due to the manufacture of HDPE, whether compression molded or blow-molded. Although the research by Mohammad Amjadi and Ali Fatemi presents extensive theoretical and empirical work predicting the long-term behavior of HDPE using tensile tests, some issues can be pointed out below to improve analysis in this area of engineering research.

The materials in real applications are always in contact with degrading media, whether they are solids, liquid gases, or the environment itself, which generates a possible premature deterioration of the material, causing the actual flow behavior of the material already in the application to be very different from that carried out in controlled tests. In addition, although the temperature is also a factor that degrades the material, it is not the only one, and other degrading means could be considered to know how feasible are the correlations of the theoretical methods with the empirical ones. Likewise, the method of carrying out creep by traction has the limitation of being very laborious and destructible, which is why special test pieces are required under normality to be carried out, which in many cases is not the most adequate and limits other possibilities in the knowledge of the creep behavior. In the same way, taking a prediction model will sometimes depend on the working temperature to correctly simulate the creep behavior curves. Prediction of time to rupture could be avoided by performing indentation creep tests. Another factor to consider would be the acquisition of the material since it was not purchased commercially. Probably in an application, a material that is in stock could be very different in its properties than when it was specially created for research, so a prediction involving a commercial purchase of the material could be interesting to know if there are significant differences in the creep behavior. The prediction of creep behavior should include more information about the application of the material, as well as empirical non-destructive methods. Polymers are materials that are very sensitive to the media to which they are exposed, so predicting their behavior with models would be very complex and is not comparable to an experimental method of shorter duration such as the indentation creep method.

Finally, it would also be necessary to add some additional mechanical tests such as hardness or other mechanical properties that are being affected in the material causing an increase or decrease in the useful life of the material, which is related to the creep in polymer materials.

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Aguilar, G.E., García, J.S., Aguilera, L.D., Hernández, M.T., Moreno, K.J. (2022, diciembre). Physical characterization of degraded ultra-high molecular weight polyethylene (UHMW-PE) and nylamid. *Pistas Educativas*. Recuperado de https://pistaseducativas.celaya.tecnm.mx/index.php/pistas/article/viewFile/2878/2212.

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