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PROJECT AND CONSTRUCTION OF A POLYMER FLOW TEST DEVICE

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Abstract. Industries have been applying polymers in many different ways for decades, such as structural materials, cars and planes components, mechanical parts, etc. However, the polymeric materials exhibit viscoelastoplastic behavior meaning their properties vary as time goes by. In the case of high density polyethylene (HDPE), this behavior is non-linear viscoelastic and, therefore, the material properties also varying according to the applied tension level. One way to characterize the behavior of HDPE is by using uniaxial creep test. In this work, a device capable of performing creep tests was developed. For this purpose, PDP guidelines were followed in order to develop a equipment with high acceptance among its users. The test machine has been designed in CAD software and the manufacture of the componentes was made by using conventional and CNC machines. Each part of the device was made of stainless steel. After the setting, a potential signal acquisition system was provided. Finally, a creep test was performed to evaluate the efficiency of the device.

Key-words: HDPE, Uniaxial creep, PDP, signal acquisition.

1. INTRODUCTION

Over the years, in many applications, metallic materials have been replaced by polymers. This growth is only due to the fact that polymeric materials have interesting properties in structural engineering, such as: good abrasion and corrosion resistance, low cost, good fatigue response and flexibility, easy manufacture and low weight (Kühl, 2014). Nevertheless, the polymeric materials have viscoelastic behavior, while their properties change over time. In the case of HDPE, this behavior is non-linear viscoelastic, meaning the material parameters also varies according to the tension level that has been applied (Wasilkoski, 2006).

In general, to characterize the behavior of the HDPE, researchers employ a uniaxial creep test, which consists in the application of a constant load where the strain is monitored during a certain period (Kühl, 2011). Thus, this work seeks to design and develop a mechanism to perform creep tests on samples extracted from HDPE pipes and acquire data from a strain gage attached to the material.

2. EXPERIMENTAL PROCEDURE

Advances in technology allow the manufacture of a vast range of components made of polymers, especially in the automotive industry. By using these technologies, companies are able to reduce weight, improve design and consequently decrease productivity costs (Neto, 2012).

Therefore, by those savings, the consumption of fuel and water decreases, minimizing the emission of gases in the environment. As far as this scenario goes, the main goal of this paper is to characterize the viscoelastic behavior of the polymers using a simple technique. For this reason, it is necessary to build a compact and lean creep device, as well as a cheap acquisition system to obtain the information needed.

Samples were taken from HDPE pipes using a hydraulic machine, both the tubes and the hydraulic machine were supplied by TIGRE S/A. They follow the ASTM E8 standard for test specimens. The mechanism was designed respecting the useful length of the sample, as shown in the Figure 1.

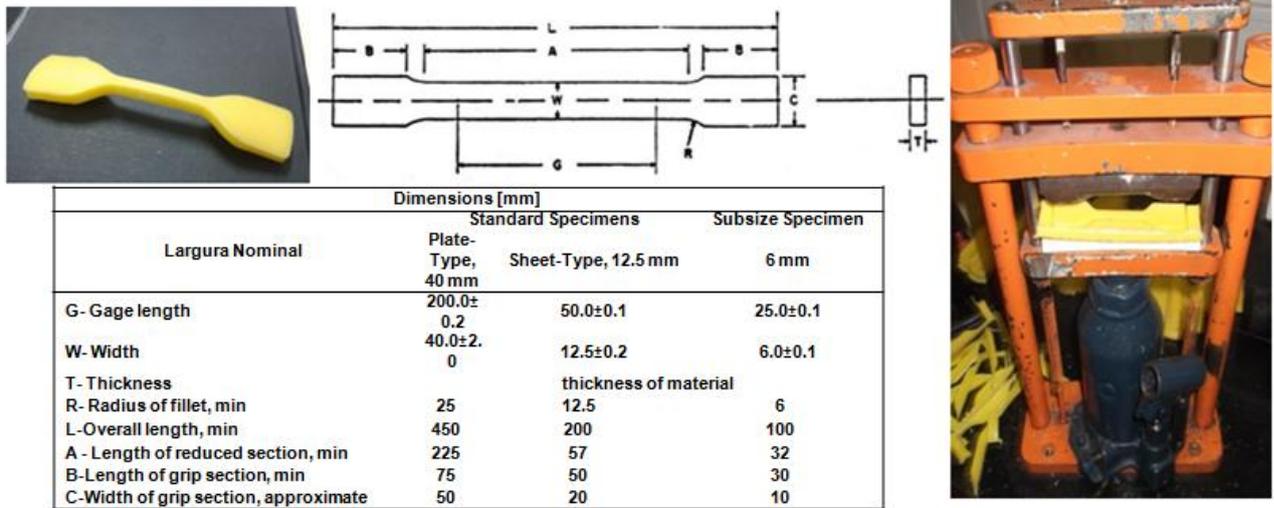


Figure 1: Sample's Dimensions.

2.1 Generate of Alternatives

The guidelines of Product Development Policy (PDP) were taken as basis for the design, in order to elaborate a device with maximum acceptance among its users (Pereira, 2015).

The first stage was the informational project, where questions were raised to define the shape of the project (Ferreira, 2013). During this stage a reference model was defined, this means that a device that already exists in the market with the same function was taken as reference. This equipment, which works with dead weight, is called **KAPPA LA** and is shown in the following figure:



Figure 2: KAPPA LA with dead weight.

Based on this reference model, it was possible to start analyzing the alternatives which could better respond to customer expectancy. The objective of this step was to design a compact device, decreasing costs and meeting the characteristics in the users' requirements.

After this evaluation, different proposals were developed and evaluated (Figure 2). The first alternative studied was a test device found at the University of the State of Santa Catarina (UDESC), but this alternative had some disadvantages, such as an unpleasant aesthetic, the necessity of doing some welding work, high cost, oxidation resistance, etc.

Another possibility suggested was using a pneumatic piston instead of a lever arm. This change made the reduction of the device possible, although this alternative had the following disadvantages: difficulty in fixing the hydraulic piston and the necessity of a pump.

The third alternative evaluated was using dead weights, just as the first one. Nevertheless, the dead weights should be placed just below the specimens and should be bigger than the other alternatives. This design is necessary because

there is no lever arm to amplify the load. Thus, this third design was well accepted because it allied portability and low cost.

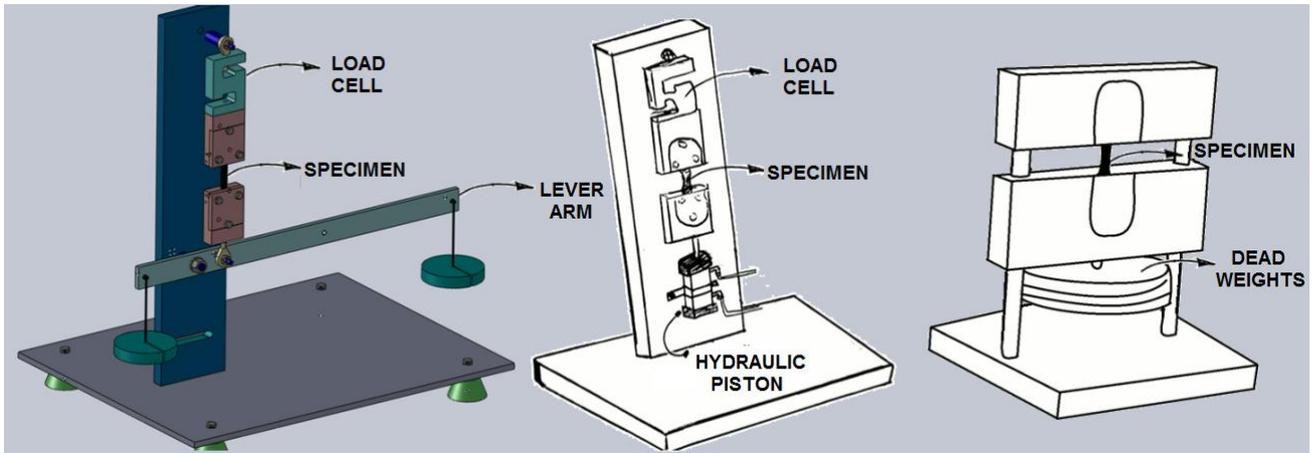


Figure 3: Generated Alternatives.

Since the alternative was chosen, the authors have started the projects using the CAD system SolidWorks®.

A CAE system was employed to evaluate the strains in the samples and to guarantee that the guide columns must have the correct length. This properly length is important due to the fact that when the specimen is tested, the dead weights must not collide with the base (Figure 3). However, the total strain of the specimen is unknown, so, by using the CAE system available in SolidWorks®, it was possible to predict the HDPE sample strain. Finally, all measurements of the components were defined.

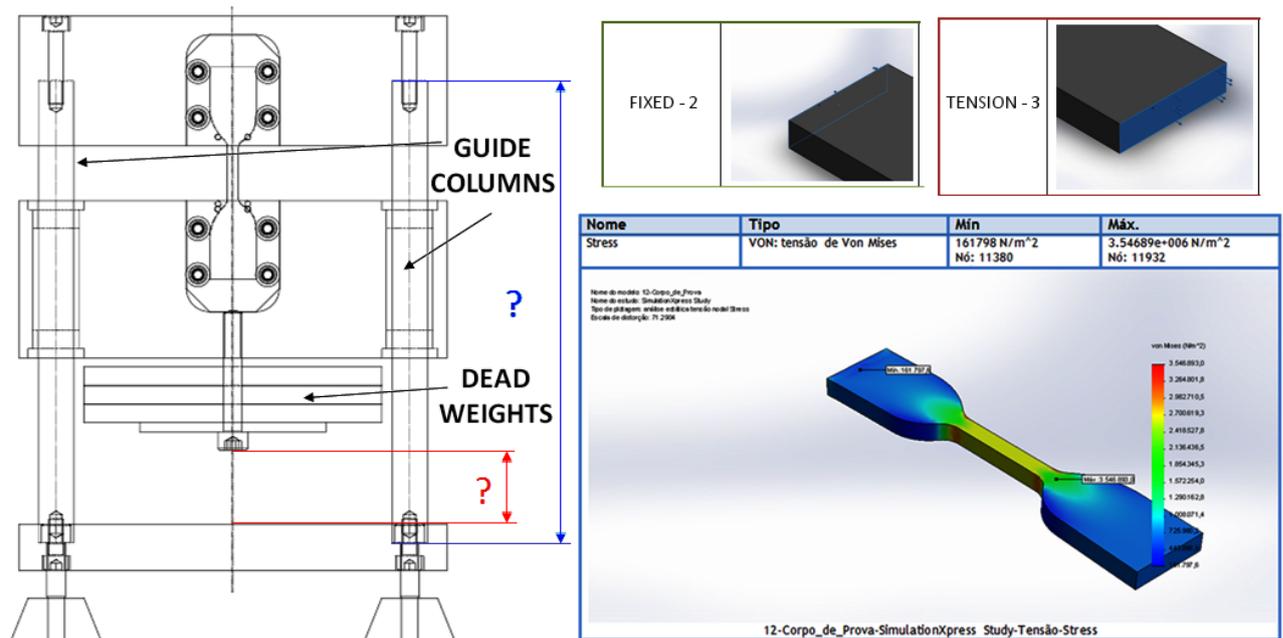


Figure 4: CAE Simulation.

The next step consisted of manufacturing the parts of the device. The components were made by using conventional and CNC machines. Once the parts were manufactured, the device was assembled.

2.2 Acquisition Data System

The strain gage is the method that uses the principle of the relationship between mechanical stresses and strains on bodies subjected to mechanical stresses, as established by Robert Hooke's studies in the XVII century (Souza and Júnior, 2014).

Thus, strain gages are resistant devices that, when deformed, undergo a variation in resistance proportional to the applied force (Perboni, 2013).

The most widely used strain gages are those with nominal resistance equal to 120Ω or 350Ω (Ribeiro, 2014). In this device, uniaxial strain gages of nominal value 120Ω were employed.

For the fixation of the extensometers to the specimen, epoxy adhesives were applied. This type of adhesive presents some interesting characteristics, such as (Borges, 2012):

- High tensile strength;
- Good stiffness.
- Creep resistance;

On the other hand, it has presented the following disadvantages:

- Low impact resistance;
- High cost.

2.3 Wheatstone Bridge

During the creep test, the resistance of the extensometer changes when the sample is subjected to strain. Wheatstone bridge, composed of four resistors of the same value, including the extensometer without any deformation, is responsible for detecting this variation. A small variation in the resistance of the extensometer causes an imbalance in the Wheatstone bridge, altering the voltage E_o , proportionally (Souza and Júnior, 2014). This signal must be amplified before the tests data are recorded by computer software.

2.4 Instrumentation Amplifier

In general the instrumentation amplifiers are constituted by three operational amplifiers and it presents good stability in relation to variations of temperature and a good performance regarding power consumption.

The Figure 5 shows the basic typology of an instrumentation amplifier.

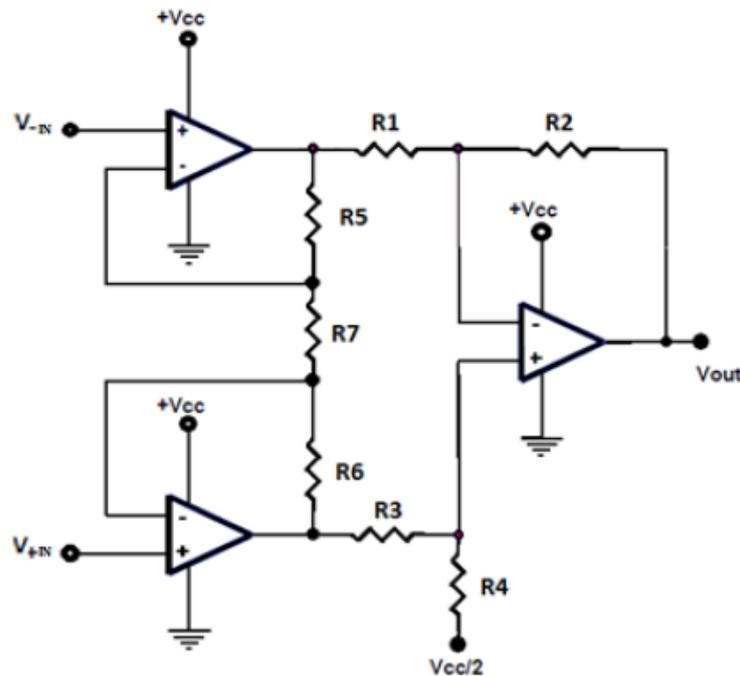


Figure 5: Instrumentation Amplifier.

As it can be seen in the Figure 5, the instrumentation amplifier has a differential input, given by the voltages V_1 and V_2 which are converted to a single voltage, V_{OUT} .

The ideal instrumentation amplifier should be able to amplify only the difference between the signals present at inputs V_1 and V_2 . The value obtained from the Wheatstone bridge will be directly related to the strength of the strain gage used.

The relationship between resistance and strains is shown below (Padilha, 2010):

$$\varepsilon = \left(\frac{1}{F}\right) * \left(\frac{DR}{R}\right) \quad (1)$$

where ε is deformation, F is the factor of the extensometer and R is the resistance of the extensometer. For a typical extensometer, F is 2 and R is 120Ω .

The Relationship between stress and strain is shown below (Ribeiro, 2014):

$$\frac{V_o}{V_{ex}} = \varepsilon F \quad (2)$$

Where V_o is the output voltage, V_{EX} is the excitation voltage, in this case provided by the power supply.

As the output value of the Wheatstone bridge is calculated by amplifier, the strain will be given by the Equation 3:

$$\varepsilon = \left(\frac{V_o}{V_{ex}}\right) * \left(\frac{1}{F}\right) \quad (3)$$

In sequence, an acquisition data system was chosen. For this purpose, an extensometer was fixed in the specimen and the variation in resistance was monitored over time. A commercial software (DATAQ DI-158U) was used to record the data during the test.

The output signal had a resistance value and this signal was changed to a voltage form by using a Wheatstone bridge. However, this output signal obtained by the Wheatstone bridge had very low amplitude, thus, for amplification of the signal a CS-9900-P1 Signal Converter / Transducer was employed.

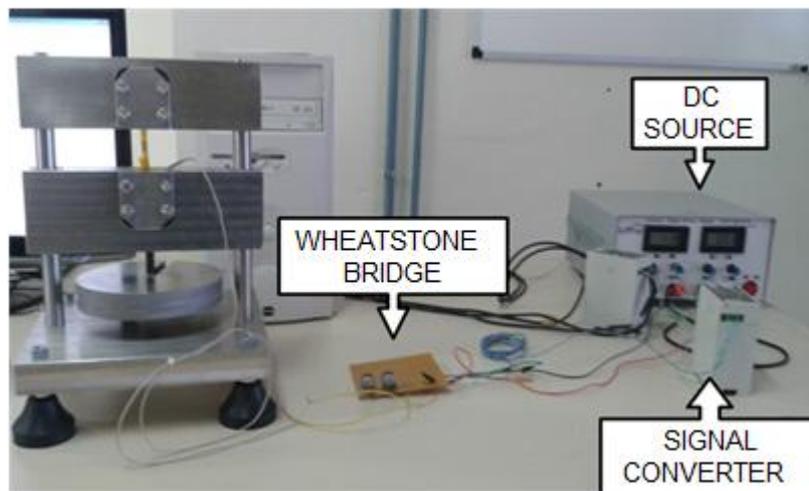


Figura 6: Creep Test.

For the voltage-time curve generated, the WinDaq software was used (available for download on the Dataq Instruments website).

The expected magnitude is the strain. To obtain this magnitude, the Equation (4) was employed:

$$\varepsilon = \left(\frac{V_o}{V_{ex}}\right) * \left(\frac{1}{F}\right) \quad (4)$$

Where

V_o is the output voltage;

V_{EX} is the excitation voltage;

F is the extensometer factor ($F=2$) (Padilha, 2015).

By doing the conversion it was possible to obtain the strain-time curve.

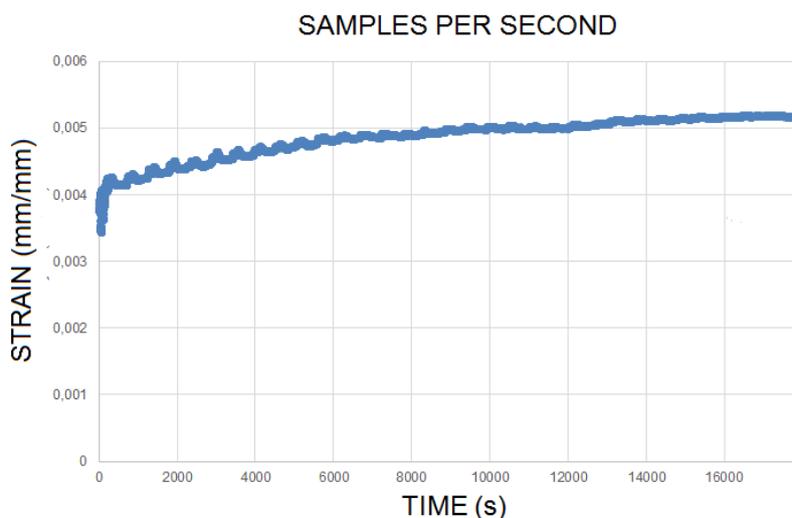


Figura 7: Strain-time curve.

Thus, it was possible to evaluate the mechanism in a temperature controlled laboratory. However, more tests are needed to validate it.

3. CONCLUSIONS

The objective of this work was reached, considering that it was possible to build a functional mechanism for HDPE creep tests, respecting the design requirements.

For future work, a higher load should be applied to the specimens (greater range of dead weights) in order to obtain results in a shorter time.

Finally, more tests must be performed and compared with results published, since the ones carried out were only qualitative.

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5. REFERENCES

- FERREIRA, C. V., 2013. "Projeto Conceitual – Geração de Alternativas de Concepção". Aug. 2015 <http://joinville.ifsc.edu.br/~antonio.dias/201502%20PMQ%20Concomitante/Aula%204%20_%20Projeto%20Conceitual%20Selecao.pdf>.
- KÜHL, A., 2014. "Uma Formulação Viscoelastoplástica Não Linear Aplicada ao Polietileno de Alta Densidade (PEAD)". Dissertação (Mestrado Acadêmico em Engenharia Mecânica) – Universidade do Estado de Santa Catarina, Joinville.
- KÜHL, A., 2011 "Projeto e Execução de um Dispositivo para Ensaio de Fluência de PEAD". Feb. 2015 <<http://www.escavador.com/pessoas/9073267>>
- MESSPHYSIK, M. T., 2014. "Product Information". May. 2015 <<http://www.zwick.net.br/br/produtos>>
- NETO, N. J. R., 2012. "A Evolução dos Polímeros na Indústria Automobilística". Monografia (Tecnologia em Polímeros) – Faculdade de Tecnologia de Sorocaba, Sorocaba.
- PADILHA, H., 2010. "Deslocamentos e Deformações". Oct. 2015 <<http://slideplayer.com.br/slide/1755847/>>
- PEREIRA, J. B., 2013. "Visão Geral do Processo de Desenvolvimento de Produtos". Mar. 2015 <<http://www.joinville.ifsc.edu.br/~josue/AULA%20-A%20PDP%20C3VISA10%20GERAL.pdf>>
- WASILKOSKI, C. M., 2006. "Comportamento Mecânico dos Materiais Poliméricos". Thesis (Doutorado em Engenharia e Ciência dos Materiais) – Universidade Federal do Paraná, Curitiba.

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