Outlook

Fw: CI3 2022 notification for paper 54

De: ci32022@easychair.org en nombre de CI3 2022 <ci32022@easychair.org>
Enviado: martes, 9 de agosto de 2022 2:30
Para: Vicente Manopanta <ingenieriatecnicamc@hotmail.com>
Asunto: CI3 2022 notification for paper 54

Dear Vicente Manopanta:

We are pleased to notify you that your paper "THERMAL CHARACTERIZATION OF RECYCLED PVC USED IN THE PRODUCTION OF VALVE CAPS FOR AUTOMOTIVE TIRES" has been accepted for oral presentation at CI3 2022, to be held form August 31 to September 2 of this year. The Conference Proceedings will be published in a Book Series of the SPRINGER Publishing House and indexed in the SCOPUS Citation Database.
To prepare the final version of your paper (version to be published), carefully read and follow the instructions cited below:

1. Papers must be prepared according to the Springer template (MS-WORD or LaTex format) without page numbers, written in English and with an extension of ** 12-15 pages, including figures and references **.

The template can be downloaded at https://www.springer.com/us/authors-editors/conference- proceedings/conference-proceedings-guidelines.
We recommend that you consider all the suggestions made by the reviewers and have a native
speaker review the English of the paper.

2. * The final version * of your work must be submitted until *** August 21, 2022 ***, with the following attached documents:

- Paper in MS-WORD or Latex format (1 file).
- Paper in PDF forms (1 file).
- Document (Word or pdf) with the paper title; Easychair paper ID (number); name and mini biography (5 lines) of the speaker (1 file).

The documents must include names of the authors, affiliations and must be sent to the email ci3@ister.edu.ec.

3. Submitted documents will undergo a similarity check using Turnitin software. The maximum percentage of similarities accepted for publication is 15%.
4. For your paper to be published, it is ** mandatory ** that at least one of the authors (speaker) register at CI3 2022. The registration must be done by paying the corresponding fee and sending the payment receipt scanned (together with your full name, affiliation, and paper ID) to the email ci3@ister.edu.ec.

Finally, we ask that you consider CI3 2019 and CI3 2020 papers for citation in your accepted publication. The CI3 2019 and CI3 2020 published papers can be consulted at the following link: https://ister.edu.ec/congreso/technical-papers/.
Feel free to contact us (ci3@ister.edu.ec) if you need more information. We look forward to hearing your presentation at the conference !!!

Regards,

CI3 2022
General Chair

THERMAL-MECHANICAL PROPERTIES OF RECYCLED PVC USED IN SCHRADER VALVE CAPS

Jose Vicente Manopanta-Aigaje[1], Diana Peralta-Zurita[2]

[1]Instituto universitario ISMAC Quito, Ecuador
vmanopanta@tecnologicoismac.edu.ec
[2]Universidad Internacional SEK Ecuador, Quito EC170134, Quito, Ecuador
diana.peralta@uisek.edu.ec

The living conditions force man to use synthetic polymers, called plastics. Their resistance to decomposition by humidity generates their accumulation in sanitary landfills. The polyvinyl chloride (PVC) has remarkable physical-mechanical characteristics and low cost, therefore, it is used to manufacture pipes and containers for medical supplies, toiletries and cosmetics. Thermal characterization of post-consumer flexible PVC from mechanically recycled talcum containers is analyzed to manufacture valve caps for automotive tires. Thermal tests are performed in the INNER laboratory according to ASTM 1131, D2240, E1269-11, D1525, D3418, D79208 standards by infrared spectroscopy to identify the material and its percentage in the composition, differential scanning calorimetry to determine thermal degradation, glass transition temperature and its mechanical properties are based on the ASTM D38-02 standard. Results that will be used for the elaboration of a valve cap prototype by gravity casting of PVC in a polyester resin mold.

Keywords: polymer, characterization, spectroscopy, infrared, differential calorimetry.

1. Introduction

The development of the automotive field at present has a great growth. While it is true that steel, aluminum and other metals are still used in structural parts and components of a car, needs of users and the development process of the automotive industry have stimulated the progressive use of other materials in the construction of cars, among which the use of plastic materials stands out [1]. Where all automotive elements are in high demand, the research project refers to the study of an alternative material for the manufacture of automotive caps. Among the most commonly used plastic materials in the automotive industry are thermoplastics, thermosets and elastomers [2]. Thermoplastics include PVC, which is generally produced in pipes, cosmetology containers and talcum powder containers. Polyvinyl chloride (PVC) is one of the most widely used materials due to its chemical and mechanical resistance properties [3]. PVC has become widespread in soft drink and water containers, in the manufacture of components for the automotive industry, housing, clothing and all types of consumer goods [4]. Plastic recycling is an alternative and an area of opportunity to solve raw material savings and reduce pollution. Plastic is a recyclable element that can be applied in the automotive field, especially in vehicle components [5]. PVC has several important aspects such as finish, product durability, high strength, and useful life [6]. It is marketed in a rigid form, but its loss of rigidity can be generated by increasing the temperature between

104 °C and 205 °C, which is an advantage for maneuverability in all activities by applying the physical, thermal and mechanical properties [7]. This research consists of thermal characterization of post-consumer flexible PVC samples subjected to mechanical recycling, since this material is found in talcum powder containers and shampoo containers, which are not subjected to recycling or to any process of recovery of this material, and even in recycling plants it has a very large place. PVC is an open-formula material because it accepts various additives or plasticizing liquids [8]. It can be stated that the recycled material has good mechanical and thermal resistance, i.e., it can be applied to the automotive field with confidence and safety.

2. Materials and Methods

2.1 Material

The characterization of the mechanical and thermal properties of post-consumer flexible PVC from containers that contained personal hygiene products will be subjected to a mechanical recycling process. PVC can be recycled in the following ways: (a) mechanical recycling, (b) chemical recycling, (c) energy recycling and (d) solvent recycling [9]. For the elaboration of thermal-mechanical tests, the analysis and tests are carried out by means of experimental measurements, analysis and testing in accordance with American Society of Testing Materials (ASTM) standards**.**

3. Methods

3.1 Physical identification methods:

Density. It begins by weighing the PVC sample, in this case 1.386 g, then it is introduced into the tank containing distilled water, the ambient temperature is 20.8 °C according to ASTM D792 08. Table 1 shows that it is within the range of the PVC compared in the laboratory.

Figure 1. INNER Density Meter

Physical identification of PVC containers: “SPI (Society of the Plastics Industry) code, which was proposed in 1981 in the United States and today is an ASTM (American Society of Testing Materials) standard, is used to identify the composition of packaging worldwide” [10]. Code 3 shown in Figure 2 states that it is PVC.

Figure 2. Side and bottom of a PVC container, Blenastor C.A.

The Beilstein test is a simple method to determine the presence of a halogen (chlorine, fluorine, bromine and iodine). A green flame, as shown in Figure 3, demonstrates the presence of halogen, i.e., it is Polyvinyl Chloride.

Figure 3. Colored flame produced by PVC in an alcohol flame.

Table 1. Specific gravity of polymers [11].

Polymer	Specific gravity [g/cm³]
Polypropylene PP	0.90 – 0.91
High Density Polyethylene HDPE	0.95 – 0.97
Low Density Polyethylene LDPE	0.92 – 0.94
Polystyrene PS	1.05 – 1.07
Polyethylene terephthalate PET	1.38 – 1.39
Polyvinyl chloride PVC	1.16– 1.35 ⬅

3.2 Spectroscopic methods. According to ASTM standard

Spectroscopic methods have brilliantly simplified this work. A structure can be determined in a few hours [12]. These methods are based on the fact that organic molecules absorb electromagnetic radiation of different wavelengths by the vibrations of their electrons, atoms and groups of atoms; the absorbed wavelength depends on the molecular structure and gives information about it. The wavelength of the absorbed light packet corresponds to the energy [13].

$$E = h * v \quad (1)$$

Where:

E: Energy

H: Planck's constant

ν: Frequency

3.3 Infrared spectroscopy (FTIR): The raw material is analyzed by transmission from 4000 to 400cm^{-1} by attenuated total reflectance (ATR) from 4000 to 600 cm^{-1}. The spectrometer used is the Thermo Sientific Nicolet iS50 FTIR model that uses the Fourier transform for data processing that has a wave resolution of 80 - 20000 cm^{-1}, the standard that governs the operation is ASTM E 1421 [14].

3.4 Glass transition temperature (Tg)

in accordance with Standard Test Method for Transition Temperatures of Polymers By Differential Scanning Calorimetry. This fact is manifested in the DSC measurements, where the Tg depends on the thermal history of the sample, particularly on the cooling rate which determines the initial glassy state of the polymer to be studied, as well as on the subsequent heating rate of the apparatus during the thermogram acquisition [15]. The collected raw material (talcum powder containers) was ground to a grain size of 40 µm, then 20 mg was used and placed inside an aluminum cell which was sealed with another cell (aluminum crucible). It was carried out with a Calorimeter HDSC PT 1600, with a temperature range from -150 °C to 1750 °C with a vacuum capacity of 10^{-5} mbar, heating rate from 0.01 to 100°C/min in a nitrogen atmosphere with a flow rate of 24 mL/min.

3.5 Thermogravimetric analysis in accordance with

Standard Test Method for Compositional Analysis by Thermogravimetry. The resulting analysis is called, respectively, dynamic and isothermal [16]. The thermogravimetric analyzer QA 5000 from TA Instruments has an accuracy of ±1µg, the test is carried out in a nitrogen atmosphere with a flow rate of 50 mL/min from the initial temperature up to 800 °C according to ASTM D 3418.

3.6 Tensile - deformation test: The tensile test is carried out in a universal testing machine MTS, model T 5002, according to ASTM D638, test specimen number IV, with a testing speed of 50.8 mm/min.

Figure 4. Test specimen for tensile test with Amsler vertical universal tensile testing machine

Source: ESPE's Laboratory of Mechanics of Materials

ASTM D638 - 02ª, Standard Test Method for Tensile Properties of Plastics, gives the dimensions of test specimen number IV for mechanical tests [17]. The recycled PVC test specimens standardized for the uniaxial tensile test are shown in Figure 5

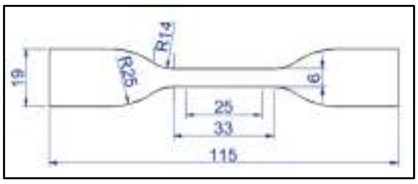

Figure 5. Tensile test specimen according to ASTM D638 - 02ª, Standard Test Method for Tensile Properties of Plastics.

4. ANALYSIS AND RESULTS

4.1 Infrared Spectroscopy Identification (FTIR) (ASTM142 Standard)

Figure 6 shows the 1423 cm^{-1} value, a signal corresponding to out-of-plane bending that confirms the C-H vibrational stretching of the aliphatic CH_2 of the signals in the region near 3000 cm^{-1}. On the other hand, the signals near 1330 and 1255 cm^{-1} are attributed to C-H finned shaped deformation modes intensified in some cases by the proximity of the chlorine atom linked to the same carbon.

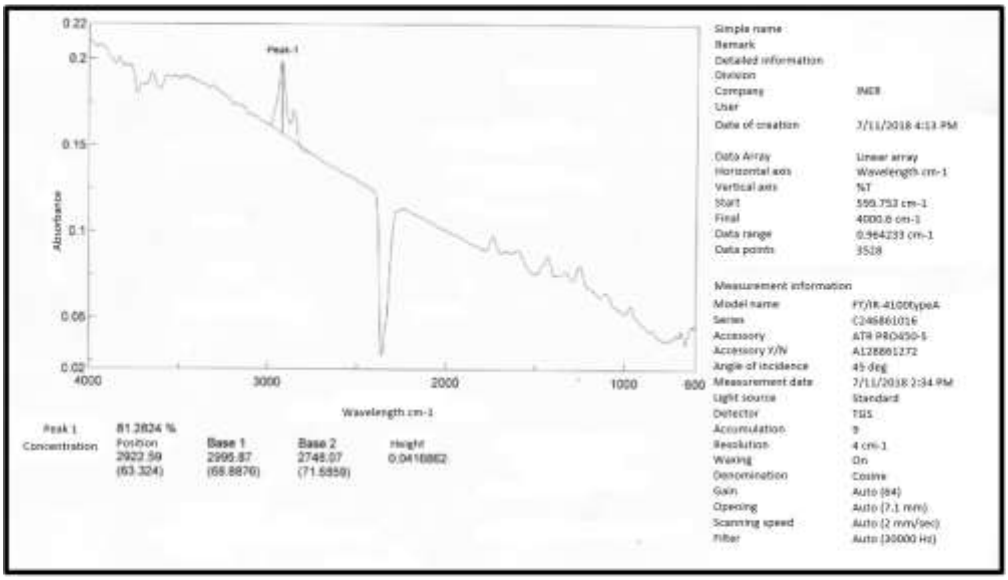

Figure 6. Infrared Spectrogram Result of Recycled PVC

- When comparing the found graph to the paper CHEMICAL RECYCLING OF POLY (VINYL CHLORIDE): ALKALINE DECHLORINATION IN ORGANIC SOLVENTS AND PLASTICIZER LEACHING IN CAUSTIC SOLUTION, the value of the bands will be 3100 - 2800cm^{-1} [18].

Table 1. The relative absorptivity of the ν(C-Cl) bands at 820-615 cm^{-1}, and ν(C-H) bands at 3100-2800 cm^{-1}.

relative absorptivity	polyvinyl chloride virgin	polyvinyl chloride degraded
ν(C-Cl)	0.4750	0.1761
ν(C-H)	0.1127	0.0844
ν(C-Cl/C-H)	4.2147	2.0854

It is mentioned that the value found versus the one compared to the paper is within the range to identify it as PVC.

The program also indicates a first degree straight line, see Figure 7, the formula is Y = A*X.

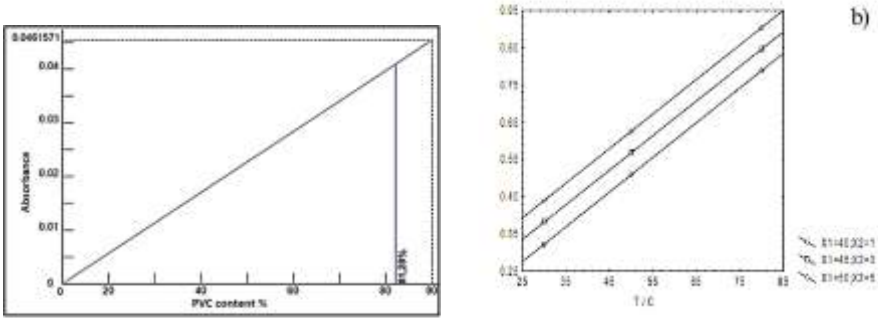

Figure 7. Result of the percentage of PVC in the sample

Figure 7 shows the equation for the line where A is the ratio factor of the formula A = 0.000512856. In the figure, comparing results, it is observed that the absorbance is within the permissible values considered in the line as PVC. Considered with a concentration of 81.28%.

4.2 Thermogravimetric Analysis: Figure 8 shows a representation of the glass transition temperature Tg with respect to the concentration of plasticizers, dioctyl phthalate DOP and diisobutyl phthalate DIPB, for the system plasticized by DOP, which after the second point (C = 20%) already altered the previous linear trend (red line), i.e., for the third point (C = 40%), the relationship between Tg and concentration no longer decreased in the same magnitude.

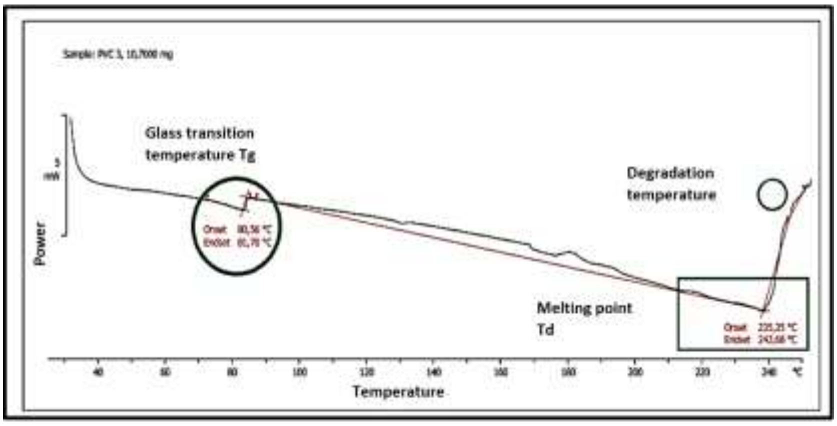

Figure 8. Thermogram Result of Recycled PVC

Table 2 shows the temperatures at which the system reached the degradation concentration.

Table 2. Thermogravimetric temperature

Glass transition temperature	
Start	80.56
Final	81.60

The temperatures will allow the plasticizer to be recovered, but when the temperature has exceeded this value, the solvent can no longer be recovered and this is due to the system reaching the critical plasticizer concentration, i.e., at this concentration the possibility of interaction ceases to be effective and, from this point on, the plasticizer is prevented from solvating [19].

4.3 Melting point by differential scanning calorimetry DSC (ASTM D 3418 Standard): The degradation temperature only establishes the starting point, there the combustion process takes place with strongly exothermic reactions, which is an irreversible process. Industrially, it is necessary to know when the material begins to be unusable due to the effect of the heat to which the polymer has been subjected, see Figure 9.

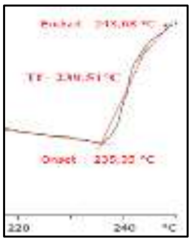

Figure 9. Melting point result

Source: (INER)

The degradation temperature Tg, the temperature at which the transition from the glassy state to the soft rubbery state begins, is the inflection point of the curve. The average of the temperature range is generally taken.

4.4 Yield stress by tensile test. Tensile-deformation mechanical tests

ASTM D638 - 02^a, Standard Test Method for Tensile Properties of Plastics, gives the dimensions of test specimen number IV for mechanical tests. The test will be done in an axial tensile equipment, AMSLER model I0II at a test speed of 50 mm/min. Place the ends of the test specimen in the upper and lower jaws, adjust and operate the hydraulic traction system. The recycled PVC test specimens standardized for the uniaxial tensile test [20].

Figure 10. Result of the tensile test according to ASTM D638 - 02ª, Standard Test Method for Tensile Properties of Plastics.

Table 3. Mechanical Test Results

So: Cross sectional area	**Result**
Lu: Last length	4.14 mm
Fe: Yield load	229.50 N
Fm: tensile load	261.35 N
Re: Yield strength	55.25 Mpa
Rm: Tensile strength	63 Mpa
A: Elongation	10.75 %

4.5 Simulation of the tire valve cap using Solidworks.

4.6 Thermal simulation of the prototype. According to the climate variables paper shown in the figure, the ambient temperature will be 27.04 °C in 2020, which is taken as the reference value for the simulation [21].

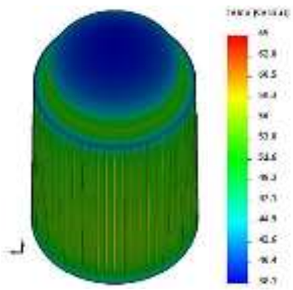

Figure 11. Thermal simulation for the recycled PVC prototype

The temperature used will not affect the element created, since it has a degradation temperature of 81 °C and is three times higher than the ambient temperature.

4. 7 Simulation of axial load inside the valve cap head: Assuming a failure in the Schrader valve closure system, the force with which the air inside the tire pushes on the valve cap can be calculated to be 2.3 lb for 80 psi internal pressure and 10 mm valve cap diameter. A value of 5 lb is taken for the simulations. The simulation results are shown in Figure 11 and 12.

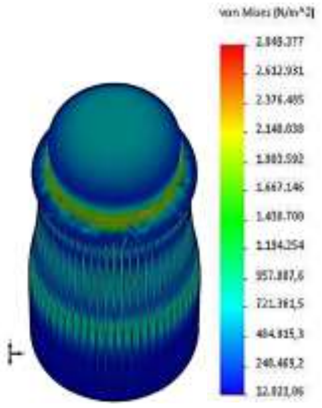

Figure 12. Mechanical simulation of tire valve caps

The simulation for the internal axial load in prototypes made of standard PVC, recycled PVC and polypropylene, shows similar values, the most critical area is the one around the head of the valve cap with a Von Mises stress of 2,140.038 N/m^2. The definition of the area is more accentuated in standard PVC, followed by recycled PVC and finally polypropylene. In any case, with values lower than the Von Mises stress 12,340.668 N/m^2 of standard PVC, value specified as maximum indicating the resistance of the material in the simulation carried out.

4.8 Simulation of the application of an external torque to the prototype: In the closing or opening operations a torque must be applied to the knurled surface of the valve cap, for the simulations a value of 0.15 Nm is assumed [22].

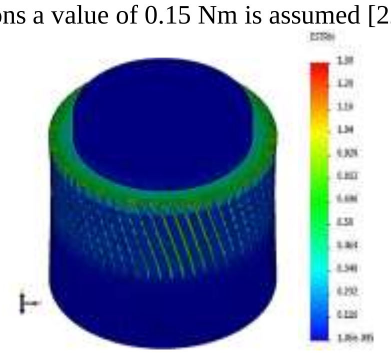

Figure 13. Mechanical simulation with torque on tire valve caps

The torque value according to the dimensions of the valve cap represents a manually applied finger force of 3 kg, a high load for a cap mechanism.The recycled PVC sample has a good amount of plasticizers used as additives, unlike the standard PVC sample, hence the difference in elongation that each presents. Recycled PVC can be subjected to stresses in the proportional zone better than standard PVC and polypropylene, which works exaggeratedly in the plastic zone. The mechanical tensile tests were performed at room temperature Tamb = 22 °C, which is much lower than the glass transition temperature Tg = 81.13 °C, for recycled PVC, so according Figures 12 and 13 the material does not fail.

4.9 Pressure exerted on the tire valve cap: The inflation pressure of a small to medium size vehicle tire can be considered as 30 psi [23], according to most manuals the force on the inside bottom of the valve cap can be calculated using the following basic formula where the diameter is taken from Figure 17:

$$F = P * A = 30\frac{lb}{pulg^2} * \frac{\pi * 0.3125^2 pulg^2}{4} = 2.30lb$$

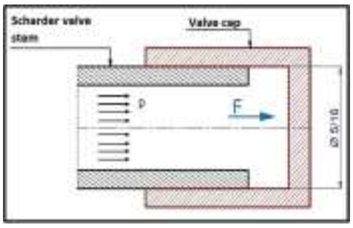

Figure 14. Tire cap stress

The thread is of the unified extra fine type, in which according to tables the area of stress is 0.0625 in^2. The normal stress produced in a single thread in the area of stress will be:

$$\sigma = \frac{F}{A_t} = \frac{2.30\ lb}{0.0625 pulg^2} = 36.8\ psi$$

The diameter of extra fine unified thread is considered as 5/16 = 0.3125 in.

The yield strength of PVC by tensile test is Sy = 55.25 MPa = 8013.33 psi. As can be seen, the applied stress σ is much lower than the yield strength, which means that the valve cap resists the pressure. The same reasoning can be made for the other materials.

5. CONCLUSION

When comparing the samples, it can be observed that it is within the permissible ranges to be able to mention that it is pure PVC and that the graphs have a similarity at the moment of comparing them, which means that it is PVC with a high percentage for its reuse in the automotive field.

It was found that the material of the post-consumer hygiene talcum containers are PVC resins with a content of 82.18% of PVC and 18.72% corresponds to additives or plasticizers that are added to the standard resin to give it flexibility characteristics. When creating the valve cap with recycled PVC, plasticizers should be added to improve the flexibility of the material since it has a very good mechanical resistance.

The tensile tests indicate the resistance values of the material placed under real conditions. By means of mathematical models, it is observed that our PVC has very good resistance properties. Therefore, PVC can be used in tire valve caps. According to mathematical models, it is a very resistant material.

Recycled PVC reaches a yield strength of 55.25 MPa, while standard PVC only reaches 15.65 MPa, which means that recycled PVC has a greater proportionality zone, i.e., in the manufacture of mechanical items and automotive parts there are better possibilities of applying mechanical loads to the part, in other words, recycled PVC offers better design and construction possibilities compared to standard PVC.

References

[1] Ferrer, H. E. S., & Fajardo, M. A. C. (2020). La importancia de la planificación de la producción en una empresa de conformado con PVC. Polo del Conocimiento: Revista científico-profesional, 5(10), 440-457.

[2] Obtenido de http://adriangonzalezeaf.blogspot.com/2012/04/principales-plasticos-utilizados-en-el.htm

[3] Alfonso, J. M. (1996). Characteristics of the thermal degradation of vinyl plastisols. Alicante, Spain: Special degree project at the University of Alicante to apply for the title of Doctor of Chemical Sciences.

[4] Castellanos Vargas, A. (2014). Estudio de la respuesta térmica de polímeros termoplásticos PVC espumado y PMMA en situaciones de incendio-análisis de propiedades mecánicas y caracterización por combustión.

[5] Mexichem. (2010). Perspectivas del Reciclaje de PVC. Obtenido de https://docplayer.es/18826473-Perspectivas-del-reciclaje-de-pvc.html

[6] Martínez Flórez, E. L., & Montañez Munar, J. (2021). Estudio de lechadas asfálticas para pavimentos con la incorporación de residuos de plástico tipo PET.

[7] Saénz, M. (2016). Elaboración de artículos plásticos para el hogar. Boletín mensual de análisis sectorial de MIPYMES, Ministerio de Industrias y Productividad, recuperado de: https://www.flacso.edu.ec/portal/pnTemp/PageMaster/1ek76ttdig4y5etomj1ag37vquo89.pdf

[8] Identificación de plásticos, Escuela Colombiana de Ingeniería Julio Garavito, Facultad de Ingeniería Industrial, Edición 2008-1 recuperado de:

[9] Gómez García, C. (2012). Caracterización térmica y mecánica de polibutilentereftalato (PBT), reforzado con fibra de vidrio. (Tesis doctoral, Universidad Politécnica de Cartagena).

[10] Primo, E. 2007. Química Orgánica Básica y Aplicada. Editorial REVERTE, S.A, Barcelona

[11] Castellano, M. (2015). Métodos de análisis térmico. Recuperado de https://docplayer.es/8941260-Metodos-de-analisis-termico.html

[12] Coreña Alonso, J. y Méndez Bautista, T. (2010). Relación estructura propiedades de los polímeros. Educ. Química. 21(4). 291-294. Recuperado de: http://www.scielo.org.mx/pdf/eq/v21n4/v21n4a6.pdf

[13] Vincent, B y Mathot, F. (2009). Métodos de análisis térmicos, Segunda Edición, Editorial John Wiley and Sons Ltd, N.Y

[14] Maciel Júnior, R. P., Gouveia Filho, M. D., & Deus, Ê. P. D. (2015). Análise do envilecimiento do polietileno de media densidad por monitor amento de propriedades mecánicas.

[15] La espectroscopia molecular en la caracterización del PVC, recuperado de: https://steemit.com/stem.../la-espectropia-molecularen-la-caracterizacion-del-pvc

[16] Aldás, M., & Inca, F. (2015, June). Reciclaje de PVC a partir de tarjetas de identificación plásticas para la obtención de un pegamento de tubería. In Congreso de Ciencia y Tecnología ESPE (Vol. 10, No. 1, pp. 176-181).

[17] Blazevska-Gilev, J., & Spaseska, D. (2007). Reciclaje químico de poli (cloruro de vinilo): decloración alcalina en disolventes orgánicos y lixiviación de plastificantes en solución cáustica. Revista de la Universidad de Tecnología Química y Metalurgia, 42(1), 29-34.

[18] González Horrillo, N. (2005). Espectroscopia InfrarroPa de Transformada de Fourier (FTIR) en el estudio de Sistemas Basados en PVC. San Sebastián, España: Universidad del país vasco

[19] Blanco Álvarez, F. (2016). Propiedades Mecánicas, Rotura. Recuperado de: http://www6uniovi.es/usr/fblanco/TemaII.2.7.PROPIEDADESMECANICAS.pdf.p28

[20] Presión de Aire en las Llantas | Goodyear

[21] Inca, F., Quiroz, F. y Aldaz, M. (2016). Recuperación de Policloruro de Vinilo (PVC) obtención de materiales plásticos.

[22] Revista Politécnica - marzo 2016, Vol 37, N°2 Maradei Garcia, M. F., Valencia Otero, A. F., & Espinel Correal, F. M. (2016). Estudio sobre la influencia del diámetro de apertura en la fuerza ejercida por cada dedo. Revista de Salud Pública.

[23] González Osorio, B. B., Barragán Monrroy, R., Simba Ochoa, L., & Rivero Herrada, M. (2020). Influencia de las variables climáticas en el rendimiento de cultivos transitorios en la provincia Los Ríos, Ecuador. *Centro Agrícola*, *47*(4), 54-64.