REDUCING CARBON EMISSIONS AND ELECTRICITY CONSUMPTION IN SET UP USING DROP-IN PLASTIC IN COMMERCIAL VEHICLE TANKS

REDUÇÃO DE EMISSÕES DE CARBONO E DE CONSUMO DE ENERGIA ELÉTRICA EM SET UP, UTILIZANDO PLÁSTICO DROP IN EM TANQUES DE VEÍCULOS COMERCIAIS

REDUCIR LAS EMISIONES DE CARBONO Y EL CONSUMO DE ELECTRICIDAD EN LAS INSTALACIONES QUE UTILIZAN PLÁSTICOS DROP-IN EN LOS DEPÓSITOS DE LOS VEHÍCULOS COMERCIALES

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Melissa Marcílio Batista[1] and Annibal Gouvêa Franco[2].

ABSTRACT
The increased demand for the production of components following global premises, such as Environmental, Social and Corporate Governance (ESG), reducing Greenhouse Gas (GHG) emissions in the process of producing raw materials and in the process of producing components, must be implemented in accordance with the United Nations Conference on Climate Change held in 2021 and ratified in 2024. The ESG agenda is used to minimize the environmental impact of business in order to build a better world with responsibility around the management process, investments and sustainability criteria. With this motivation, this research presents the use of green high-density polyethylene (Green HDPE) for use in the production of ARLA 32 and fuel tanks, as a replacement material for fossil-based high-density polyethylene (HDPE). The biomass used as a biological base for the production of Green HDPE is sugar cane leaves and/or stalks. Although the polymers have similar characteristics, some of their properties differ and, as a result, some of the equipment parameters need to be modified so that the component maintains the same geometry, thickness and appearance characteristics as the original. To this end, a series of analyses and tests were carried out to adjust the parameters of the extrusion and blow molding process and ensure viability in the desired application. The extrusion blow molding machine has electrical resistors used during production, so that the process maintains the correct temperature throughout the production process. When comparing the two materials, the main aspects of rheometry such as shear stress and shear rate result in a different flow speed within the machine's extrusion process, especially as the Fluidity Index (FI) is totally different and has a great influence on the process and the visual characteristic of the product. The manufacturer carries out its set-up process four times a week, which represents 72 hours per week, and the total set-up time is 3744 hours per year. To validate

[1] Technologist in Management Processes from the University of Santa Cecilia and academic of the specialization in Anthropology at Iguaçu College (FI).
Email: m.lissa.marcilio@gmail.com
ORCID: https://orcid.org/0009-0008-3556-8479
LATTES: http://lattes.cnpq.br/9733995262422995
[2] Master in Design from the State University of Minas Gerais (UEMG) and academic specialization in Anthropology at Iguaçu College FI).
Email: francoartedesign@gmail.com
ORCID: https://orcid.org/0009-0006-9134-300X
LATTES: http://lattes.cnpq.br/1388138609353813

the Green HDPE tanks, before they are mounted on vehicles, they are required to pass a battery of mechanical tests/trials, following international, Brazilian and internal company standards, such as pressure, impact, sledding and flammability. The results must be approved before Green HDPE can be used as a raw material. The proposed material could reduce around 180,000 tons of CO_2/year in the Latin American market, considering only commercial vehicle tanks (fuel and ARLA 32). The proposal also helps to increase the use of this material for reprocessing, thus increasing the circular economy process. Fuel and ARLA 32 tanks made from Green HDPE, after passing the functional tests described in the standards for development and validation tests, must also pass durability tests, which represent the product's application from the end user's point of view. Green HDPE is an existing material used in applications that do not receive mechanical stress, such as shampoo bottles and cleaning products. Polymers are usually commodities and produced by a company that owns the patent. The volume required to produce a given raw material is directly linked to its value. Therefore, the larger the scale of production, the better the final cost of the Green HDPE product. Replacing the fossil-based material with the renewable-based material reduces the carbon footprint of the proposed material, reduces electricity consumption in the machine set and increases productivity, which can offset the cost of the part. The configuration of carbon credits needs to be evaluated, as well as the relationship between the commercialization of these credits or tax benefits resulting from the reduction of carbon emissions in the atmosphere promoted by the proposed material.

Keywords: Green HDPE. ARLA 32 tank. Productivity. Electricity. Circular Economy.

RESUMO

O aumento da demanda para a produção de componentes seguindo premissas globais, como Governança Ambiental, Social e Corporativa (ESG), reduzindo as emissões de Gases de Efeito Estufa (GEE) no processo de produção de matérias-primas e no processo de produção de componentes, deve ser implementado de acordo com a Conferência das Nações Unidas sobre Mudanças Climáticas realizada em 2021 e ratificada em 2024. A agenda ESG é usada para minimizar o impacto ambiental dos negócios, a fim de construir um mundo melhor com responsabilidade em torno do processo de administração, investimentos e critérios de sustentabilidade. Com essa motivação, a presente pesquisa apresenta o uso do polietileno de alta densidade verde (HDPE Verde) para uso na produção de tanques de ARLA 32 e combustível, como um material de substituição do polietileno de alta densidade (HDPE) de base fóssil. A biomassa usada como base biológica para a produção de HDPE Verde, são as folhas e/ou o caule da cana-de-açúcar. Os polímeros, apesar de possuírem caraterísticas similares, algumas propriedades se distinguem e com isso, alguns parâmetros do equipamento precisam ser modificados, de maneira que o componente mantenha a mesma geometria e característica de espessura e aparência do original. Para tento, foi realizado uma série de análises e testes para ajustar os parâmetros do processo de moldagem por extrusão e sopro e garantir a viabilidade na aplicação desejada. A máquina de moldagem por extrusão e sopro possui resistências elétricas usadas durante a produção, para que o processo mantenha a temperatura correta durante todo o processo de produção. Ao comparar os dois materiais, os principais aspectos da reometria como tensão de cisalhamento e taxa de cisalhamento resultam em uma velocidade de fluxo distinta dentro do processo de extrusão da máquina, especialmente devido ao Índice de Fluidez (IF) ser totalmente distinto e que possui, grande influência no processo e na característica visual do produto. O fabricante realiza o seu processo de set up quatro vezes por semana, o que representa 72 horas por semana, e o tempo total de set up é de 3744 horas por ano. Para validar os tanques em HDPE Verde, antes de serem montados em veículos, eles são obrigados a passar por uma bateria de testes/ensaios mecânicos, seguindo normas internacionais, brasileiras e internas das empresas, tais como pressão, impacto, trenó e flamabilidade. Os resultados precisam estar aprovados, de maneira obrigatória para que a matéria prima HDPE Verde possa vir a ser utilizado como matéria-prima. O material proposto, pode reduzir cerca de 180 mil toneladas de CO2/ano no mercado latino-americano, considerando apenas os tanques de veículos comerciais (combustível e ARLA 32). A proposta também auxilia no aumento do uso desse material para reprocessamento, trazendo o incremento no processo de economia circular. Os tanques de combustível e de ARLA 32 produzidos com HDPE Verde, após aprovação nos estes funcionais descritos nas normas para os testes de desenvolvimento e validação, precisam também ser aprovado nos testes de durabilidade, que representam a aplicação do produto sob a ótica do usuário final. O HDPE Verde, é um material existente e utilizado em aplicações que não recebem esforços mecânicos, como frascos de shampoo e produtos de limpeza. Os polímeros são normalmente são comodities e produzidos por empresa que possui a patente. O volume necessário para produção de uma determinada matéria prima, está diretamente ligada ao seu valor. Dessa forma, quanto maior a produção em escala, melhor o custo final do produto com HDPE Verde. A substituição o material de base fóssil para o material de base renovável promove a redução e emissão e carbono ligada ao material proposto, a redução do consumo de energia elétrica em set upo de máquina e reflete no aumento da produtividade, que pode vir a trazer o offset do custo da peça. Precisa ser avaliado a configuração de crédito de carbono e a relação para comercialização desse crédito ou benefícios fiscais decorrente da redução da emissão de carbono na atmosfera, promovido pelo material proposto.

Palavras-chave: HDPE Verde. Tanque de ARLA 32. Produtividade. Energia Elétrica. Economia Circular.

RESUMEN

El aumento de la demanda de producción de componentes siguiendo premisas globales como la Gobernanza Ambiental, Social y Corporativa (ESG), reduciendo las emisiones de gases de efecto invernadero (GEI) en el proceso de producción de materias primas y en el proceso de producción de componentes, debe ser implementado de acuerdo con la Conferencia de las Naciones Unidas sobre el Cambio Climático celebrada en 2021 y ratificada en 2024. La agenda ESG se utiliza para minimizar el impacto ambiental de las empresas con el fin de construir un mundo mejor con responsabilidad en torno al proceso de gestión, las inversiones y los criterios de sostenibilidad. Con esta motivación, esta investigación presenta el uso de polietileno verde de alta densidad (Green HDPE) para su uso en la producción de ARLA 32 y tanques de combustible, como material sustitutivo del polietileno de alta densidad (HDPE) de origen fósil. La biomasa utilizada como base biológica para la producción de HDPE Verde son hojas y/o tallos de caña de azúcar. Aunque los polímeros tienen características similares, algunas de sus propiedades difieren y, en consecuencia, es necesario modificar algunos de los parámetros del equipo para que el componente conserve las mismas características de geometría, espesor y aspecto que el original. Con este fin, se llevaron a cabo una serie de análisis y pruebas para ajustar los parámetros del proceso de extrusión y soplado y garantizar la viabilidad en la aplicación deseada. La máquina de extrusión-soplado dispone de resistencias eléctricas que se utilizan durante la producción para que el proceso mantenga la temperatura correcta durante todo el proceso de producción. Al comparar los dos materiales, los principales aspectos de la reometría, como el esfuerzo cortante y la velocidad de cizallamiento, dan como resultado una velocidad de flujo diferente dentro del proceso de extrusión de la máquina, sobre todo porque el índice de fluidez (FI) es totalmente diferente y tiene una gran influencia en el proceso y en la característica visual del producto. El fabricante lleva a cabo su proceso de puesta a punto cuatro veces por semana, lo que representa 72 horas semanales, y el tiempo total de puesta a punto es de 3744 horas al año. Para validar los tanques de PEAD Verde, antes de ser montados en los vehículos, es necesario que superen una batería de pruebas/ensayos mecánicos, siguiendo normas internacionales, brasileñas e internas de la empresa, como presión, impacto, trineo e inflamabilidad. Los resultados deben ser aprobados antes de que el HDPE Verde pueda ser utilizado como materia prima. El material propuesto podría reducir cerca de 180.000 toneladas de CO_2/año en el mercado latinoamericano, considerando solamente los tanques de vehículos comerciales (combustible y ARLA 32). La propuesta también ayuda a aumentar el uso de este material para el reprocesamiento, aumentando así el proceso de economía circular. Los depósitos de combustible y ARLA 32 fabricados con HDPE Verde, tras superar las pruebas funcionales descritas en las normas para las pruebas de desarrollo y validación, deben superar también las pruebas de durabilidad, que representan la aplicación del producto desde el punto de vista del usuario final. El HDPE ecológico es un material existente que se utiliza en aplicaciones que no reciben estrés mecánico, como botellas de champú y productos de limpieza. Los polímeros suelen ser materias primas y los produce una empresa propietaria de la patente. El volumen necesario para producir una determinada materia prima está directamente relacionado con su valor. Por lo tanto, cuanto mayor sea la escala de producción, mejor será el coste final del producto de HDPE ecológico. La sustitución de material de origen fósil por material de origen renovable reduce la huella de carbono del material propuesto, reduce el consumo de electricidad en la puesta a punto de la máquina y aumenta la productividad, lo que puede compensar el coste de la pieza. Es necesario evaluar la configuración de los créditos de carbono y la relación para comercializar estos créditos o los beneficios fiscales derivados de la reducción de emisiones de carbono a la atmósfera promovida por el material propuesto.

Palabras clave: HDPE verde. Depósito ARLA 32. Productividad. Electricidad. Economía circular.

APPLICABILITY

All ARLA 32 and fuel tanks produced by the blow extrusion process can use this raw material, without the need to change the molds or equipment. Obviously, the process parameters need to be modified to meet the characteristics of the GPE, in order to maintain the same conditions of thickness and appearance of the model produced with material from fossil sources.

OBJECTIVE

The objective of the present work is to address the effects and environmental implications caused by the use of Green HDPE in ARLA 32 tanks, as well as to show the gain in the reduction and use of electrical energy during the mechanical extrusion-blow molding process and also to mention the tests used to validate the use of these tanks as a high reliability component.

The main effects are:

- **Reduction of CO2 emissions using raw material from renewable sources;**
- **Reduce the cost of electricity in the production set-up, due to the characteristics of Green HDPE;**
- **To increase the productivity of ARLA 32 tanks, as a result of the rheometric and mechanical properties and the IF of Green HDPE.**

INTRODUCTION

With studies on the effects caused by greenhouse gases (GHG) on the environment, new topics are being put on the agenda globally, aiming at the concern with the future of the planet and how to mitigate GHG emissions and the environmental impacts generated. Through these premises, new policies and trends fall on the means of production and consumer goods.

In this context, the automotive sector receives high demand for components produced in HDPE and the development of biomass-based materials emerges as a possibility to add value in the development and responsible use of natural resources by companies, reducing the carbon footprint and increasing the circular economy. In this context, polymeric materials in general emerge as a great possibility, mainly due to the opportunity to replace the use of petroleum by new sources of raw materials of renewable origin for production.

In addition, this development has ample conditions to influence the improvement of production, in terms of efficiency, and the reduction of energy consumption in the production process, since new materials are introduced along with new projects and new alternatives for production.

PREPARATION OF THE TECHNICAL WORK

INITIATIVES TO MITIGATE GLOBAL WARMING

The concern with responsible development deals with three different dimensions, namely: Environmental, social and economic. With this, the highlight is on the ESG agenda that encompasses these three parts and proposes guidelines for sustainable development. The acronym ESG comes from the English "environmental, social and governance", and refers to the three dimensions mentioned above, but focused on providing a path for organizations and leading to the sustainable development of environmental, social and governance practices of companies [1].

Recently, it has gained greater visibility and adherence, based on a growing concern in the financial market with sustainability, being considered one of the main guidelines today. In 2020, ESG funds raised billionaire investments, causing pressure on the business sector [1].

In Europe there are already definitions established by the European Commission (EC) [2] in order to force investment and the development of new sustainable technologies in industry, through the "European Green Deal" [3] which aims to modernize Europe with efficient use of resources, competitive economy and reduction of greenhouse gas emissions to practically "zero" by 2050, without losing economic strength and concern for the quality of life of its inhabitants [4].

The UN also has definitions, agreements and goals that have been elaborated by nations from all over the planet at international conferences. - The objective is to generate global engagement to recognize the emergency of the problem, accelerate actions and meet the goals established in the Paris agreement [5].

At COP26, one of the most recent UN conferences, these goals were focused on reducing environmental impacts through the conscious extraction of natural resources, replacement of fossil-based raw materials with raw materials from renewable sources, and increasing efficiency in energy matrices. For the automotive industry, this means developing methods/models for decarbonizing production chains and producing vehicles with residual or zero impact on emissions by 2040 [6].

These discussions are mainly based on the reduction in gas emissions in order to follow the warning of the "Intergovernmental Panel on Climate Change" (IPCC) [7]. The alert advises keeping the planet's temperature limited to 1.5º C, comprising the period of the first industrial revolution until 2030. For the goal to be achieved, there are initiatives that are within the agenda of Environmental, Social and Corporate Governance (ESG) responsibilities [8] of each company, and for each institution to do its part, goals based on climate science (SBTi) [9] are being created supported by the Global Compact network in Brazil [4] [10].

IMPLICATIONS FOR THE USE OF GREEN HDPE

The initiatives directly affect the way companies think and the direction of this survey, which are the commercial vehicle manufacturers. The focus becomes the reduction in the environmental impact left by the entire production chain until the production of the final product, this includes the way energy is produced and used, how the materials of the components are extracted, how the manufacturing process and conformation of the components is done, as well as the realization of recycling, reuse or disposal.

In this new environment, the bioeconomy and the circular economy play a fundamental role in changing the production value chain. Some authors already defend the existence of the circular bioeconomy, where material of renewable or biodegradable origin is treated to generate value throughout its life cycle [11].

Within this context, the number of applicable studies and solutions has been growing [12]. Among them are the "Drop in" compounds, which is nothing more than the development of a source of renewable origin in order to replace an existing compound, but derived from petroleum [13]. As in the case of high-density polyethylene (HDPE), for example, HDPE is derived from petroleum, but a production process using sugarcane as raw material has already been identified in the market, and the result is the same HDPE, but from a renewable source, which earns it the name Green HDPE [14].

HIGH DENSITY POLYETHYLENE

Polyethylene is a polymer widely used in industries due to its non-toxicity and inertness against various chemicals. It is obtained mainly by the polymerization of ethylene by addition, derived from fossil sources [17], through the cracking of naphtha from petroleum refining. Ethylene goes through the purification stage, where it is transformed into polyethylene [18]. Figure 1 represents a polyethylene monomer.

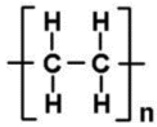


Fig. 1. Polyethylene Monomer [17].

Figure 2 below shows the processing flow of fossil-based polyethylene.

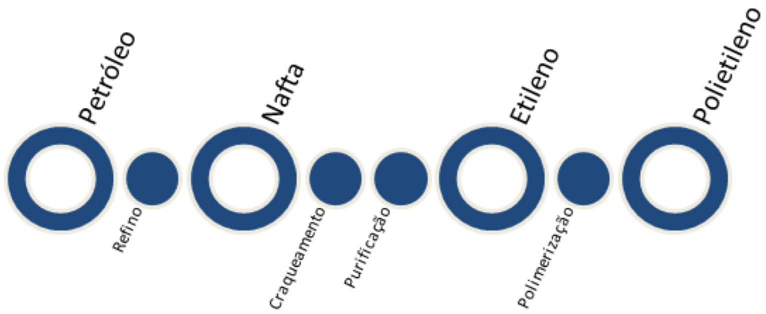


Fig. 2. Stages of the Polyethylene manufacturing process.

According to the boundary conditions defined in polymerization, some types of polyethylene can be produced, namely: Low-density polyethylene (LDPE or LDPE); High-density polyethylene (HDPE or HDPE); Linear low-density polyethylene (LLDPE or LLDPE); Ultra high molecular weight polyethylene (UHMWPE or UHMWPE); Ultra low density polyethylene (PEUBD or ULDPE) [19].

When referring to Polyethylene and High Density, it can be classified as a thermoplastic polymer with a highly crystalline structure with values of up to 90% and low branching content, as seen in figure 3, where the formations of branched chains in different types of Polyethylene are compared. The linearity of the chains makes packaging more efficient, generating more intense intermolecular forces [20].

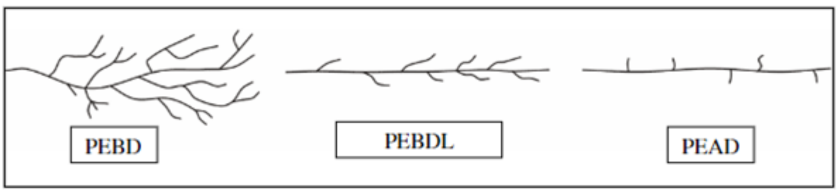


Fig. 3. Different types of Polyethylene and their ramifications [20] [19].

GREEN HIGH-DENSITY POLYETHYLENE

Green High Density Polyethylene (Green HDPE) can be classified as green plastic, green polymer, biopolymer and is the first plastic in the world to be certified that it is obtained from a renewable source. The production of green polyethylene occurs from ethylene obtained through ethanol dehydration [4]. Green HDPE has a Drop in characteristic, that is, it is a material equivalent to the fossil, with similar properties, changing only its source, as shown in figure 4. Therefore, it can be applied for the same purposes as petrochemical resins [19][21].

The great advantage of this green polymer is that it does not require investments in machinery or major changes in the forming process, in addition to having a competitive production cost in the world scenario, which is a very important aspect for industrial use [22].

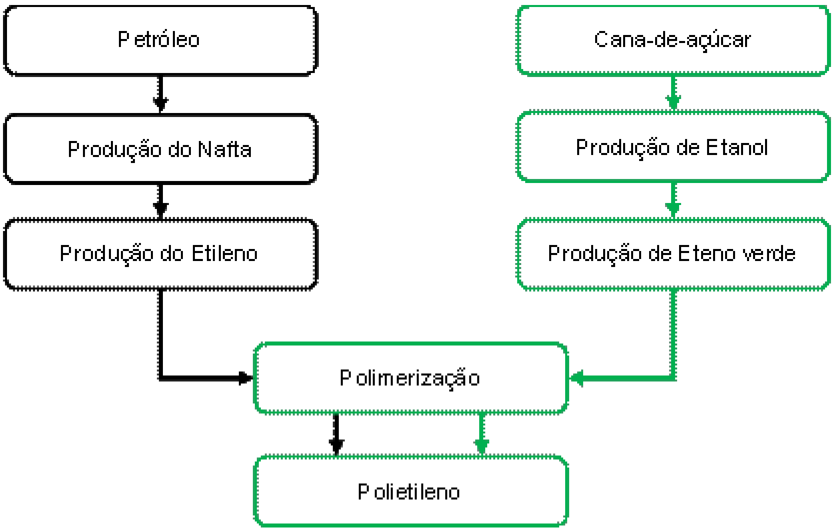


Fig. 4. Comparison between the fossil and green matter of Polyethylene.

It is important to note that in the design of the ARLA 32 tanks, the HDPE originally used does not have the same grade as the proposed Green HDPE, due to this, it is worth noting that, despite the similarities in material, there are some differences in properties. This ended up generating a positive impact on the production process, as will be detailed later in this work. In order to facilitate understanding, the fossil HDPE used will be referred to as the original HDPE and the new HDPE as Green HDPE. See Table 1.

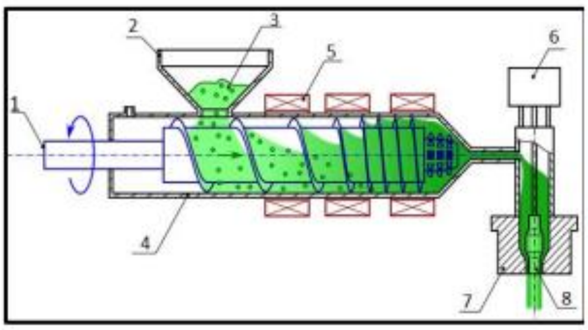
Teste	PEAD HS4506A	PEAD SGF4950 (Verde)
Índice de fluidez (190 ºC / 21,6 Kg) [g/10min]	5	28
Densidade [g/m^3]	0,945	0,956
Tensão de escoamento [MPa]	24	28
Tensão de ruptura [MPa]	38	31
Módulo de flexão Secante a 1% [MPa]	930	1060
Dureza (Shore D)	63	63
Resistência ao impacto [J/m]	700	145
Temperatura de Amolecimento Vicat [ºC]	125	129
Temperatura de Deflexão Térmica (0,455 MPa) [ºC]	62	75
Teor mínimo de C14 [%]	-	96

Table 1: Comparison between HDPE blends

EXTRUSION-BLOW FORMING PROCESS

The blow molding (extrusion) blow molding process, also known as EBM, occurs with the use of an extruder machine shown in figure 5, where the most important components of the equipment are highlighted, as well as the nomenclature of each one, commonly used in the industry.

First, the granulated polymer, also called pelletized, is inserted into the hopper or supply hopper, and by gravity reaches the cylinder with the extruder screw. During its passage through the cylinder, the material undergoes shear, due to the rotation of the screw, causing it to heat up, which must reach its melting point so that there is greater fluidity during the process. This step of the process is closely linked to the Melt Flow Index (IF) of the material. When this shear force generated by the screw is not sufficient to achieve the melting and homogenization of the material, the electrical resistors are turned on in order to heat it. With the resistors on, the material goes through three stages of heating, ensuring its plasticization (melting/homogenization) and allowing its flow [24], [25].



1. Parafuso de extrusão
2. Tremonha
3. Matéria-Prima
4. Cilindro
5. Resistências de aquecimento
6. Afinador de peso
7. Fieira
8. Núcleo

Fig. 5. Process and nomenclature of extrusion-blowing equipment [25].

The molten material is transported by the extrusion screw or screw to the mold, where it is poured. Inside the mold, there is a displacement to the blowing zones, where the components called calibrators inflate the material so that it gains the geometry of the mold. After cooling, the product is removed from the mold and the final finishing processes are carried out. The part of the process related to blowing can, in a simplistic way, be compared to a balloon, which when inflated and restricted by a certain geometry, a mold, acquires the shape of that same geometry [25].

Bearing in mind this principle, the process of forming an object by extrusion blowing begins with the formation of a sleeve, usually called Parison. The sleeve is inserted into the mould, usually composed of two halves, and blown in such a way that the sleeve, now stretched, contacts the cold walls of the mould and acquires the desired shape. Once cooled, the newly formed object is removed from the mold, however, it is necessary to remove the excess material from the molding process until the final product is obtained [25]. The process can be observed in sequence according to Figure 6.

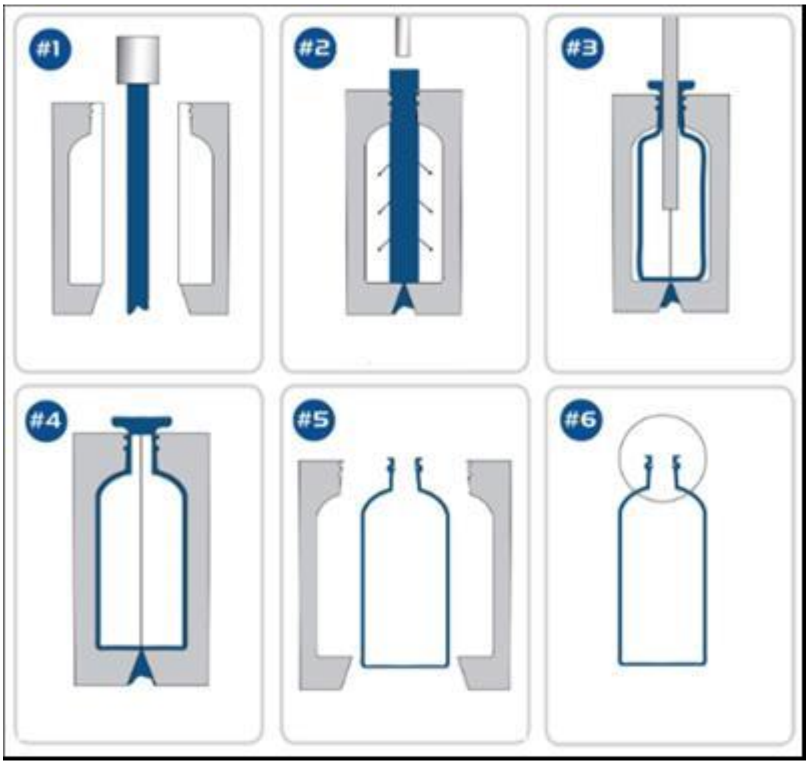


Fig. 6. Blowing Process [25].

MANUFACTURING PROCESS OF ARLA 32 TANKS AND FUEL

As it is a synthetically produced plastic, polyethylene goes through a series of processes before acquiring its final raw material format, as described in the previous chapters. At this stage of the process, the manufacturer uses petroleum or sugarcane as a base and obtains granulated or pelletized plastic as a product, which is transported to the tank processor, so that it can be formed. Regardless of the choice, the equipment used, the production process is basically the same, that is, extrusion-blowing. Figure 7 shows a piece of equipment currently used in the production of ARLA 32 tanks.

Fig. 7. Extrusion-blowing equipment.

In this process, the raw material will be transformed into a usable component, adding value to the product. High Density Polyethylene arrives in granulated form and is mixed with carbon black (NF) with percentages that can vary between 1.5 and 2%, before being taken to the extruder. The use of NF provides the most economically efficient means to achieve the required level of protection of polyethylene against weathering linked to ultraviolet rays (UV), necessary without compromising the final performance requirements and helps to improve the mechanical properties of the final product.

In the processor, some details of the parameterization of the equipment are adjusted to carry out the Set up of the extrusion-blow molding machine. This type of more detailed adjustment varies according to the type of HDPE used. It is at this moment that the differences come to the fore. During the passage through the cylinder, the Green HDPE is able to reach the ideal temperature and flow through the equipment without the need to activate the electrical resistances. In this case, electrical resistances are necessary during the post-Set up production process.

Due to this, the study of the mass flow inside the extruder machine is carried out, which has a high dependence on the flow rate of the material to avoid cracks of the screw/crushing thread, and the resistors must be used to obtain the necessary temperature to process and support the parison, before closing the tooling and blowing, under controlled pressure, the dough to copy the mold. With this, a new Set up configuration is defined.

Set up is the set of settings applied to the process through the adjustment of the equipment, modifying the control parameters, such as blowing time, cooling time, extrusion speed, mold closing time, mold opening time, among other variables that need to be changed, using the Green HDPE to remove the first approved part so that production can be released.

REDUCTION OF ELECTRICITY CONSUMPTION THROUGH THE USE OF GREEN HDPE IN THE PROCESS

In the development of this Green HDPE applied to ARLA 32 tanks, it was identified that, during the extrusion-blowing process of the tanks, the ideal operating temperature of the machine in Set up was reached without the need to turn on the equipment's electrical resistances, which saves a significant amount of energy required in the process during this procedure.

The application of this idea in a large-scale production of ARLA 32 and Fuel tanks, where approximately 130,000 ARLA 32 tanks are produced per year, the result would be a reduction in energy consumption for the manufacture of this component, therefore, a benefit in the energy efficiency promoted by the raw material in the manufacturing process.

Taking into account the data of energy consumption, set up time, number of set up per week and the number of machines, it is possible to find the number of hours used for set up in the year and later the amount of energy spent in the year. Table 2 below shows these data for fossil-based HDPE production.

Dados	Valores
Gasto energético/máquina (kW/h)	130
Tempo de Set up (h)	3
Quantidade de Setup semana (para 1 máquina)	4
Quantidade de máquinas	6

Table 2: Values used in the calculation of electricity

Applying simple calculations, according to equation 1, with the data in table 2, the total Set up time per week was first calculated in hours, as: Set up time (h) x Quantity of Setup per week (for 1 machine) x Number of machines.

$$P = \frac{E}{\Delta t} \qquad \text{Equação 1}$$

P ➔ Electric Power [kW]

E ➔ Energy measured in kilowatt per hour [kWh]

Δt ➔ Change in time, measured in hours [h]

Taking into account that the year has 52 weeks, the number of hours spent in Set up per year was calculated. Multiplying this value by the energy expenditure/machine (kW/h), the total electricity expenditure per year is obtained, only during the set-up process.

Calculos	Valores
Total de set up por semana (h)	72
Semanas trabalhadas no Ano	52
Quantidade de Setup ano (h)	3.744
Energia elétrica consumida/Ano em Set Up (kW)	486.720

Table 3: Electricity consumed per year

In this way, to produce the same product with Green HDPE, electricity consumption is reduced by about 20%, according to data from the ARLA 32 tank manufacturer itself. Therefore, if we consider all the production of ARLA 32 tanks and fossil HDPE fuel carried out by this plant being replaced by Green HDPE, about 97,344 kW of electricity would be saved per year.

Bringing it to the economic sphere, the annual cost reduction was calculated. Taking into account an average energy cost of R$ 0.50 per kW/h, there is an annual cost reduction of R$ 48,672.00. Obviously, this bill will vary depending on the location of the plant, due to differences in tariffs.

In Brazil there are at least four more large companies producing HDPE tanks, which have a production volume similar to that described above, if included in the account, the annual cost reduction would be approximately R$ 243,360.00/company. In terms of volume, this account is associated with an estimated production of 7000 tons of raw material per year.

Regarding the blow extrusion process, the parameters were changed to meet the new configuration, demanded by the raw material. Figure 8 shows the blowing equipment and the forming of the sleeve before it is inserted and blown into the one mold.

Fig. 8. Formation of the preform or Parison.

BIOECONOMY

The concept has been widely discussed by the community due to the current context. The European Commission, for example, has defined the bioeconomy as the use of renewable biological resources existing on planet earth for the production of food, materials or energy [26]. Some authors complete the definition by inserting the bioeconomy as the commitment to development to improve a series of factors, such as chemical compounds, construction materials, use of biomass replacing fossil sources for energy generation, manufacture of fuels and polymers [11][23].

Bioeconomy has different visions and in general aims at economic growth, the creation of new jobs, environmental sustainability, ecological processes that improve energy use, favor biodiversity and reduce the degradation of the planet as a whole, through the development of new technologies and methods of using biomass. Biomass is an extremely rich source of energy and the raw material, if worked consciously, will be perpetuated as being renewable [23].

The bioeconomy inserted in the supply chain for automotive components shows a picture where other raw materials, now from renewable sources, are integrated into the production processes of parts and, depending on the case, it is even possible to use the same equipment already used for materials from non-renewable sources, as is the case of the Drop in application [12]. One or both requirements must be met for a material to be considered a renewable source, which can be renewable and/or biodegradable [27].

Simplified, the concept of Drop in means the production of an equivalent green material, through the use of a renewable source. In this process, the equivalent material reaches the same final compound and acquires the same and/or similar properties to the original, and may even share part of the production chain. Generally the term is used in relation to commodity chemicals and polymers with large production volumes. Drop-in chemicals are easy to implement technically as existing infrastructure can be used. Examples: Methane (extracted from biomass), ethylene/PE/PET, propylene/PP and bionaphtha, all of which can be extracted from alternative renewable sources [13]. Figure 9 below exemplifies the concept.

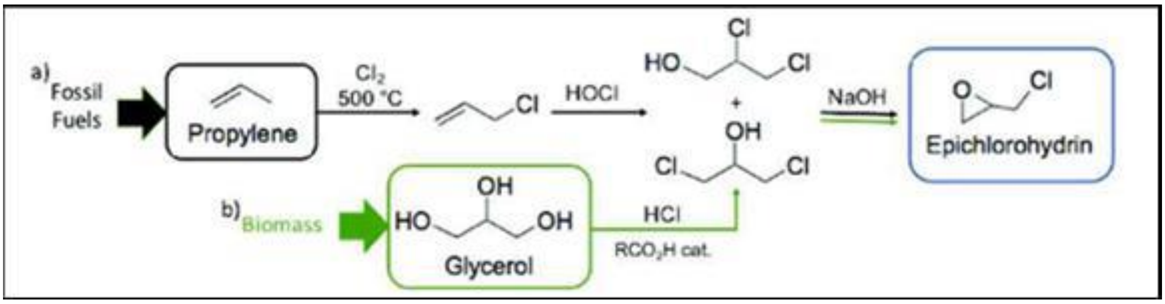


Fig. 9 Drop in material concept [11].

Dealing with the bioeconomy in Brazil, several competitive advantages can be highlighted, giving the country a great opportunity to be one of the protagonists in the segment. Among the positive points, we can mention:

i. Have enormous biodiversity;
ii. Low cost in the production of biomass, especially sugarcane;
iii. Possess advanced tropical agriculture, based on the application of science and technology. In addition, the territory has vast space for the implementation of agricultural crops [28].

In addition to replacing the use of a finite source of resources that is oil, the use of Green HDPE reduces the carbon footprint left in the environment. In the case of the ARLA 32 Green HDPE tank, the calculation of the carbon footprint during its manufacturing process takes into account that during the planting and growth of sugarcane, there is removal of CO2 from the environment, causing its use to reverse the current scenario of fossil origin and, in this way, the production chain, as a whole, starts to remove CO2 from the environment instead of emitting it. As shown in figure 10.

Fig. 10. Reduction of CO2 emissions per ton of green PE produced [14].

The production process of fossil-based polyethylene emits 2.1 tons of CO2 per ton produced, while green polyethylene removes 2.5 tons of CO2 per ton from the environment, thanks to the planting of sugarcane, eliminating a delta of 4.6 tons of CO2 from the atmosphere per ton produced [14], [23]. With this, the application of green polyethylene can be evaluated as something possible and with great positive impacts for the sector.

Framing this project in the concept of circular bioeconomy, we see an excellent contribution to the environment, in addition to the demonstration of how research and tests can reach a technology capable of using biomass in commercial vehicles with a product that reduces CO2 emissions in its production chain and at the end of its life cycle is 100% recyclable, contributing to the environment for the reduction of garbage and waste. Figure 11 shows the image of ARLA 32 tanks produced.

In all, the application of green polyethylene in ARLA 32 tanks and fuel in commercial vehicles can lead to a reduction of up to 180,000 tons of CO2 per year in the South American market.

Fig. 11. Newly produced ARLA 32 tanks.

VALIDATION TESTS

After adjusting the blow extrusion equipment and obtaining tanks with the acceptable dimension, controlled tests were carried out, according to the standard, to validate its use. The tank in question is used for extra heavy vehicles and has a capacity of 100L. The automaker uses three main tests (figure 12) to ensure the application of the tanks, they are:

- Sled test, according to internal standards;
- Resistance Test under internal pressure, according to NBR 11474;
- Pendulum-type impact resistance test according to NBR-11473;

Fig. 12. Validation tests required for Arla tank validation

In addition, to support the validation in Diesel fuel tanks, the flammability test was carried out according to the NBR 11478 standard. The figure shows some test images.

Fig. 13. Additional test required for the fuel tank.

The rigor of the tests means that the history of field failures for ARLA 32 tanks that passed the tests is considered zero, since no tank breakage was detected without direct external action, such as vehicular collision, for example. Therefore, the approval represents enough confidence to mount the component in a production vehicle.

Despite the differences between HDPE and Green HDPE, it has passed all tests, showing that it is possible and reliable to use it in vehicles.

Vehicles with full vehicle durability were carried out for the following conditions:

- City Cycle
- Structural Testing
- Road Cycle

As the vehicles accumulated mileage, scheduled stops were carried out in which inspections take place on the ARLA 32 tank, in order to ensure that there is no defect in the part. Currently, all vehicles and production are being produced with the Green HDPE blend in tanks with volumes of 100 liters and 60 liters.

Fig. 14. ARLA 32 tank of HDPE Green.

Vehicle tests were carried out to certify the representativeness of the ARLA 32 tank life in Green HDPE in the most critical conditions. Figure 15 shows the test configurations performed, as well as the mileages and test cycles performed.

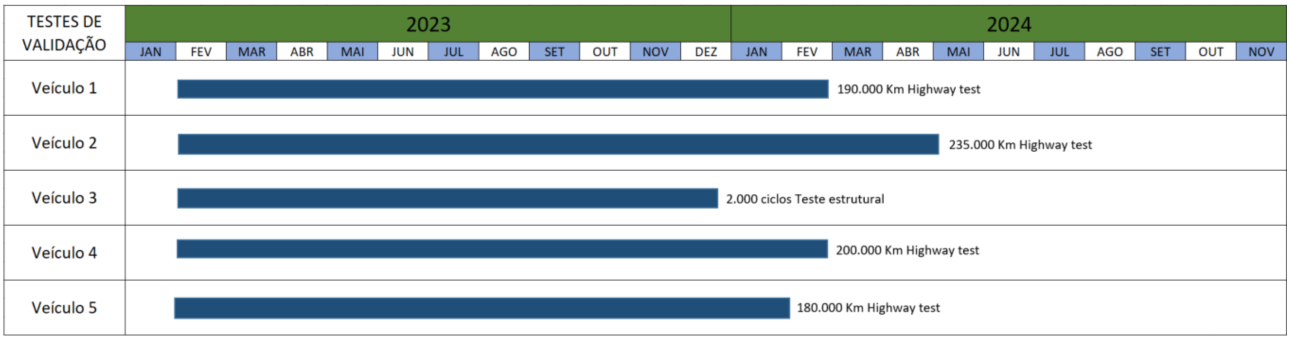


Fig. 15. Schedule of tests carried out for product validation.

CONCLUSIONS

- Green HDPE brought some interesting results during the production process post Set up.
- The IF of Green HDPE generated the need for changes in the process parameters of the extrusion blow molding equipment and consequently brought an increase in productivity, increasing by 3 more pieces per hour.
- The decision to carry out the flammability test, which was initially unplanned, was made after the results obtained in the impact and sled tests, which promoted confidence in verifying how the material would behave as a fuel tank. The result of this test brought another product configuration that, at first, was not being considered. The mass volume of fuel tanks with Green HDPE for the automaker with the highest volume in the market, promotes a reduction in CO_2 emissions of around 2300 tons/year, due to the raw material alone.

- The reduction in electrical power was a big surprise observed during the set up of the equipment to produce parts for validation testing. From the initial moment until the start of production, the electrical resistances were not activated and this was repeated in the following days, where the process was repeated and thus confirming that it did not need to be activated.
- The productivity per hour has also changed, with an increase of 3 more pieces.
- The configuration of increased productivity and reduction of electricity consumption during the Set up, lead to assist in the offset of the current price of Green HDPE,

which is still on a pilot scale. As soon as production becomes a large-scale condition, costs should become more attractive.

- The automaker that supported the tests implemented the ARLA 32 Green tank in its production at the end of 2023, due to the carbon footprint, the established sustainability goals, and the circular economy that this material promotes, increasing the percentage of reuse of process shavings.

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