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STUDY OF THE INFLUENCE OF PROCESSING PARAMETERS ON THE MECHANICAL PROPERTIES OF POLYAMIDE 66 AND GLASS FIBER COMPOSITES OBTAINED BY THE INJECTION MOLDING PROCESS.

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Abstract. *Sustainability stands as one of the driving forces of today's industry. When it comes to component manufacturing, considerations extend beyond costs, production impacts and disposal processes. One strategy is replacing traditional metals with lightweight composites, via methods such as injection molding. This study evaluated the influence of processing parameters on Polyamide 66 components, especially on microstructure and mechanical properties. The study investigated polyamide composites with varying glass fiber contents by weight (30%, 35% and 50%), injection pressure (1000, 1500 and 2000 bar), temperature (320, 330 and 340°C) and speed (100, 125 and 150 mm/s). Through Taguchi Method, the number of possible combinations were reduced from 3^4 to 9. Archimedes' density measurement characterized the injected components density and presence of voids, and SEM analysis evaluated the fiber-matrix adhesion. Tensile tests and dynamic mechanical analysis (DMA) evaluated the mechanical and thermomechanical characteristics of the composites. Results revealed glass fiber content as the primary factor influencing mechanical properties, followed by pressure, temperature, and injection speed. Optimal parameters are estimated to be 1000 bar, 320°C and 100 mm/s. This study tried to align energy and material efficient practices with manufacturing excellence to achieve high-performance composites with enhanced mechanical properties.*

Keywords: *Injection molding, fiber-reinforced polymers, composite materials, mechanical properties.*

1. INTRODUCTION

High performance and energy efficiency have always been the main objectives when designing mechanical systems and components. Fiber-reinforced polymers provide not only great chemical stability but also higher strength-to-weight ratio when compared to traditional metals, such as low alloy steels (Altenbach et al., 2004). Hence, their wide acceptance stems from the need for lightweight components and applications (D. Zhao, 2014).

Composite materials can be defined as the combination of two or more materials without blending or dispersing into each other, resulting in a combination of properties which are expected to surpass those exhibited by the individual elements. Reinforcements are usually divided into two main groups: particles which can provide isotropic characteristics to the composite; and fibers, both long and short, responsible for anisotropic behavior (Altenbach et al., 2004). The presence and type of reinforcement are directly responsible for the composites' properties, as well as its classification and processing routes.

Glass Fiber Reinforced Polymers (GFRPs) have been extensively explored in the industry due to their potential to replace conventional materials in various applications. Polyamides were one of the first engineering polymers commercially available, and their popularity rose due to a few factors such as being semicrystalline, which allows for

high temperature applications (Li, 2012; Plamen et al., 2007). Not only that, but polyamides also provide great chemical resistance and a combination of both toughness and stiffness (Kutz, 2011; Seyyedvahid et al., 2014). On the other hand, among synthetic reinforcements, glass fiber stands out as the most widely employed option, primarily due to its high strength and both thermal and chemical stability (Rajak et al., 2019; Autay et al., 2019).

The substitution of metal components with GFRP is a trend in various industries such as aerospace, refrigeration and food processing. This is mainly associated with their high processability, even in complex geometries, as well as a high strength-to-weight ratio (Altenbach et al., 2004; Kutz, 2011). These composites have the potential to reduce weight by 25 to 35% when replacing conventional metal components, in addition to their competitive mechanical properties when compared to other engineering metals (Sarfras et al., 2021; Das, 2001). Also, their compatibility with injection molding offers the advantage of producing high-precision parts within a short period of time. However, despite being an efficient and cost-effective manufacturing process, careful attention must be given to injection parameters as they exert significant influence, particularly on the mechanical properties of the final component. Parameters such as injection temperature, mold temperature, pressure, injection speed, and cooling time are crucial to ensure proper mold filling. Furthermore, the residual stress resulting from high shear rates can lead to excessive shrinkage and component warpage (Farotti and Natalini, 2018).

This study evaluated the following parameters: mass fraction of fiberglass, injection pressure, temperature, and injection speed. The influence of these processing parameters on the composite was characterized through density analysis, morphology examination, dynamic mechanical analysis (DMA), and tensile testing. Therefore, this study aimed to analyze the influence of specific parameters on various aspects of injection molded components, such as mechanical properties, density, and fiber-matrix adhesion.

For the design of the experiments, the DOE Taguchi method was used, with an L9 orthogonal array. The purpose of the Taguchi method is to optimize the production process using statistical techniques. This analysis allows for the identification of parameters that may minimize or even eliminate the influence of noise factors on product performance (Ranjit K. Roy, 2001). The method was selected because it is one of the main "off-line" tools, i.e., it occurs before the project is carried out. It was also chosen because it suited the number of variables to be analyzed in the project and their levels of variation (SK Karna, R Sahai, 2012). The tool was employed in conjunction with the MiniTab 17 software.

Understanding the influence of injection parameters on these properties is crucial for the development of high-performance glass fiber reinforced polyamide composites. The results of this study provided important information for the optimization of the manufacturing process of these composites, as well as for the adequate selection of the injection parameters, aiming to obtain materials with improved mechanical and thermomechanical characteristics.

2. MATERIALS AND METHODS

2.1 Materials and Parameters

In order to enhance the manufacturing process of the final component, it is necessary to map the influence of process parameters on the properties of the injected material. Therefore, process parameters that could have the most impact on changes in the final properties of the component were selected based on the available literature (Siegmann et al.,1982; Gu et al., 2014). The selected parameters for the study were: injection temperature (°C), injection pressure (bar), and injection speed (mm/s), with each of these parameters varying at three levels. Furthermore, another parameter was the amount of reinforcement present in the PA 66 matrix (30%, 35%, and 50% by weight).

In addition to the aforementioned classification of these materials, Figure 1 exemplifies four commonly used types of composites, with item d) representing the result of the injection process expected in this study. The raw material was supplied in the form of pellets, and the injection process helped to align the fibers throughout the volume of the component, which exhibit anisotropic behavior.

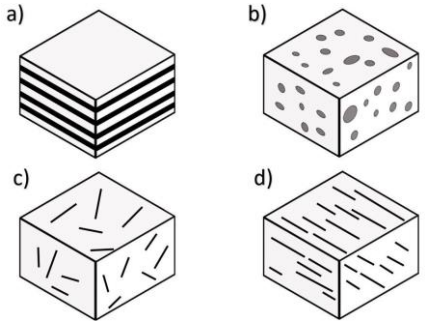


Figure 1. Classification of composites: a) Laminate; b) Particle reinforced, c) Short fibers randomly oriented and d) Oriented short fibers.

Using the Taguchi method in conjunction with the MiniTab17 software, 9 sets of process parameters were obtained that allow us to evaluate their influence on the final properties of the composite. This step of the study aimed to establish a methodology that would allow the adequate characterization of the material and the manufacturing process. Each group represents a combination of parameters, and these are shown in Table 1. After evaluation, a new reference group was injected using the "optimal" parameters indicated by the statistical tool.

Table 1. Sample groups and combinations of parameters obtained through Taguchi method.

Group	Glass fiber (wt%)	Injection pressure (bar)	Injection speed (mm/s)	Temperature (°C)
GF301	30	1000	100	320
GF302	30	1500	125	330
GF303	30	2000	150	340
GF351	35	1500	150	320
GF352	35	2000	100	330
GF353	35	1000	125	340
GF501	50	2000	125	320
GF502	50	1000	150	330
GF503	50	1500	100	340

2.2 Characterizations

Density and morphology

One way to quantify the effectiveness of the process is to evaluate the filling of injection cavities by calculating the density and presence of voids. It is known that determining the density of an injected component based solely on the geometry of the injection cavity can lead to inaccurate values, especially because the component may have irregular shapes, shrinkage, and other factors that affect the accuracy of the measurement. Therefore, a convenient approach to calculate these densities is through the principle of Archimedes. It states that when an object is submerged in a fluid, it experiences an apparent weight loss equal to the weight of the fluid displacement. Also, the buoyant force on the object is equal to the weight of the displaced fluid. By measuring this difference in mass, the density of either the object or the fluid can be determined, providing valuable information about the object's density. The presence of voids is calculated through Eq. (1), which has as input the density provided by the supplier and the one measured experimentally.

$$Voids\ (\%) = \frac{Theoretical\ density - Experimental\ density}{Theoretical\ density} \quad (1)$$

SEM analysis aimed to evaluate fiber-matrix adhesion, fiber distribution and alignment, and presence of voids. Not only that but the analysis of the fractured region allows for the identification of potential failure mechanisms such as delamination, fiber pull out and cracks (Malchev, 2010). For this analysis, the samples had their cross section evaluated after undergoing cryogenic fracturing. They were then sent to a Scanning Electron Microscope TESCAN VEGA 3.

Tensile and dynamic mechanical analysis

Tensile tests were carried out to evaluate the mechanical properties such as their behavior under different loading mechanisms. These results were essential for evaluating the performance of composites, as well as for comparison purposes and the development of new materials with superior properties. The parameters evaluated during the tensile test were the Ultimate Strength (MPa), which is the maximum tension supported by the sample before failure occurs, and the Elastic Modulus (GPa), which is a measure of the stiffness of the material and represents the relationship between applied stress and elastic deformation. Five samples from each group were tested, where the tests were performed according to ASTM D638 standard, with geometry samples as shown in Figure 2 (a), using a Universal Testing Machine MTS Model Criterion 45, with a crosshead speed of 5 mm/min.

Dynamic Mechanical Analysis (DMA) allows the characterization of the mechanical properties of materials under the action of dynamic forces, with controlled stress, strain, and frequency over a wide temperature range. Through DMA, it is possible to analyze the viscoelastic behavior, phase transitions, stiffness, dissipative factor, and resistance to relaxation of materials, including polymer matrix composites. This information helps in understanding the mechanical properties under different loads and temperature conditions, consequently, it assist in the selection of materials for specific applications. The analysis was carried out in a NETZSCH DMA 242 E model equipment, under the dual-cantilever mode,

with geometry samples as shown in Figure 2 (b). The specimens were tested at a frequency of 1 Hz over a temperature range of 25 to 200 ºC, at a heating rate of 2 ºC/min, force of 8N and peak-to-peak displacement of 25 µm.

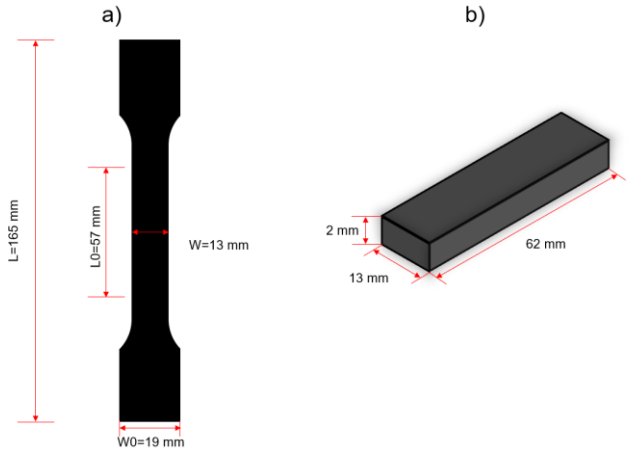


Figure 2. Different specimen's geometries according to a) ASTM D638 type I and b) a DMA specimen.

3. RESULTS AND DISCUSSION

3.1 Evaluation of the effectiveness of the injection process

After the molding process, one way to evaluate its effectiveness is to verify the filling of the injection cavity, through the calculation of the density reached by the specimens and the calculation of voids. The density calculated using Archimedes' principle and the presence of voids for the glass fiber reinforced polyamide groups are shown in Table 2, respectively.

Table 2. Density and volume of voids calculated for the sample groups

	GF301	**GF302**	**GF303**	**GF351**	**GF352**	**GF353**	**GF501**	**GF502**	**GF503**
Density (g/cm³)	1.36	1.36	1.36	1.49	1.49	1.48	1.56	1.56	1.56
Voids (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%

The theoretical densities of the materials used for the production of the components are 1.36, 1.5 and 1.58 g/cm³ for materials with 30, 35 and 50% glass fiber, respectively. Taking these values into account and comparing them with the density of the components calculated by the Archimedes method, it is seen that all groups reached 99% of the theoretical density, regardless of the process parameter. Theoretical density represents the expected density of the composite material when fully filled and consolidated, and a density close to 100% in the injected component can indicate good cavity filling during the molding process, which is extremely important since inadequate filling of the cavity can result in defects such as voids, lower density, lack of adhesion between fibers matrix, among other defects. They compromise the resistance and integrity of the component, which can lead to premature failures during use, therefore, ensuring an adequate filling of the injection cavity is essential to obtain high quality components, with superior mechanical properties and greater reliability. However, it is important to note that density is not the only factor to be considered when evaluating the quality of cavity filling. Other aspects, such as the absence of voids, structural integrity, adhesion between the fibers and the matrix, must also be considered. Using Eq. (1), it is possible to calculate the volume of voids in the composites. After the calculation, it was verified that all groups of samples presented 1% of voids, which did not vary due to the change in process parameters, as shown in Table 2. A void volume of 1% calculated for the components injected can be considered adequate, and as well as the analysis performed for the density values, this value may indicate that the cavity was adequately filled during the injection process, resulting in a denser and more homogeneous structure. However, the acceptability of this value may depend on the specific context of the application. In some critical industries or applications, it may be necessary to achieve even lower void levels to ensure component strength, durability, and reliability. In addition, it is important to evaluate the distribution of voids within the component. If the voids are localizated in specific areas, such as regions of high geometric complexity or in points of restricted flow,

this can negatively impact the mechanical properties and strength of the component. To complete this analysis, a characterization of the morphology of the components was performed, as shown in Figure 3.

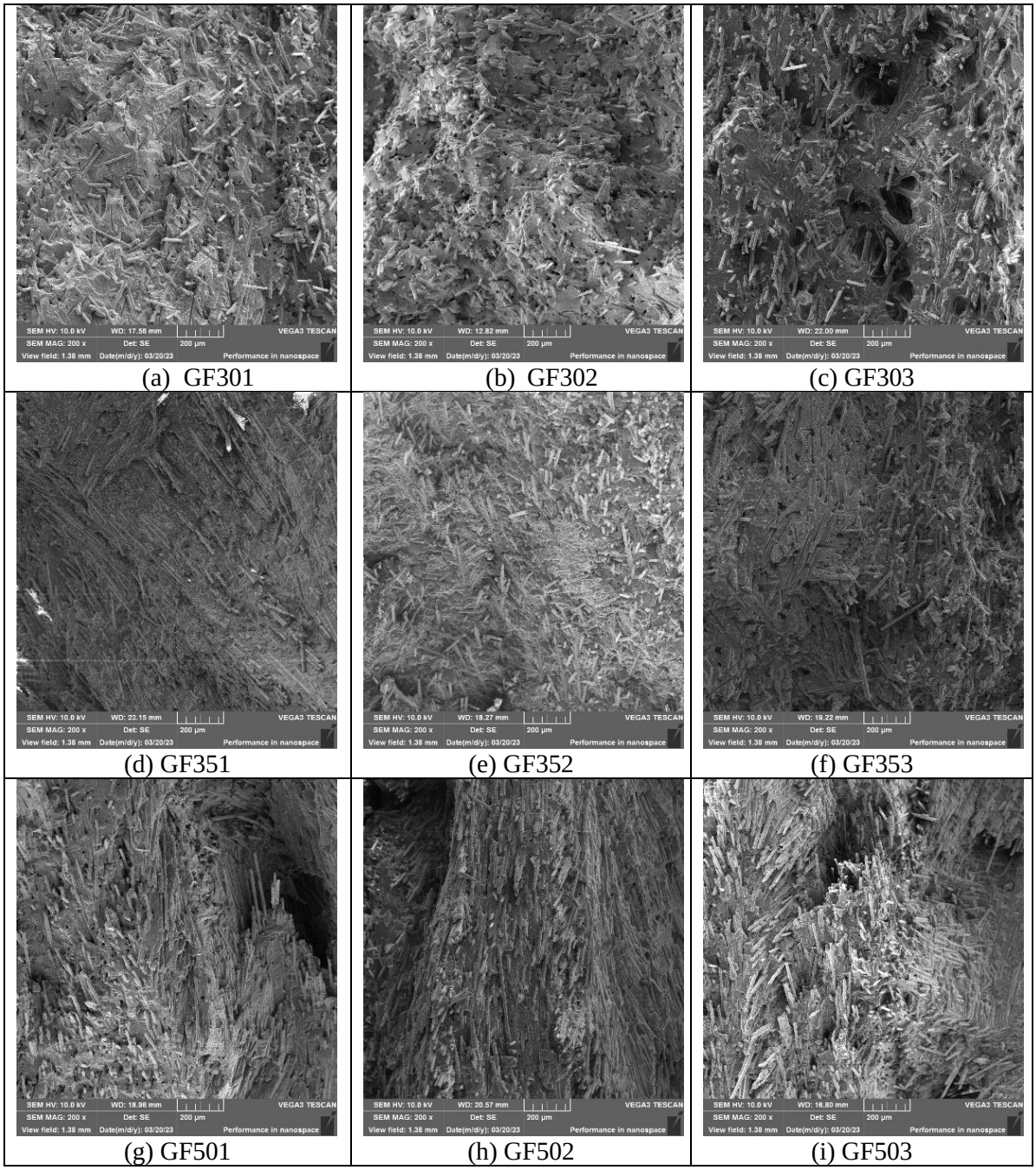
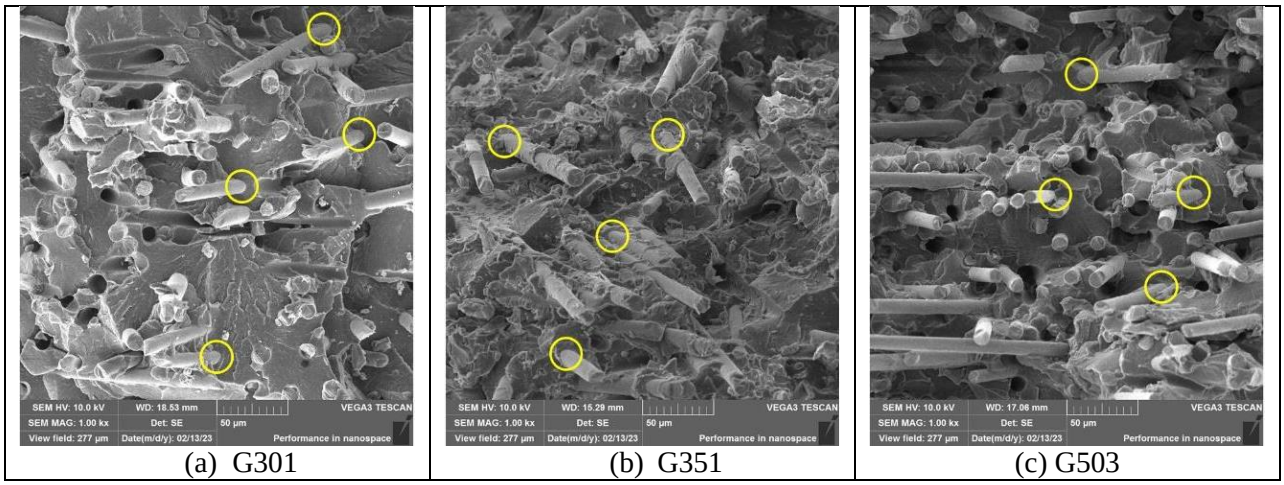


Figure 3. Sem micrographs of the injected composites.

SEM analysis plays a key role in investigating the morphology, microstructure, interfaces, and defects of injected samples of Polyamide composites with glass fiber. Through this analysis, it is possible to evaluate the distribution of glass fibers in the polyamide matrix, observe the interface between the fibers and the matrix, and identify adhesion failures or discontinuities. This information is essential to understand the influence of processing parameters on the mechanical behavior and properties of the composite. In all groups of samples, it was identified that the fibers are uniformly dispersed in the matrix, without agglomerates or areas with excessive number of fibers. This is important, as an uneven distribution can lead to non-uniform load transfer between the fibers and the matrix, compromising the strength and integrity of the composite. A homogeneous distribution of the fibers also contributes to a better adhesion between the fibers and the matrix. When the fibers are well distributed, there is a greater contact interface between them and the matrix, allowing efficient load transfer and a more uniform distribution of mechanical stresses along the material.

As can also be seen, with the increase in the fiberglass mass fraction, there was an increase in the preferential direction of these fibers, possibly due to their arrangement during the injection process. In relation to the other process parameters, differences in the morphology of the composites were not observed. The adhesion between the glass fiber and the matrix is also an essential point to be evaluated by SEM analysis, as it is a characteristic that directly influences the mechanical performance of the material. A strong and effective adhesion between the glass fibers and the Polyamide matrix promotes stress transfer and uniform distribution of applied loads. This can result in a significant improvement in the mechanical strength, stiffness, toughness and fatigue strength of the composite. Good adhesion also prevents the fibers from slipping in relation to the matrix, which could compromise the effectiveness of the load transferred between the phases. In addition, adequate adhesion can improve delamination resistance, decreasing crack propagation and improving material durability.

The adhesion between the glass fibers and the polymeric matrix proved to be adequate and homogeneous for all groups of samples, without the presence of voids or discontinuities in the interface, as highlighted in the Figure 4. Samples with different amounts of glass fiber were selected to illustrate this adhesion.



(a) G301 (b) G351 (c) G503

Figure 4. Analysis of the fiber-matrix interface region.

Regarding the processing parameters, the composites showed clear visual differences only due to the change in the fiberglass load, with the exception of sample G303, as observed in Figure 3 (c). The samples produced using the set of process parameters G303 showed a high number of voids in its structure, resulting of the fibers pullout. These voids can lead to a reduction in the structural integrity of the component, causing damage to the properties of the composite. The impact of the presence of these voids in the specimens can be evaluated in the mechanical characterization.

3.2 Mechanical properties

The tensile test is one of the most important tests to evaluate the mechanical properties of a material. After carrying out the tests, the average values for ultimate strength (MPa) and elastic modulus (GPa) were obtained for each group, as shown in Table 3.

Table 3. Mechanical properties obtained through tensile tests.

Group	Ultimate Strength (MPa)	Elastic modulus (GPa)
GF301	167.8 ± 3.4	11.4 ± 0.2
GF302	151.9 ± 4.4	11.7 ± 0.5
GF303	n/a	n/a
GF351	182.0 ± 5.5	13.3 ± 2.0
GF352	169.2 ± 9.7	13.7 ± 0.2
GF353	169.0 ± 12.0	14.0 ± 0.4
GF501	224.6 ± 2.3	19.1 ± 0.8
GF502	226.8 ± 7.4	19.1 ± 0.4
GF503	228.0 ± 0.7	18.0 ± 1.4

By analyzing the results of the composites' tensile strength, a connection between the amount of glass fiber present in the polymeric matrix and the resistance to rupture of the materials was observed. Tensile strength values increased from 150 MPa to 230 MPa as the fiberglass mass fraction increased from 30% to 50%. This indicates that the addition of fiberglass resulted in a significant increase in the strength of the composites. It is possible to stablish a direct connection between the elastic modulus which went from 11 GPa to 19 GPa with the increase of glass fiber content from 30% in 50% in mass.

It is also observed that, as the fiberglass fraction increases in composites, the influence of injection parameters on the mechanical property decreases. This can be observed by the results of the samples with 30% reinforcement (GF301, GF302 and GF303), which presented different values of rupture tension. On the other hand, composites with 50% reinforcement (GF501, GF502 and GF503) obtained results within the same average. As for the elastic modulus, no significant variations were detected between groups containing the same fraction of reinforcement. This suggests that, regardless of the fiberglass fraction present in the composites, the modulus of elasticity was not strongly influenced by the process' parameters.

The samples from the G303 group could not be properly evaluated, as the specimens presented rupture outside the narrow section during the tensile tests, even using the techniques indicated by the standard. This situation may indicate that the set of process parameters used for the injection of the group in question may not be suitable for the manufacture of composites. Such evaluation could be confirmed by the Taguchi analysis, where it was verified that the process parameters that imply in composites with lower mechanical resistance were 30% of glass fiber, 340 ºC of injection temperature, 2000 bar of injection pressure and 100 mm /s of injection speed. Simultaneously, they are the parameters used to obtain the G303 sample group.

The use of the Taguchi method to evaluate the influence of processing variables on the ultimate strength of the samples made it possible to establish a ranking of process parameters based on their contribution to the breakdown stress variation. By identifying the most influential parameters, it became possible to determine the optimal process parameters that maximize the ultimate strength. Table 4 (a) shows the ranking of parameters that exert the greatest influence on the composites' tensile strength, and Table 4 (b) shows the optimum values for these parameters.

Table 4 (a). Ranking of influence on the mechanical properties.

Parameter	**Glass fiber (wt%)**	**Injection pressure (bar)**	**Injection speed (mm/s)**	**Temperature (°C)**
Rank	1	2	4	3

Table 4 (b). Optimal processing parameters obtained through the Taguchi method

Group	**Glass fiber (wt%)**	**Injection pressure (bar)**	**Injection speed (mm/s)**	**Temperature (°C)**
GF504	50	1000	100	320

Analyzing the values on Table 4 (a), it was confirmed that the glass fiber fraction has a great influence on the composite's tensile strength. This finding is in line with existing literature, which points to the amount of reinforcement as a determining factor for the mechanical strength of composite materials. Furthermore, it is interesting to observe that, after the fiberglass mass fraction parameter, the process parameters that most influence the mechanical properties of the samples are pressure, temperature and injection speed, in that order.

The injection pressure plays a crucial role in the proper compaction of the polymeric matrix around the glass fibers, directly influencing the charge transfer between the phases of the composite. Inadequate pressure can result in a heterogeneous stress distribution, negatively affecting mechanical strength. Injection temperature also plays an important role, as it affects polymer rheological properties. Very high temperatures can cause degradation of the polymer matrix, while very low temperatures can result in poor melting of the components, compromising the quality of the composite. The injection speed is related to the filling rate of the injection cavity. Inadequate speed can lead to problems such as air occlusions, void formation and discontinuities in the composite structure. Therefore, precise control of the injection speed is essential to ensure uniform fiber distribution and good fiber-matrix adhesion. These conclusions underscore the importance of precise control of process parameters during the manufacture of glass fiber polyamide composites. Understanding these relationships between process parameters and mechanical properties allows optimizing the production process, aiming to obtain composites with better performance and adequate characteristics for the desired applications.

In order to evaluate the assertiveness of this analysis, a new group of samples was injected, as shown in Table 4 (b), using the optimal injection parameters indicated by the statistical method. The new group of injected samples presented

results consistent with expectations, since, in Table 5, it was observed that these composites obtained the highest values of rupture tension (MPa) and elastic modulus (GPa). Based on the analysis carried out and the results obtained, it is possible to select the processing variables in order to obtain composites with the highest possible mechanical properties, or according to the specific needs of the project. However, it is important to consider that the adjustment of process parameters can have impacts on other properties of the composite. Therefore, it is necessary to find a balance between the desired properties, taking into account the specific constraints and requirements of the project.

Table 5. Mechanical properties obtained through tensile tests.

Group	Stress at break (MPa)	Elastic modulus (GPa)
GF504	230,0 ± 1,2	19,3 ± 0,5

DMA analyzes were performed on the sample groups, where the values of the storage modulus (G') and the temperature up to which the storage modulus remains constant (Constant G') were obtained, as shown in Table 6. These results are important to understand the stiffness of the material and its ability to store elastic energy. Furthermore, it was possible to obtain the temperatures where the Tan δ peaks of the composites occur. Tan δ values indicate energy dissipation during mechanical deformation of the composites, where higher values of Tan δ indicate greater viscosity of the material.

Table 6. Values of G', constant G' and Tan δ, obtained from the DMA analysis.

Group	G' (MPa)	Constant G' (ºC)	tan δ (ºC)
GF301	1161 ± 133	115 ± 0	131 ± 2
GF302	1089 ± 489	109 ± 6	129 ± 2
GF303	1074 ± 57	108 ± 4	126 ± 3
GF351	816 ± 124	99 ± 3	122 ± 3
GF352	996 ± 220	96 ± 4	118 ± 4
GF353	1042 ± 373	92 ± 3	115 ± 2
GF501	737 ± 50	93 ±0	116 ± 0
GF502	1055 ± 320	90 ± 4	112 ± 6
GF503	788 ± 363	79 ± 8	101 ± 6

It was not possible to identify the direct influence of the injection parameters on the G' storage modulus values, due to the high deviation in the obtained results. A slight reduction on the average values of storage modulus (G') is observed due to the increase in glass fiber fraction in the composite. Composites with 30% reinforcement had an average G' of approximately 1100 MPa, while composites with 35% fiber had an average G' of approximately 950 MPa and composites with 50% fiber had an average G' of approximately 860 MPa. This trend indicates a reduction in the dynamic mechanical properties of the composites with the increase in the FV mass fraction. It was observed that the temperature at which the storage modulus remains constant (Constant G'), decreases with the increase in the amount of reinforcement, going from 111 ºC in samples with 30% glass fiber, to 96 ºC in samples with 35 % glass fiber and to 79°C in samples with 30% glass fiber. This parameter is important because it represents the temperature range in which the material can be used without showing changes in its mechanical properties, changing from a rigid state to a rubbery behavior.

Thus, it was observed that increasing the fiberglass mass fraction reduced the dynamic mechanical properties of the material, reduced the material's ability to maintain its E' modulus constant, and also increased the mobility of the amorphous phase. A reduction in Tan δ values was also observed with the increase in the reinforcement mass fraction, which is associated with the glass transition temperature (Tg) of the polyamide matrix.

Regarding the other processing parameters, the one that had the greatest impact on the results obtained was the injection temperature, as pointed out by the Taguchi analysis. Followed by pressure and injection speed, which had a relatively low influence. Through Table it is seen that by keeping the glass fiber fraction constant and increasing the injection temperature, there is a tendency towards a reduction in the temperature where the Tan δ peaks occur. The Tan δ peak indicates a significant viscoelastic transition in the material, and is related to changes in molecular structure, mobility and relaxation of polymer chains or other molecular interactions present in the material. Tan δ peak temperature is often

associated with a glass transition or other temperature-related transitions in polymeric materials. Thus, it is inferred that for higher processing temperatures, the material's ability to dissipate heat energy is reduced, resulting in a more elastic response.

Table 7. Variation of tan delta peak value as a function of injection temperature.

Group	Glass fiber (wt%)	Injection Temperature (°C)	tan δ (ºC)
GF301	30	320	131 ± 2
GF302	30	330	129 ± 2
GF303	30	340	126 ± 3
GF351	35	320	122 ± 3
GF352	35	330	118 ± 4
GF353	35	340	115 ± 2
GF501	50	320	116 ± 0
GF502	50	330	112 ± 6
GF503	50	340	101 ± 6

Correlating these results with the results obtained by the tensile test, it was observed that with the increase in the reinforcement fraction, the dynamic-mechanical behavior (DMA) had its values reduced, while the mechanical behavior (tensile test) obtained an increase in the values of mechanical resistance. Unlike the results obtained in the tensile test, the injection temperature had a relevant impact on the dynamic mechanical properties of the composites. As with the results from tensile tests, by varying the parameters of speed and injection pressure, no significant impacts were observed.

4. CONCLUSION

It was verified that the ranges of parameters selected for the injection process of the components proved to be adequate. This was evidenced by the filling of the injection cavities in all groups of composites, as observed in the density analyzes and calculation of the void volume.

The analysis of the morphology of the composites revealed a uniform dispersion of the glass fibers in the polymeric matrix, with a preferential orientation in the injection direction. Good adhesion between fibers and matrix was also observed, which is crucial to guarantee the integrity and performance of the composites. With the increase in the fiberglass mass fraction, there was an increase in the preferential direction of these fibers, possibly due to their arrangement during the injection process. Regarding the other processing parameters, no major impacts were observed on the morphology of the samples. In the G303 sample group, pullout, voids and discontinuities in the composite structure were observed, suggesting that the process parameters used during injection may not have been adequate. These failures in the formation of the part during the molding process were confirmed by the tensile tests, in which the samples from this group showed fractures occurring outside the narrow section of the specimens.

After carrying out the tensile tests, with the aid of the statistical tool, it was concluded that among the parameters studied, the one that most influences the mechanical properties of the composite is the fiberglass content present in the matrix, followed by the injection pressure, temperature and injection speed. Furthermore, it is estimated that the most adequate injection parameters to maximize the tensile strength of the material are: injection pressure of 1000 bar, temperature of 320 °C and speed of 100 mm/s. It was possible to verify that with the increase in the amount of fiber in the polymeric matrix, higher is the tensile strength of the composite. As a correlation with the results obtained by the SEM analysis, it can be said that the increase in the FV mass fraction, the alignment of the FV and the good interfacial adhesion contributed to the increase in the mechanical properties of the material.

After the DMA analysis, it was verified that the increase of the fiberglass fraction in the polymeric matrix, despite increasing the tensile strength of the material, can impair the integrity of the composites in applications at higher temperatures, decreasing the temperature at which the material shows a change from an elastic behavior to a rubbery behavior. It was also possible to visualize that, with the increase of the glass fiber content, the composite tends to present a more elastic behavior. This analysis corroborates the results of modulus of elasticity obtained in the tensile test. It was also possible to visualize a strong influence of the injection temperature on the dynamic-mechanical properties of the composites, where samples processed at higher temperatures present more elastic responses.

Each composite property responds differently to a change in the process parameter, and this mapping is necessary to meet the design requirements of a component.

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