Research Article

Open Access

Victor de Cerjat Beltrão, Marco Antonio Gaya de Figueiredo and Harrison Lourenço Corrêa*

Preliminary market analysis of PEEK in South America: opportunities and challenges

<https://doi.org/10.1515/epoly-2019-0035>

Received November 27, 2018; accepted February 06, 2019.

Abstract: The increasing applications of poly-ether-ether-ketone (PEEK) in the industry makes this polymer appealing for the development of a new industry focused on its production. PEEK displays remarkable mechanical properties that are not commonly found in polymeric materials, and its biocompatibility becomes attractive for the manufacture of prosthesis, stents and many other medical apparatuses. In addition, the new technique of Additive Manufacturing (AM) enables the printing of highly complex geometries with low weight, aiming the automotive and aeronautic industries as well. Despite not being relatively new, there are not many enterprises producing PEEK in the world, especially in the South American market. This raises a question regarding the size of the PEEK market in this region and the expected demand for the upcoming years. Therefore, this paper aims to analyze and predict the demand of PEEK for the Mercosur and Brazil markets, verifying the feasibility of the creation of a specialized industry in the region.

Keywords: evaluation; market; polymers

1 Introduction

Nowadays, when an idea is created towards the development of a new enterprise, entrepreneurs usually do not ask themselves about the most important aspect of any successful business: is there enough feasibility for its

implementation? In the current context of high rates of fast information exchange, what people usually forget is that the product or service requires a careful planning in all its features as well as characteristics related to the company. In addition, a high money investment is frequently needed; however, the amount is not easily achieved by the associates responsible for the enterprise. Therefore, the required conditions for the accomplishment of the company's project must be thoroughly examined through a feasibility analysis.

The creation of any type of enterprise must first pass through a previous market validation. Buarque (1) observed that the determination of the society's necessity level in relation to a given service or product is extremely important, as it dictates the feasibility of the development of the project. Thus, the market research is the starting point for the enterprise project.

One of the major objectives of the market research is the characterization of the product that will be sold, in a way that guarantees it will meet the market expectation. Understanding primarily the nature of the product and the type of segment it attends is crucial. Through this characterization, the expected real price of the product can be investigated and future demands of the market can be predicted. Based on that, the amount of sales and future revenue can be estimated (2).

PEEK (poly-ether-ether-ketone) is a thermoplastic semi crystalline homopolymer that belongs to the poly-aryl-ether-ketones (PAEK) family. This family has the ketones and ethers functional groups linked together through aromatic groups. Besides PEEK, modification in the bonding of the monomers from this family may create other polymers, such as poly-ether-ketone (PEK) and poly-ether-ketone-ketone (PEKK) (3). PEEK is currently considered a high-performance polymer due to its optimized properties compared to other polymers, which makes it fit to high-demand applications.

Among these properties, the most recurrent is the polymer biocompatibility, which makes PEEK extensively used in the health industry, especially in the carbon fiber composite form. This composite possesses high mechanical properties, high resistance in hostile environments like

* **Corresponding author: Harrison Lourenço Corrêa**, Universidade Federal do Paraná, Setor de Tecnologia, Departamento de Engenharia Mecânica, Curitiba, PR, Brazil; UFRuralRJ, Departamento de Engenharia de Materiais, Seropédica, RJ, Brazil, email: harry.lou.correa@gmail.com.

Victor de Cerjat Beltrão, Laboratório de Materiais Poliméricos, Setor de Tecnologia, Departamento de Engenharia Mecânica, Universidade Federal do Paraná, 81530-000 Curitiba, PR, Brazil.

Marco Antonio Gaya de Figueiredo, Laboratório de Engenharia e Tecnologia de Petróleo e Petroquímica, Instituto de Química, Universidade do Estado do Rio de Janeiro, RJ, Brazil.

the human body, and good fatigue resistance. Therefore, it may display high acceptance in orthopedics, mainly as an intervertebral cage in column surgeries. It can also be found mixed with other composites, used in cranial prosthesis, dental prosthesis substitutes, autoclavable cases and even stents for blood vessel substitution (4).

PEEK is majorly synthesized via nucleophilic route, which has had greater commercial success throughout the years (5). This method of polymerization utilizes a highly electronegative group to remove protons from the edge of aromatic chains of a nucleophilic compound, normally a bisphenol, like hydroquinone. Following, the bonds become active and react with alkaline metals present in 4,4' difluorobenzophenone and a carbonate to produce the final polymer through polycondensation (6). It is recommended to use a blend of sodium and potassium carbonate to achieve good final performance of the polymer (7). To obtain PEEK with high molecular weight, it is necessary the utilization of a solvent that can overcome the problem of fast crystallization common in the polycondensation of this polymer, which limits this property (8). Diphenylsulfone is employed for that matter, close to the PEEK's melt temperature, achieving high physical properties.

Several processing methods of this polymer have already been studied, and, recently, researchers have focused their efforts in additive manufacturing techniques (AM). This technique enables the manufacturing of high geometrical complexity prosthesis and anatomical models with greater simplicity and velocity, which is not possible with the usual processing technologies (9). Furthermore, the prosthesis and anatomical models parts can be printed directly in the hospital centers, optimizing the logistics and allowing a faster treatment of the patient.

PEEK has commercial applications in many industrial areas. For example, it can be highlighted its use in aircraft components. In this industry, they can be found in a broad range of applications, like turbine, aircraft fuselage and aircraft seats (10). Also, since 1990's this polymer is tested in clinical studies and it shows high potential to replace some metal implant components (11), having thermal stability at high temperature. This synthetic material has excelled in medical applications due to its durability, stiffness and elasticity similar to human bones (12). Other requirements can also be noted by this polymer in clinical using: fast recovery of patients, accuracy, efficiency, easy implementation in surgery, flexibility and increased success rate of operation (13). There are high expectations about PEEK application for construction of femoral components. One of these is the decreased risk related to metal-sensitivity reactions. Although the materials used

for knee arthroplasty (TKA) are well known, particularly for their good biocompatibility, the corrosion of the implant components and metal could be a trouble (14). In addition, PEEK is gaining higher acceptance in odontology, where it can be found as a substitute of titanium for dental prosthesis. This is due to its controllable aesthetically colors and less allergenic potential (15). With aid of additive manufacturing, the products created with PEEK can achieve much higher geometric complexity, making it an alternative for customizable complex parts, such as specific cranial prosthesis (16). For industrial processing units, PEEK has an advantage compared to other polymers: he can be soluble in common solvents (17), which could help in the cleaning process of machines.

As PEEK displays a large number of applications and the innovation the AM presents, we hypothesized that the market of prosthesis produced by this technique is growing. The South American market, particularly, may be a target, since there is no industry producing PEEK in this region and the demand is potentially high. Therefore, this study aims to analyze and estimate the PEEK demand as an input for the manufacture of prosthesis, verifying the feasibility of an industry in the Brazilian and Mercosur (Common Market Group of South America) markets.

2 Materials and methods

2.1 Demand

The first step in the market analysis is the projection of the demand. Demand is the data calculated based on the client's perception. It indicates the amount of a given product that the market wants, in product units or monetary units. A method for determining the apparent value of the demand is presented in Eq. 1, explained by Hirschfeld (18):

$$\text{Demand} = \text{Imports} + \text{Production} - \text{Exports} \quad (1)$$

The Brazilian import and export relevant data for international products can be easily accessed through the platform "Aliceweb", provided by the Brazilian Minister of Industry, Foreign Trade and Services (MDIC, Ministério da Indústria, Comércio Exterior e Serviços). By signing up, the values for import and export are disposed by product, period, company in charge, and State or City. The products in the database bank are registered using the Mercosur Common Nomenclature (NCM, Nomenclatura Comum do Mercosul, in Portuguese), a catalog used to facilitate the

taxation and exemption of taxes between countries that belong to the Mercosur. Since there is no NCM dedicated exclusively to PEEK, we chose the NCM 39119024 related to Polyetherimide (PEI), a polymer that has both properties and the market fairly similar to those of PEEK. PEI is also manufactured as a 3D filament, under the name ULTEM®, by the company Stratasys.

After obtaining the values for the demand, algebraic methods can be applied to estimate the future demand of the product. This was achieved using a special tool present in the program Excel 2016 version, which enables the creation of a forecast spreadsheet automatically using the method of exponential smoothing. This method is a temporal technique based on historical data and its explanation can be found elsewhere (19). The historical data found for the demand is inserted in chronological order and the smoothing factor is calculated internally with an optimization tool. The confidence interval was 95%.

Considering the product we explored has relatively poor prevalence in the Brazilian market, we opted to use neighboring markets, more precisely the commercial alliance of the Mercosur. This group is composed of Brazil, Uruguay, Paraguay and Argentina and its objective is to facilitate commercial operations between those countries and the block as a whole with commercial partners around the world. Import and export data of PEI for Mercosur were found in the database “Trade Map”, granted by the International Trade Centre (ITC). This platform consists of

an excellent tool for the research of data related to foreign commerce. Information about import and export of almost every recognized country in the world are available on the website. The products are registered through the Harmonized System (HS), a number with up to 8 digits, from which the NCM derives.

3 Results and discussions

The values for export and import of raw PEI are presented in Figure 1. They are disposed in units of tones of the polymer and Free on Board (FOB) million dollars. FOB indicates the absence of insurance and import taxes in the final value.

We noted a growth in the export of PEI in the last four years, and a decrease in its import, particularly during the last year we evaluated. This performance may be explained by the recession moment that the Brazilian macroeconomy had passed in this period; however, these values cannot be discarded. The quantity produced has a stable and direct relation with the exported and imported monetary value, which exposes a stabilization of the price of PEI over the following years.

The trade balance Evolution of PEI for the Mercosur Market is presented in Figure 2. Inside Mercosur, Brazil is the major importer country, resulting in the strongest influence on the groups’ behavior curve. However, Uruguay also exhibits a growth tendency, different from

Figure 1: Trade balance of PEI for the Brazilian market.

Figure 2: Trade balance of PEI for the Mercosur market.

Figure 3: Prediction of future demands of PEI for Mercosur.

the other countries, replacing Brazil in 2016. Argentina's market shows a decrease on the demand, while Paraguay displays a low amount of demand.

Using the values of import and export obtained earlier, we performed the prediction of future demands for the Mercosur. The results are exposed in Figure 3.

The analysis of the chart exposed a tendency of decrease in the demand for the period between 2018 and January 2020. If we do not include the production of PEI, this scenario, cannot be considered completely valid in comparison with the real situation. These production values are not available to the public in databases, specialized magazines or even plastic industry yearbooks.

Besides, there are outside factors that can interfere in the market expectations, like economic recession, feedstock availability, presence of new technologies and others. However, it already shows a decrease prospect in PEI demand for the Mercosur countries.

Regarding data collection for the PEEK market, major companies holding the biggest polymer production values, in a worldwide level, include: Solvay Specialty Polymers, Ensinger, Victrex, Evonik, Quadrant, and SABIC. All of these companies have export data contained in the Trade Map platform; however these values are scattered in multiple HS numbers, which makes it difficult to quantify the exact value related to PEEK. This is due to

Figure 4: Commercial trade of PEEK to the Mercosur.

the fact that there are many categories of polymers inside each HS number.

To obtain a more relevant and direct information, our research focused only on one specific HS number, 391690. Many ramifications can be found within this number, one of which is the category of bars and pellets of PEEK. We calculated the amount of companies inside the HS number and then we found an estimated ratio (0.45% to 2.18%). This estimate is very important, as the companies inserted in the HS repeat throughout the different categories, which indicates that the number of companies in a category automatically relates to the number of exportations of the product. Still, it is not possible to attribute certainty to the data, since each export has a different quantity of product in a load, resulting in a different value. Therefore, the amount of PEEK export was based in the total export calculated through this method.

The major exporting countries, based on the amount exported, were Germany, China, India, Italy, Belgium and France. The evolution of the commercial trade between these countries and the Mercosur is shown in Figure 4. We can highlight China, Germany and India as possible emerging producers of the polymers. Additionally, it is important to notice that the two biggest markets of PEEK producers, USA and United Kingdom, where the big companies Victrex and Solvay have their head offices, do not input their data in the Trade Map. This can reduce the

total amount of export calculated in comparison with the possible real data. Therefore, the final result can be seen as a pessimistic view of the raw PEEK market.

The prediction of future demands of PEEK to the Mercosur countries is displayed in Figure 5. The values for demands according to weight were calculated using the historical price of \$99.20 per kg (<http://www.plasticsnews.com/resin/high-temperature-thermoplastics/historical-pricing?grade=1330601%7CVol2>). Even though the polymer has a growth perspective in the period analyzed, the apparent demand value close to 2 tones is probably not enough to justify the production of raw PEEK to supply Mercosur. Because PEEK is a product with a high expected price, the plant industry must have a low production to keep up with the small demand.

The evaluation of import, export and production data of orthopedic prosthesis in Brazil is shown in Figure 6. We noted the existence of a much higher value of import compared to the export for these products. This behavior can suggest a possible repressed demand related to the current Brazilian industry. When we examined the values of production, we noted a growth in this factor, which indicates that the industrial sector is expanding to keep up with the increasing demand in the country. Particularly, it is interesting to analyze the behavior of the curve in the period between 2014 and 2015, in which there has been a vertiginous increase in production, a large drop in

Figure 5: Future demand prediction of PEEK for Mercosur.

Figure 6: Commercial trade of orthopedic prosthesis in Brazil.

import, and stability in export. Within this scenario, we suppose the Brazilian market is absorbing the industrial production, but there is not enough amount of orthopedic prosthesis to create a high export in this moment.

Figure 7 shows the predictions for the apparent future demand of orthopedic prosthesis in Brazil.

Future demands have a clear growth perspective. Such demands show a positive tendency and the data spreadsheet estimates a value of R\$ 720 million in 2020. Using the estimate created by the Gardner Company (20), which indicates that by 2020 almost 30% of all

prosthesis will be manufactured via 3D printing, we calculated a value of approximately R\$ 216,212,000,00 for the demand. This would be the possible final size of the Brazilian market of additive manufactured prosthesis and medical implants. Adding to this it is important to notice that the number of scientific articles published in the past decade related to PEEK polymer. The Brazilian database CAPES was used for the purpose (21). Researchers are developing more interest in PEEK, with possible benefits for the industry regarding the development of new technologies and increasing

Figure 7: Future demand predictions of orthopedic prosthesis in Brazil (confident limits of 95%).

applications. The number of articles more than doubled since 2008. This scenario indicates that PEEK popularity shows a remarkable growth and that its market will probably greater expansion in the future.

4 Conclusions

In the outline we presented above, the establishment of an industry focused in the processing of PEEK in a filament form would be possible. The market will be growing in the period we analyzed and little to none competition is expected, due to the absence of the product in the South American market. The future demand for PEEK is higher to historical demand (2016 to 2020). And considering that the future demand predictions of orthopedic prosthesis in Brazil tends to be higher than \$ 720 million, it is expected that the consumption for PEEK occasionally used for prosthesis grows up too. The data collected indicates good perspectives for PEEK consume. But it is important to notice that the two biggest markets of PEEK producers, USA and United Kingdom, do not input their data in the Trade Map. This can reduce the total amount of export calculated in comparison with the possible real data. Therefore, the final result can be seen as a pessimistic view of the raw PEEK market. Because of the great complexity related to the polymerization of PEEK, the feasibility of raw PEEK production is uncertain. A deeper investigation regarding production costs and the installed production capacity of the industry is needed.

Acknowledgments: The authors would like to thank the Academic Publishing Advisory Center (Centro de

Assessoria de Publicação Acadêmica, CAPA – www.capa.ufpr.br) of the Federal University of Paraná for assistance with English language editing.

References

1. Buarque C., Ochoa H.J., Avaliação econômica de projetos. Elsevier, Rio de Janeiro, 1995.
2. Neto J.F.C., Elaboração e avaliação de projetos de investimento: considerando o risco. Elsevier, Rio de Janeiro, 2009.
3. Fink J.K., High performance polymers (2nd ed.). Elsevier, 2014.
4. Kurtz S.M., Devine J.N., PEEK biomaterials in trauma, orthopedic, and spinal implants. *Biomaterials*, 2007, 28(32), 4845-4869.
5. Kurtz S., PEEK Biomaterials Handbook. *Plastics Design Library*, 2012, 1-7.
6. Gibson A.G. Thermoplastic aromatic polymer composites. *Int. Mater. Rev.*, 1994, 39(3), 124-124.
7. Imperial Chemical Industries Limited. EP0001879, European Patent Office, United Kingdom, 1978.
8. Attwood T.E., Dawson P.C., Freeman J.L., Hoy R.J., Rose J.B., Staniland P.A., PEEK: poly (oxy-1, 4 phenyleneoxy-1, 4 phenylene carbonyl-1, 4 phenylene). *Polymer*, 1981, 22, 1096.
9. Wong K.V., Hernandez A., A Review of Additive Manufacturing. *ISRN Mech. Eng.*, 2012, 1-10.
10. Barile C., Casavola C., De Cillis F., Mechanical comparison of new composite materials for aerospace applications. *Compos. Part B-Eng.*, 2019.
11. Kumar D., Rajmohan T., Venkatachalapathi S., Wear behavior of PEEK matrix composites: a review. *Mater. Today-Proc.*, 2018, 5.
12. Panayotov V.I., Orti V., Cuisinier F., Yachouh J., Polyetheretherketone (PEEK) for medical applications. *J. Mater. Sci.-Mater. M.*, 2016, 27.
13. Haleem A., Javaid M., Polyether ether ketone (PEEK) and its 3D printed implants applications in medical field: An overview. *Clinical Epidemiology and Global Health*, 2019.

14. Granchi D., Cenni E., Tigani D., Trisolino G., Baldini N., Giunti A., Sensitivity to implant materials in patients with total knee arthroplasties. *Biomaterials*, 2008, 29, 10.
15. Verma A., Novel innovations in dental implant biomaterials science: Zirconia and PEEK polymers. *Int. J. Appl. Dent. Sci.*, 2018, 4(4), 25-29.
16. NG Z.Y., Nawaz I., Computer-Designed PEEK Implants. *J. Craniofac. Surg.*, 2014, 25(1), e55-e58.
17. Yang J., Brown P., Highly gas permselective polyetherketone hollow fibre membranes using aqueous sulfuric acid solution as coagulant. *e-Polymers*, 2007, 7(1), 1-12.
18. Hirschfeld H., Viabilidade tecnico-economica de empreendimentos - roteiro completo de um projeto. Atlas, São Paulo, 1987.
19. Makridakis S., Wheelwright S.C., Hyndman F., *Methods and applications* (3rd ed.). John Willey & Sons, 1998.
20. Basiliere P., Predicts 2017: 3D Printing Accelerates. 2017, <https://blogs.gartner.com/pete-basiliere/2016/12/29/predicts-2017-3d-printing-accelerates/>.
21. CAPES. Coordenação de Aperfeiçoamento de Pessoal de Nível Superior. Brasil, 2018, <http://capes.gov.br>.