



BIBLIOMETRIX ANALYSIS OF ABS OBTAINED BY FFF UNDER FATIGUE USING THE BIBLIOMETRIX SOFTWARE

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ABSTRACT

Fatigue is an important phenomenon considered when using ABS parts produced by fused filament fabrication. Therefore, this paper uses the bibliometrix software to present the data related to the production of scientific work in the area. It was clear that there was a large production of work in the United States, followed by Iran and India. The culture and economy of each country seem to be key points in the production of work related to the topic. Furthermore, there is an accelerated growth in the number of projects developed. Finally, it became clear how the choice of search words directly influences the results found and how to use fewer specific names look to increase the number of citations.

KEYWORDS

bibliometrix, bibliometric, ABS, fatigue, 3D print.

INTRODUCTION

The use of polymers has gained notoriety in recent years. Technological growth and development have led to a wider range of materials being applied. As a result, there's use of polymers and derivatives in various industries, such as aerospace, automotive, and biomedical, is becoming increasingly common (1).

Due to this technological growth in materials, the fused filament fabrication (FFF) process, previously known as fused deposition modeling (FDM), emerged to facilitate the creation of complex parts (2). This method creates parts in which the material extruded through a nozzle at high temperature moves to create

overlapping filaments. Because of this, it is possible to create complex and highly personalized geometries. However, this process creates a series of defects due to the interfaces between the layers (2, 3). As a result, the part becomes susceptible to mechanical fatigue.

The phenomenon of Mechanical Fatigue involves repetitive loads below ultimate stress that led to the gradual weakening of the part until it ruptures. This occurs due to the formation and growth of cracks due to imperfections inherent to the material (4).

The study of fatigue in polymers produced by FFF has gained notoriety in the last ten years, caused by a growth of most diverse application to this type of material. One of the most commercially used materials is Acrylonitrile Butadiene Styrene (ABS).

ABS possesses various appealing characteristics such as low cost and low density. In addition to these attributes, it is a recyclable material and is easy to mold (5). Consequently, ABS has emerged as one of the primary materials employed in the FFF process, gaining significant recognition in academia as a result.

This article seeks to develop a bibliographic review. In this regard, the ABS material, the FFF manufacturing process, and the Fatigue phenomenon will be considered. For this purpose, Bibliometrix software will be used as a guide.

MATERIALS AND METHODS

Initially, an analysis on necessary teams of necessary teams for research on the subject addressed was carried out. For this, it was divided into three parts: one related to the material production method, the FFF; the second is the term reserved for ABS material; finally, the last part of the research is the phenomenon of Fatigue itself.

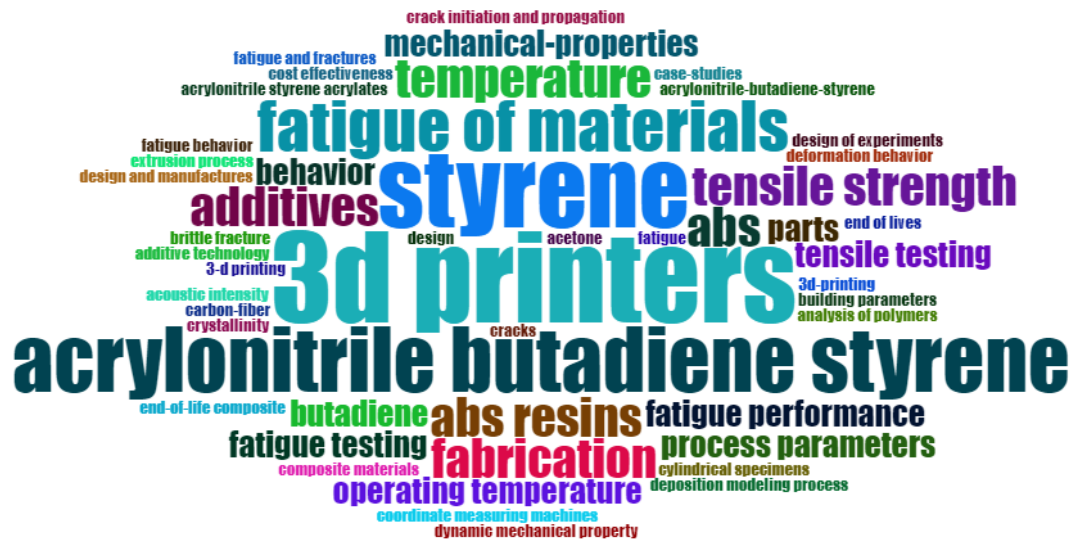
From this first survey, a series of assumptions were made to find the best terms that related to the three areas mentioned.

The Table 1 shows the keywords initially used to search on the Scopus and Web of Science platform. Therefore, the search ("abs" and "fff" and "fatigue") was carried out on both platforms. The bibliometrix software was then used to evaluate the results. The initial assessment was given about the word cloud, in which main words that relates to the research can be seen, as can be seen in Figure 1.

Table 1: First Keywords

Material	Production method	Rupture phenomenon
abs	fff	fatigue

Figure 1: First Word Cloud



The word cloud showed the need to also use the name of the material in full. Furthermore, in relation to the production method, it was clear that "3d printers" are important for research. The nomenclature passed to FFF, i.e. FDM will also be added. Below is the new keyword table in Table 2.

Table 2: Second keywords

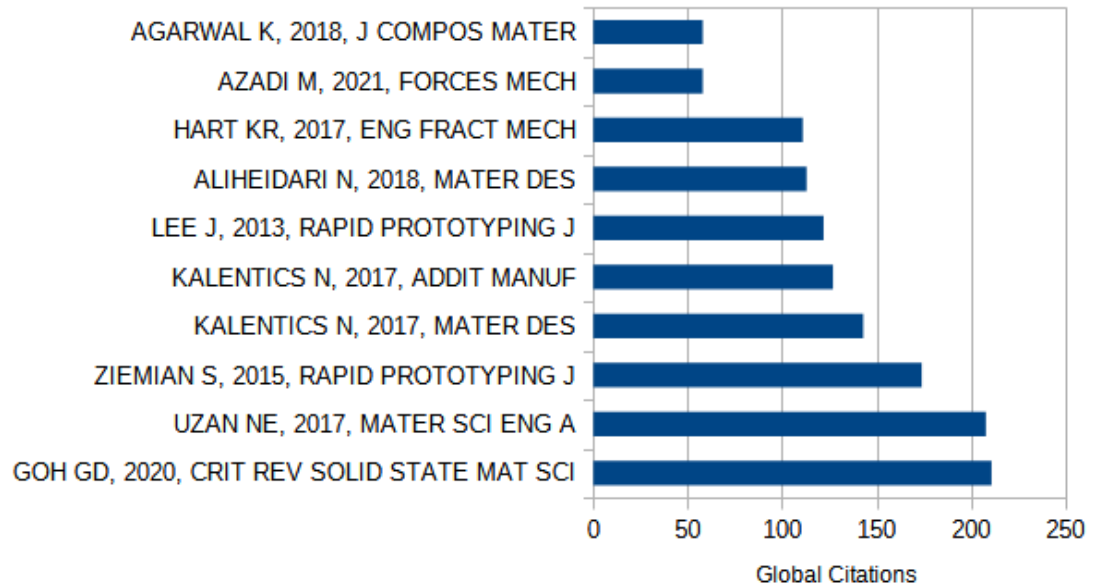
Material	Production method	Rupture Phenomenon
abs	3d print* ¹	fatigue
acrylonitrile butadiene styrene	fff	-
-	fused filament fabrication	-
-	fdm	-
-	fused deposition modeling	-

¹ Search platforms use the symbol "*" to search for words that have the same beginning as the one before it.

Based on the new words, the search becomes: ("fatigue") and ("fdm" or "fused deposition modeling" or "fff" or "fused filament fabrication" or "3d print**") and ("abs" or "acrylonitrile butadiene styrene").

Based on the new words, among other things, the most cited articles were evaluated, as can be seen in the Figure 2.

Figure 2: Most Global Cited Documents



Several of the articles do not mention the ABS material, Kalentics et al. (2017) and Uzan et al. (2017), for example, work in the area of metal additive manufacturing and Goh et al. (2020) did work on polymers in general. The hypothesis was raised that the presence of the word "abs" could interfere with the results, as it is a non-specific abbreviation, which could refer to other things, or be calling words like "abstract". Therefore, the word in question was removed, leaving only "acrylonitrile butadiene styrene" about the material. The keyword table changes as can be seen in Table 3.

Table 3: Third keywords

Material	Production method	Rupture Phenomenon
acrylonitrile butadiene styrene	3d print* ¹	fatigue
-	fff	-
-	fused filament fabrication	-
-	fdm	-
-	fused deposition modeling	-

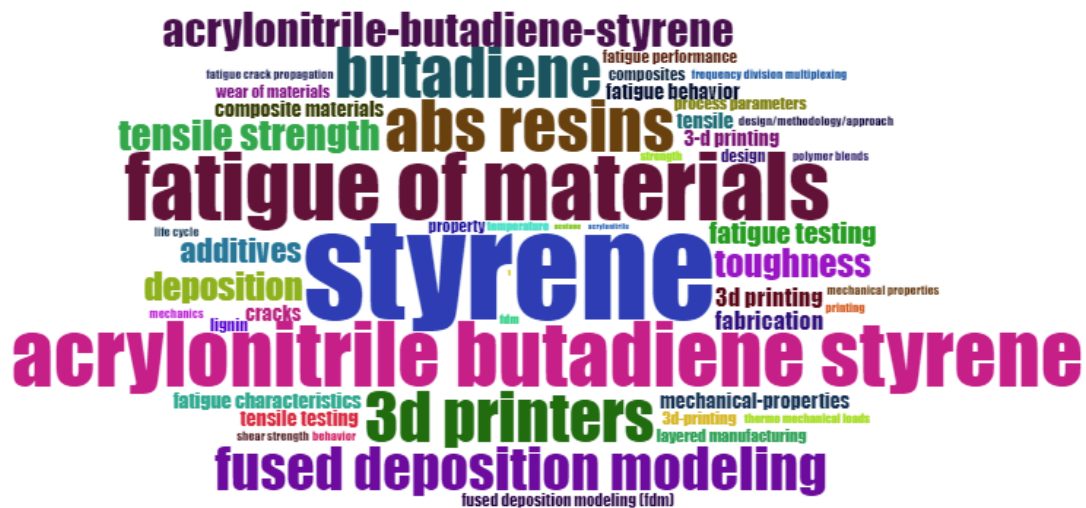
¹Search platforms use the symbol "*" to search for words that have the same beginning as the one before it.

Based on the new words, the search becomes: ("fatigue") and ("fdm" or "fused deposition modeling" or "fff" or "fused filament fabrication" or "3d print*") and ("acrylonitrile butadiene styrene").

RESULTS AND DISCUSSION

The research yielded 59 articles, and the outcome is represented in Figure 3, the second word cloud.

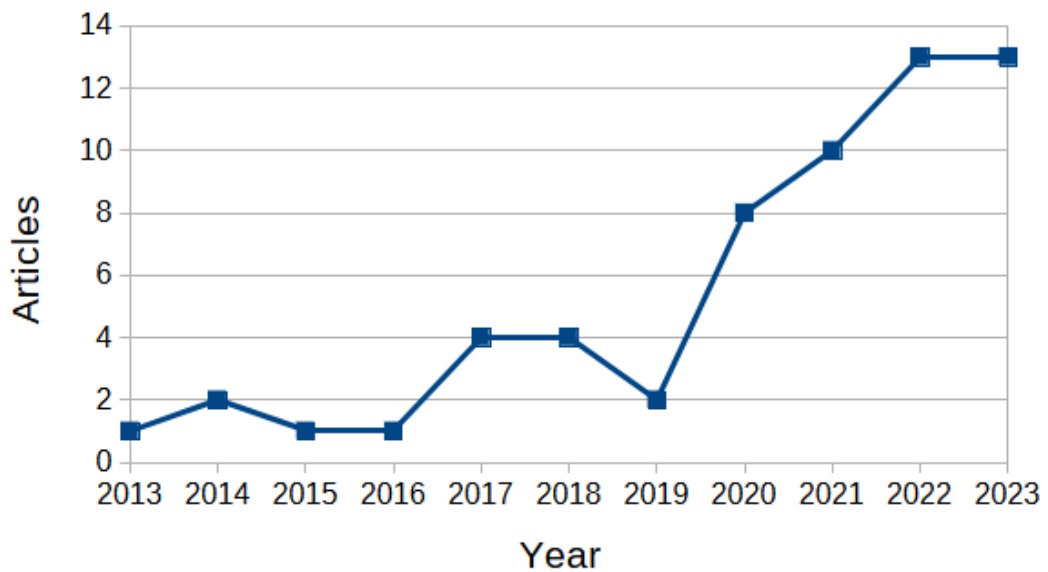
Figure 3: Second Word Cloud



The terms "fatigue of materials" and "acrylonitrile butadiene styrene", being isolated in their appropriate categories, were expected to be more prevalent, reflecting greater terms in the word cloud. However, "3d printers" was not expected to be as prevalent as "fatigue", for example, since in its category there are two other terms that perform the same role. This can be attributed to being a more general term, which encompasses 3D printing production methods. Furthermore, the term "fused filament fabrication" is still rarely mentioned compared to the old version of "fused deposition modeling", there must be some time to adapt to the adoption of the new nomenclature.

Using the bibliometrix software allows you to bring together and organize the researched information, including the growth of publications is one of the most interesting pieces of information to observe, as several scattered pieces of information can be confirmed. This information can be seen in Figure 4.

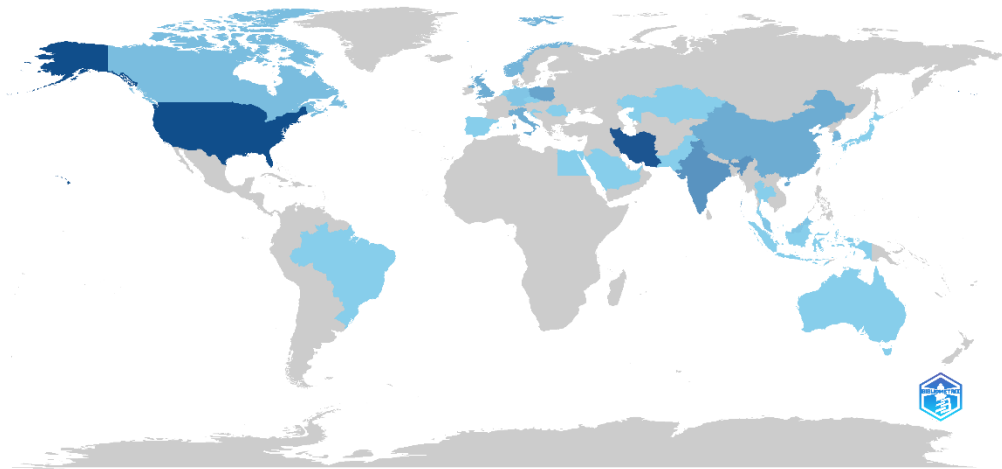
Figure 4: Annual Scientific Production



There has been a high growth in publications about ABS produced by FFF in fatigue, which was already expected, considering the growth in the popularization of FFF technology and the high use of ABS material. Furthermore, it is possible to notice, from the graph, a decrease in the number of publications in 2019 with a big jump in 2020, the same period where the COVID-19 pandemic started.

Scientific research on the subject in question can serve to understand various aspects of the countries that produce it. It is expected that in countries that have greater investment in Fatigue and FFF, there will also be a greater number of publications. The map in Figure 5 shows the countries with the greatest contributions to the topic.

Figure 5: Country Scientific Production
Country Scientific Production



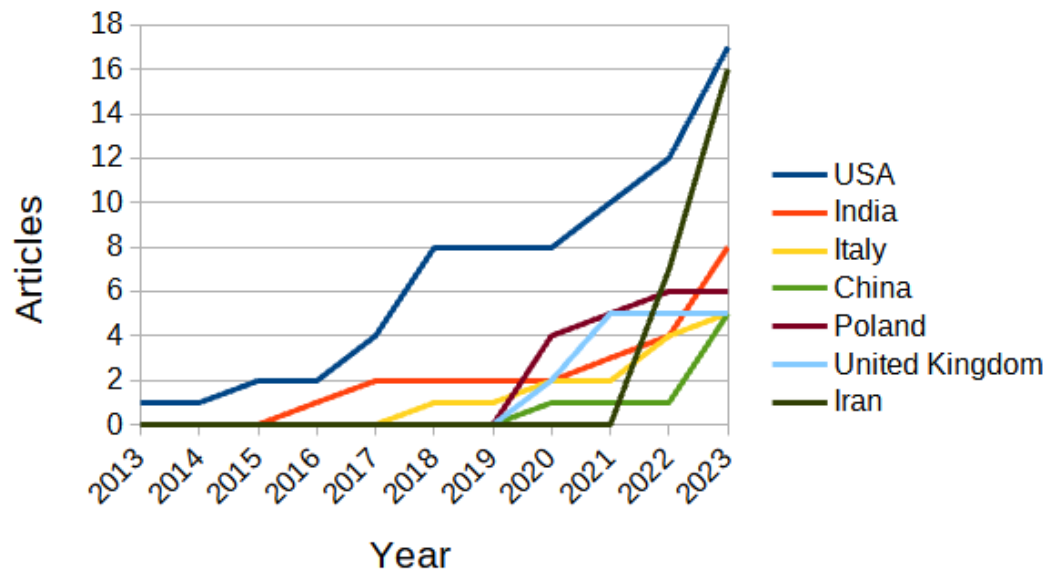
The United States leads the ranking of productions in the area, which was already expected, as it is an economic and scientific powerhouse. However, second place was Iran, followed by India and some European countries. China appears in fifth, despite being the second largest economy in the world, while Brazil only has one publication in the area in question.

Iran, as a large oil producer, has a robust industry in the area in question (6). Therefore, ABS material becomes attractive, as it is a petroleum derivative. India, on the other hand, boasts a burgeoning industry characterized by inexpensive labor and the manufacturing of plastic products, factors that could have contributed to the expansion of research in the field (7). Despite China's status as a country responsible for 32% of global plastic production, its reported results fell below expectations, and it did not emerge as one of the major contributors to scientific advancements in the field (8). Another country that presented a negative surprise was Japan, like Brazil, with only one published material. Given its advanced automotive industry, akin to China, higher scientific production in the ABS field was anticipated. However, the production method and the Failure phenomenon can be impediments that reduce the country's results. In addition, the high use of ABS is not necessarily related to the adoption of the FFF process, which is often a more specialized process with less industrial applications. On contrary, Germany presented a high scientific production in the area, like Japan, it has a highly developed automotive sector, in addition to being an example in several other sectors of Engineering and this may have been an influence on the development of related research (9).

Despite the large amount of production in the countries, there is not much collaboration between them. The only country that has more than one exchange is Iran, which has four projects developed with Norway, one with the Czech Republic and one with Germany.

The growth of scientific production over the years by country serves to further clarify what was previously discussed. This information can be seen in Figure 6.

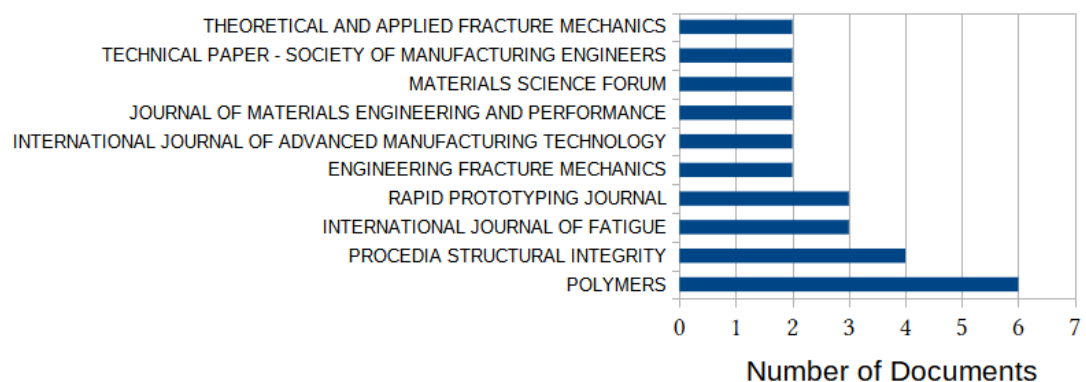
Figure 6: Country Over Time



Most countries have shown similar growth over the years. Iran, however, demonstrated a huge leap in scientific production in the area.

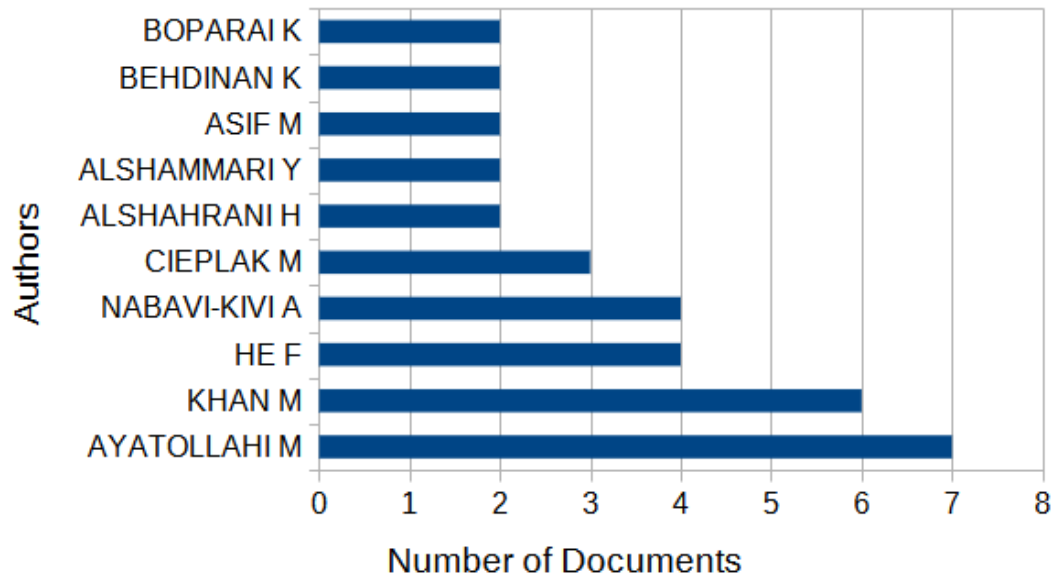
There are several papers with the possibility of publication on ABS obtained by FFF on fatigue. Typically, they will have one of these three areas as their main characteristic. Figure 7 shows the main sources for this case.

Figure 7: Most Relevant Sources



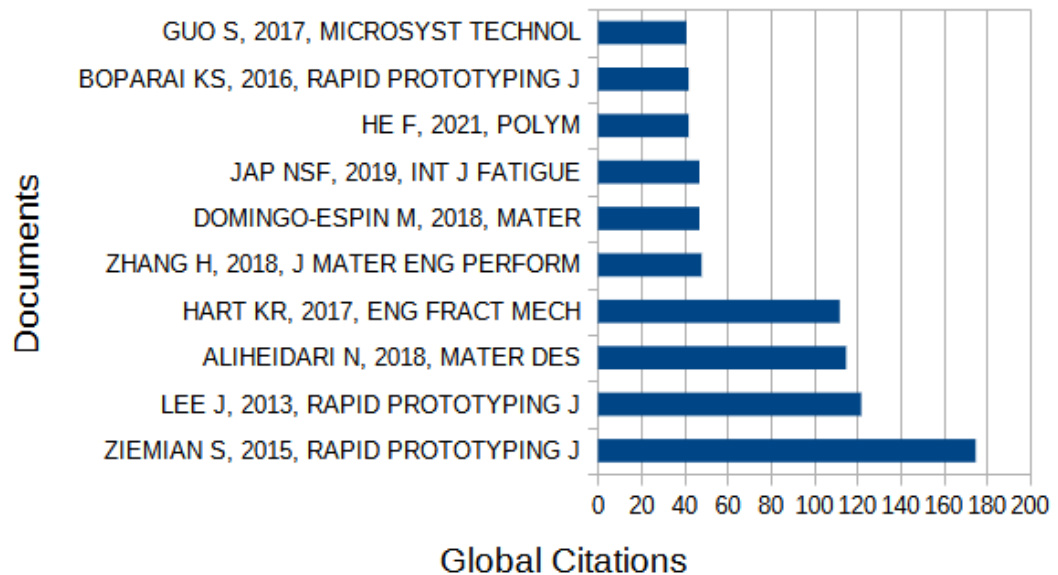
The number of publications by the author often exceeds the number of publications in entire countries. This information can be seen in Figure 8.

Figure 8: Most Relevant Authors



However, an author with a large number of publications does not necessarily have a work with many citations. The number of citations can be seen in Figure 9.

Figure 9: Most Global Cited Documents



Note that Ayatollahi M. which appears first in Figure 8 does not appear in the citation graph. The large number of citations is probably due to the scope and quality of the work.

Ziemian et al. (2015) developed a fatigue test on ABS with different filament directions, in addition to showing microscopic images of the tested specimens. The high citation index, in turn, is possibly due to the same reasons as the previous article, added to the tabular display of test data in the article in question, which opens the door for reworking.

Lee and Huang (2013) developed work that considered the directions of ABS filaments in fatigue. One of the points that may have been crucial in the high number of citations is probably due to the title, "Fatigue analysis of FDM materials", in which there was no limitation regarding the material used.

Aliheidari (2018) did work focusing on the variation of printing parameters in the behavior of the material, using mechanical tests and microscopic images for this. Like Lee and Huang (2013), he used a generic title, "Interlayer adhesion and fracture resistance of polymers printed through melt extrusion additive manufacturing process", which was probably decisive in the high number of citations.

Hart (2017), in addition to the filament directions, the crack-tip also varied. Note again the use of a generic and non-limiting title, "Fracture behavior of additively manufactured acrylonitrile butadiene styrene (ABS) materials", opening the possibility of a greater number of citations.

CONCLUSIONS

The results showed that the choice of words must be made precisely, not using "3d print*", for example, would have restricted the search, showing limited results on the subject.

The map of countries with the most publications in Fatigue in ABS produced by FFF demonstrated the great cultural influence of the place. In addition, the realities and characteristics of each country directly influence their scientific production. An example of this is Iran, possibly influenced by the production capacity of petroleum products. However, although there is a co-citation network, the number of countries working together is limited.

The area studied has demonstrated high growth in recent years, even with the apparent influence of the COVID-19 pandemic. This demonstrates that the growth in applications of polymers, specially produced by FFF, has reverberated in the academic world.

Finally, it was possible to realize that the relevance of a work is not linked to the quantity of work that the author produces but is probably related to the quality and scope of the work.

The use of generic and non-limiting titles seems to be quite relevant in the number of citations of the work. Furthermore, as expected, older articles also show a higher number of citations.

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