# تأثير تركيز الألياف الزجاجية على الخواص الميكانيكية لنيلون 6,6 معد بالحقن في قوالب

إعداد: د. أسماء مصباح سعيد ، سميه مصباح سعيد ، إبراهيم رمضان عياد
كلية الموارد الطبيعية العجيلات ـ جامعة الزاوية

**الملخص :**

مادة البوليمر بدون تقوية بالمواد المحسنة هي مادة صلبة لكنها ضعيفة نسبيا، والتي يتم تعزيزها بواسطة مواد محسنة مثل صفائح دقيقة من الزجاج مما يجعلها أقوى وأكثر صلابة. تعتمد مادة البوليمر المحسنة على الخواص الميكانيكية لكل من الصفائح المضافة والمادة بدون الصفائح، وحجمها بالنسبة لبعضها البعض، وطول الصفائح واتجاهه في المادة. يحدث تعزيز المادة بحكم تعريفها عندما تُظهر المادة بعد الإظافة قوة أو مرونة متزايدة بالنسبة لقوة المادة ومرونتها وحدها. يعد نايلون 6,6 واحدا من أكثر النايلون شيوعا، فقد كانت رائدة في مجال الصناعة لأكثر من 70 عامًا. مادة نايلون 6,6 لديها تطبيقات لا حدود لها مثل العلب وربط الكابلات لمكونات السيارات المعقدة. توضح هذه الورقة التغير في خصائص الجودة الميكانيكية وخصائص المرونة في النايلون المقوى بالألياف الزجاجية، بعد إجراء برنامج تجريبي على المادة باستخدام الصفائح الزجاجية، وبدون استخدام الصفائح الزجاجية، بنسب مئوية مختلفة 0%، و 30%، و 50%، في نايلون 6,6 لتحسين الخواص الميكانيكية وسلوك العلاقة بين الإجهاد والإنفعال وتحسين المقاومة ضد الانشقاقات. تم تحضير العينة المختبرة في هذا البحث بواسطة ألة تشكيل اللدائن بالحقن في قوالب. في ضوء النتائج التي تم الحصول عليها من التجربة، يستنتج أن كلاً من الصفائح ومادة البوليمر يمكنهما الاحتفاظ بخصائصهما الفيزيائية والمادية وأنهما يوفران مزيجًا من الخصائص التي لا يمكن تحقيقها عندما تعمل هذه المواد بمفردها. والنتيجة تشير إلى أن استخدام صفائح االزجاج ميكانيكيا تزيد قوة النايلون المقوى بواسطة الصفائح الزجاجية.

# The Effect of Concentration of Glass Fibres on the Mechanical Properties of An Injection-Molded Nylon 6,6 (Zytel)

Assma musbah said, Somia mosbah said, Ibrahim Ramadan Ayad
Zawia University Ejelat-Libya

## Abstract

The polymer material without fibre reinforcement is a tough but relatively weak plastic that is reinforced by stiffer stronger reinforcing fibres. A fibre reinforcement polymer FRP depends on the mechanical properties of both the fibre and material without fibre, their volume relative to one another, and the fibre length and orientation within the matrix. Reinforcement of the matrix occurs by definition when the FRP material exhibits increased strength or elasticity relative to the strength and elasticity of the matrix alone. Zytel is one of the most versatile of nylons, it has been an industry leader for more than 70 years. Zytel has limitless Applications from gearbox housings and cable ties to complex automotive components. This paper exhibits the change in the mechanical quality properties and flexibility properties of glass fiber reinforced nylon (Zytel). An Experimental program was done with and without utilizing glass fibre in various rates 0, 30, and 50 percentages in nylon 6,6 (Zytel) to enhance the mechanical properties, stretch strain conduct and arrangement of splits. The tested sample in this work was prepared by two-shot injection molding. In light of the outcomes acquired from the trial comes about the conclusion is that both fiber and Zytel can hold their physical and substance properties and they deliver a blend of properties that can’t be accomplished when these segments are acting alone. The result is refers to that using glass fibre mechanically enhanced the strength elasticity of nylon fibre-reinforced plastics.

**Key words -** fibre reinforcement, nylon 6,6, injection molding, polymer, shrinkage.

## 1. Introduction

Fiber-reinforced polymer is a composite material made from a polymer matrix reinforced with fibres. The fibres are usually glass in fibre glass, carbon in fibre carbon reinforced polymer and basalt or aramid. fibre-reinforced polymer are commonly used in the aerospace, automotive, marine, and construction industries. Characteristically, because of variety in temperature small cracks will be available in polymer materials. In addition, solid experiences low rigidity, constrained flexibility and little protection from splitting; the materials will create splits because of plastic shrinkage, drying shrinkage and different reasons also.

The polymer is generally manufactured by addition polymerization or step growth polymerization. When combined with various agents to enhance the material properties of polymers, those types of polymer that result from bonding two or more homogeneous materials with different material properties to derive a final product with certain desired material and mechanical properties. The reinforced of glass fibres in matrix shows higher compressive strength than plain matrix. The fibres interlock and trap around aggregates significantly decrease the workability, while the mix becomes more cohesive and less prone to segregation [3]. The fibres improves the resistance towards shrinkage and creep movements of reinforced.

Glass fiber reinforced (GFR) are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between them, and protects them from environmental damage. In fact, the fibres provide reinforcement for the matrix [2,3].

Glass fibres can be incorporated into a matrix either in continuous lengths or in discontinuous (chopped) lengths [3]. GFR provides an ideal system for achieving the durability requirements of new constructions. This research study investigated the characteristics of GFR with varying percentage of addition to nylon 6,6 Zytel. The objectives of the research work was to study the properties of zytel with varying percentages of addition of glass fibers 0.0 %, 30 % and 50 % the samples was made by injection molding. The following Tables 1 to 3 illustrated main properties of nylon 6,6 30 % fiber reinforced.

Table 1. Physical and mechanical properties of nylon 6,6 30% fiber reinforced [2].

| | |
|---|---|
| Density ( g $cm^{-3}$ ) | 1.4 |
| Flammability | HB |
| Limiting oxygen index ( % ) | 22 |
| Water absorption - over 24 hours ( % ) | 1-5 |
| Hardness – Rockwell | M100 |
| Elongation at break ( % ) | 5 |
| Izod impact strength ( J $m^{-1}$ ) | 120 |

Table 2. Thermal properties of nylon 6,6 30% fibre reinforced [2].

| | |
|---|---|
| Coefficient of thermal expansion ($x10^{-6}$ $K^{-1}$) | 30-60 |
| Heat-deflection temperature - 0.45MPa (C) | 257 |
| Heat-deflection temperature - 1.8MPa (C) | 252 |
| Thermal conductivity 23C (W $m^{-1}$ $K^{-1}$) | 0.23 |
| Upper working temperature (C) | 80-200 |

Table 3. Chemical resistance of nylon 6,6 30% fibre reinforced [2].

| | |
|---|---|
| Alcohols | Good |
| Acids – dilute | Poor |
| Acids – concentrated | Poor |
| Alkalis | Good-Fair |
| Greases and oils | Good |
| Aromatic hydrocarbons | Good |
| Halogenated Hydrocarbons | Good-Poor |
| Ketones | Good-Poor |
| Halogens | Poor |

The relationship between the mechanical properties of the composite and those of the fibers, the matrix and interfaces is complex and depends on the statistical distributions of the fiber lengths as well as fiber orientations [4]. These components require dimensional stability and mechanical properties which depend heavily on the ability to transfer stress across fiber-matrix interface. So, a strong interface generally leads to the best composite properties. According to the studies of Thomason a comparison of the mechanical performance of injection moulded long and short glass fibre-polypropylene compounds; the comparison of these systems has been made over the 40 wt% fibre content range; at the same fibre concentration and diameter, fibre content long glass fibre gives significant improvements tensile and flexural strength in room temperature. It also gives increasingly higher modulus over short glass fibre as the strain is increased. [4,5], and Shao-Yun Fu [10] has accorded similar result, there are other variables such as fiber diameter, and orientation that have an effect on the thermoplastic composites properties. Typically injection molded samples structure rely on the fiber orientation [4,6]. During injection molding processes and extrusion compounding, progressive and continuous changes in fiber orientation throughout the molded components take place. The changes are related in a complex way to the size and concentration of fibers, the flow behavior of melted polymer matrix, the mold cavity and the processing conditions. An orientation distribution generally requires a three-dimensional description. However, when investigating the effect of the fiber orientation angle on the strength of short-fiber composites, only the angle, θ, between the fiber axis and the loading direction needs to be considered [6].

Injection moulding is an important technology and it is the most common manufacturing technique for plastic components, its capability of producing high precision, complex components with an excellent surface finish makes it ideal for automotive and aerospace components as well as electrical parts and housings e.g. computer enclosures and mobile phone cases; other applications are fittings, tool handles, crates and containers.

## 2. Experimental procedure

### 2.1 Sample preparation

The sample was preparing by injection molding, there was number of stages for injection molding as following:

1. Material granules from the hopper feed into the heated barrel and rotating screw.

Material melted by heat, friction and shear force is forced through a check valve to the front by the rotating screw [7,8].

2. Materials moved backwards by the shot of material at the front, the screw was forced forward by a hydraulic ram. This action injects material into the mould cavity in the closed mould tool, Fig 1.

3. The tool is held closed under pressure until the plastic material cools and sets hard in the mould tool cavity. This is often the longest part of the injection moulding process, as showing in Figure 1.

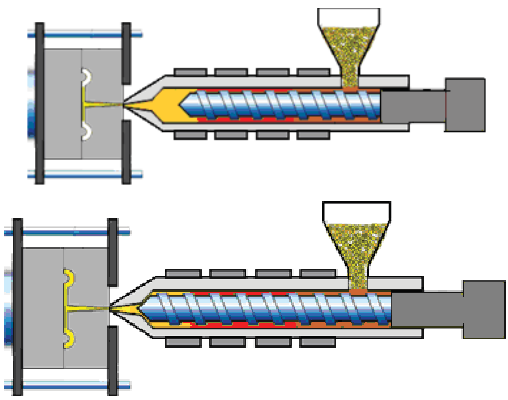

Fig 1. Schematic of the shot of material at the front, and the tool is held closed.

4. The screw starts to move back for the next moulding. The tool then opens and the finished plastic part is ejected the shape of products depends on the mold design as will illustrate in mold design section. The tool is closed and the injection moulding process starts again at 1, as showing in Figure 2.

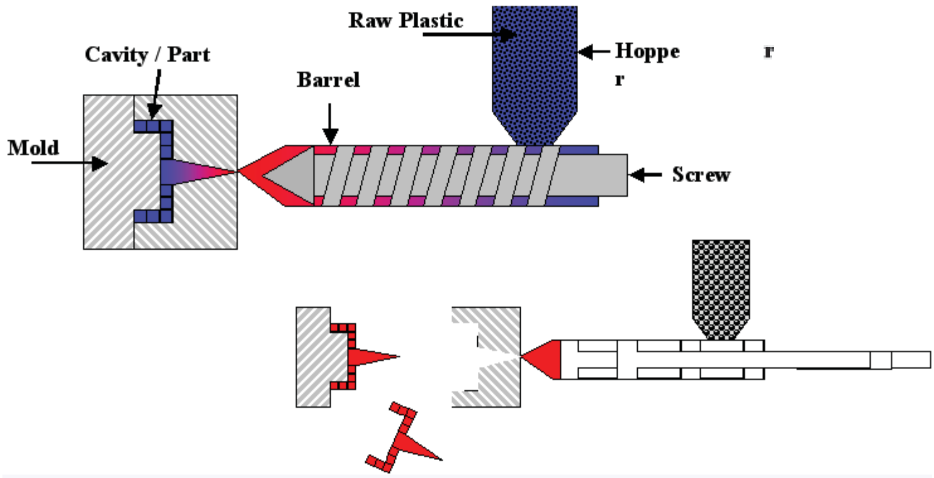


Fig. 2. Schematic of a typical injection molding machine; the tool opens and the finished sample is ejected [8].

## 2.2 Mold design

The mold design depends on the needed shape, as in Fig 3.

.Mobile phone cases

Thin-wall protects diving glasses spoons and forks

Fig 3. The mold design with different shapes.

Thin-wall technology is a recently developed and cost-effective plastic design technology. Using thin-wall technology is not only saves material due to reduced wall-thickness; it also needs short time for cooling which, helps optimize cycle time. The reduction of component thickness is limited by the following conditions:

- Knowing the material including its mechanical and, in particular, rheological properties, thin-walled components can be produced by injection moulding.
- In thin-wall technology, requirements have become more stringent regarding part design and processing compared to conventional injection molding processes.
- With The loss of rigidity as a result of reduced wall thickness can be compensated using glass-filled materials.
- Using these materials in combination with proper flow behaviour, E-modulus and, consequently, rigidity can be increased.

**2.3 Part design**

Reduced rigidity as a consequence of reduced wall thickness is usually compensated by using stiffening ribs. Unfavourable rib design, however, may result in sink marks visible on the outer surface. If excellent surface finish is required optical an appropriate rib/wall thickness ratio is necessary. In contrast to standard injection molding, there are further differences in thin-wall technology regarding component design:

- Molding draft angle: The draft angle must be increased by a value between 0.5 $^{o}$ and 1° depending on surface structure and depth of the texture.
- Shrinkage: The level of shrinkage depends on the material used, and a great extent determined by the filling pressure and wall thickness.

**2.4 Gate concept**

The gate concept is an important in thin-wall technology. The processing window of the plastic largely depends on type, position and geometry with regard to the production of high-quality articles. Therefore, also a gate system designed by means of rheological filling simulation for thin-wall technology.
Aside from temperature and shear, the following parameters must be observed

- flow path
- filling volume
- pressure
- pressure distribution

**2.5 Mold temperature control**

It is very important to reduced cycle time; the cooling system must be designed as to evenly conduct melt heat out of the mold within a short time

**2.6 Processing**

In order to reduce the filling pressure, however, it is usually recommended to increase melts temperature as far as possible within an acceptable range. In connection with a long melt residence time in the barrel, this can lead to critical material reduction. In order to avoid freezing effects during the filling process, the injection time is rather short. In case of cellular phone covers, standard injection times are <0.5s. Figures 4-6 illustrated injection moulding machine and diagram of injection cycle.

Fig 4. Injection moulding machine with gas assisted injection, Battenfeld beam robot, and Polymer Insights intelligent process monitoring, polymer engineering laboratory at Bradford University [9].

Fig 5. Fanuc Roboshot 50 tonne servo-electric injection moulding machine with Fanuc 5-axis robot. Polymer engineering laboratory at Bradford University [9].

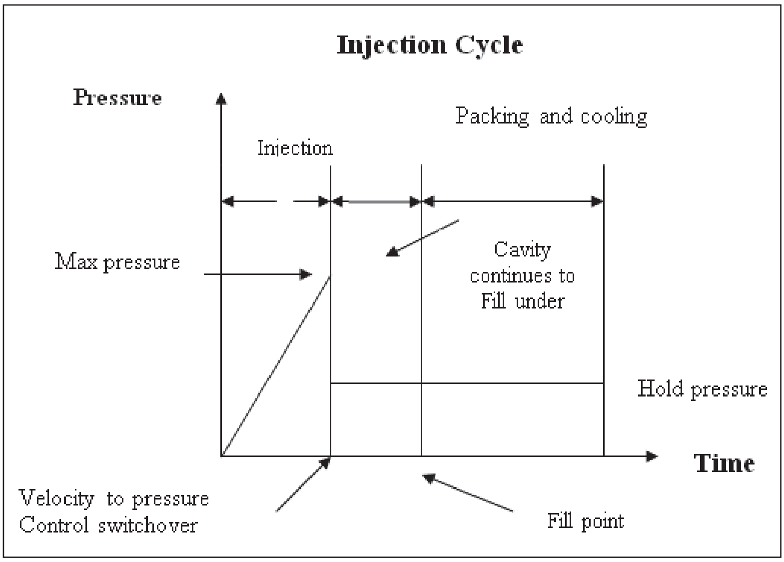


Fig 6. Diagram of injection cycle.

## 3. Results

The trial examinations are directed so as to contemplate the compressive strength and stress-strain conduct of different parameters on nylon 6,6 (Zytel) with and without glass fiber. Effect of glass fiber on strain at ultimate; from the graphs Fig. 7 and 8, it was observed that, fibres improve strength and strain capacity compared with zytel without fibre. The following diagram is about typical relationship between pressure and time.

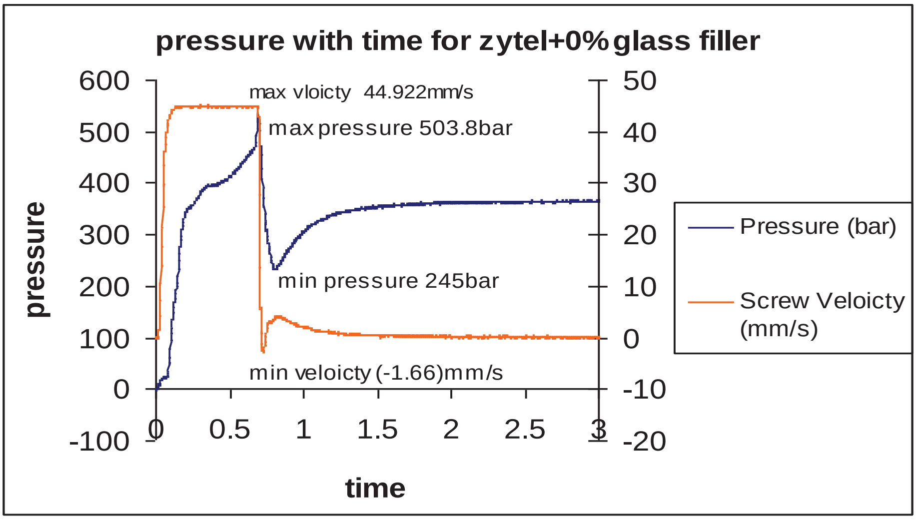


Fig 7. Curve illustrates relationship between pressure and time for nylon 6,6 with time for zytel with 0% glas filler.

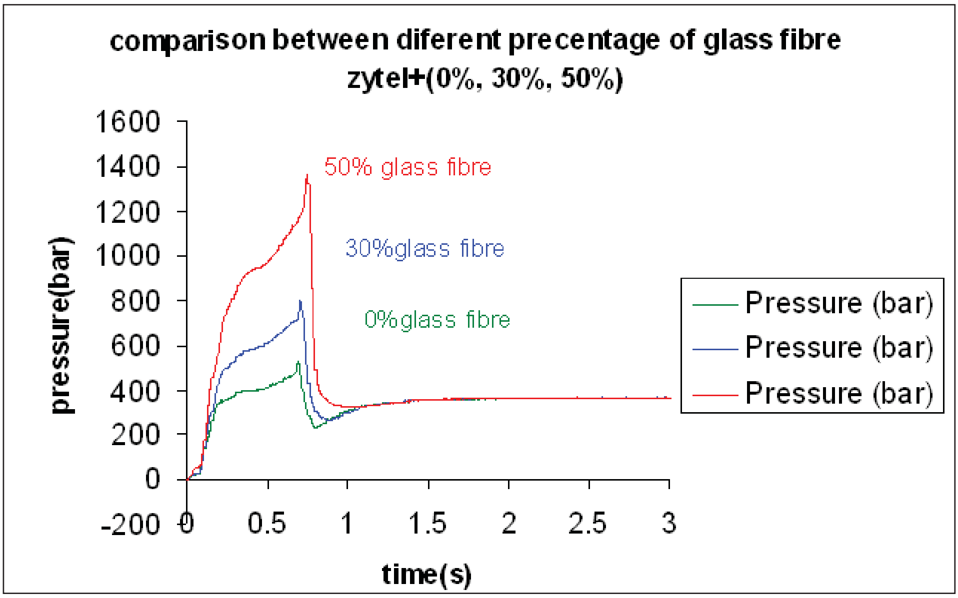


Fig. 8. Comparison between zytel with different percentage of glass fibre (0%, 30%, and 50%).

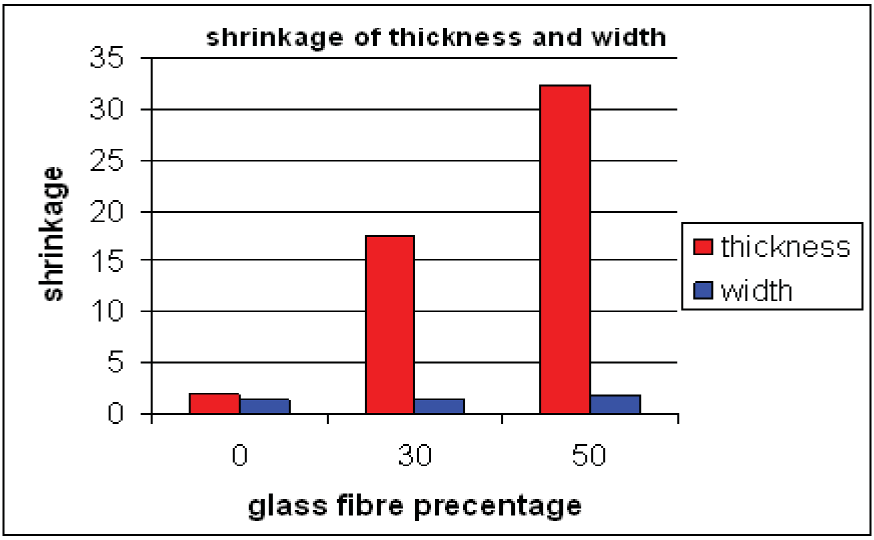


Fig 9. Comparison of shrinkage between three different nylon with different percentage of glass fibre (0%, 30%, and 50%).

GFR specimens have shown improved deformation capacity after reaching ultimate load. As the percentage of fibre increased, deformation, i.e. strain at breaking has increased. Compressive strength - From Fig. 7 to Fig. 9 indicates that with the addition of glass fibre, the pre-peak loading portion of the load-deflection curve changes very slightly, but the post peak loading portion of the load-deflection curve becomes less steep, which resulted in a higher ductility of the material. Also as the percentage of fibre increases, the compressive strength increases.This result is agreed with the concluded of Tasnim *et al.* [4] and Shao-Yun Fu [6]. In addition it indicates that with the addition of glass fiber in the outer shell of the cubes the compressive strength is gradually increased with increased percentage of fiber, a similar result has been concluded by Karacaer *et al.* [2,10].

## 4. Conclusion

This investigation comprise of testing specimens comprehend the improvement of compressive strength, stress strain quality of nylon 6,6 (Zytel) with various rates of fibers. Compressive strength of material is expanded with the expansion in level of glass fibres of the three fiber substance, i.e., 0.0%, 30% and 50%, Example with 50% gave higher increment in strength than the other two. It is noticed that change in strength and strain of glass fibre reinforced example past extreme quality expanded with increase in fiber. This may be due to the fact that the fibers in outer shell have contributed to confinement; also confinement effect can be realized only after reaching ultimate strength. Hence it can be concluded that GFR specimens have demonstrated enhanced disfigurement limit subsequent to achieving extreme load. In addition for different way to process it, the modern ways is complex, to give more soft, more resistance to environment, but the principle way is simple injection molding, and its properties depend on choosing material and processing.

## 5. References

[1] R. E. Smallman, R. J. Bishop. Modern Physical Metallurgy and Materials Engineering. Oxford. A division of Reed Educational and Professional Publishing Ltd, 1999.

[2] Goodfellow. polymind nylon 6,6 30%glass fibre reinforced material information. available on: http://www.goodfellow.com/E/Polyamide-Nylon-6-6-30-Glass-Fibre-Reinforced.html [1-12-2016]

[3] Kiran kumar poloju, chiranjeeevi rahul, vine the anil. Glass fiber reinforced concrete (GFRC) - strength and stress strain behavior for different grades of concrete. International Journal of Engineering and Technology. 2019.

[4] Tasnim Kossentini Kallel, Rym Taktak, Noamen Guermazi , Nizar Mnif. Mechanical and Structural Properties of Glass Fiber-Reinforced Polypropylene (PPGF) Composites. Tunisia. 2017.

[5] J.L.Thomason. The influence of fibre length and concentration on the properties of glass fibre reinforced polypropylene: 5. Injection moulded long and short fibre PP. ScienceDirect. 2002

[6] Shao-Yun Fu and Bernd Lauke. Effects of Fiber Length and Fiber Orientation
Distributions on the Tensile Strength of Short-Fiber-Reinforced Polymers. Composite Science and Technology 56 1996.

[7] Injection molding onlin. Injection Molding. available on: http://www.injection moldingonline.com/Molding101/InjectionMolding.aspx. [12-05-2019]

[8] Ashis Gopal Banerjee. Computer Aided Design of Side Actions for Injection Molding of Complex Parts. University of Washington Seattle. 2006.

[9]P. D. Coates. Polymer engineering research, Mechanical & Medical Engineering/ IRC in Polymer Science & Technology. Bradford university. 2000.

[10] Özgül Karacaer, Tülin N Polat, Arzu Tezvergıl, Lippo V.J Lassıla, Pekka K Vallıttu, Docent. The effect of length and concentration of glass fibers on the mechanical properties of an injection- and a compression-molded denture base polymer. The Journal of Prosthetic Dentistry, Since direct. 2003.