USAGE OF SHEAR THICKENING FLUID TO ENHANCE THE IMPACT PROPERTY OF KEVLAR FIBERS WITHIN A COMPOSITE MATERIAL

Dhuha T. Abdalkadhem [1]
Dhuhatalib676@gmail.com
[1] Department of Materials College Engineering, University of Kufa, Iraq

Dr. Moayed A. Albozahid [2]
moayad.zahid@uokufa.edu.iq
[2] Department of Materials College of Engineering, University of Kufa, Iraq

ABSTRACT

In the current work, multi-layers were manufactured based on epoxy polymer using Nano Graphine and aramid (Kevlar) fiber as fillers.

Nano Graphine was added by 1, 2, 3 wt% to the epoxy matrix and the Kevlar sheets were embedded within these composites. The die casting process is used to prepare the composite plate with thickness of 3mm.

To improve the performance of Kevlar fibers, these fibers impregnated in the shear thickening fluid (STF), which is composed of fumed Nano silica and polyethylene glycol (PEG). By using ultrasonic dispersion method to dispersion nano particles into the composite and then preparation the sample ,some mechanical (tensile strength, impact strength, and hardness test) According to our findings, the best result was for (2%wt Gnps) the tensile, impact strength, and hardness values 260.2 MPa, 51.194 kJ/m2, and 69.5 MPa, respectively, by soaking these fabrics with shear thickening fluids we observe improve the mechanical properties for the composite materials for the 2%wt Gnps percentage (tensile strength, impact strength, and hardness) are (290.9 MPa, 77.82 kJ/m2, and 72.22 MPa) respectively.

KEYWORDS: graphene; epoxy; kevelar fibers; silica fume, peg, tensile strength; impact strength; hardness.

INTRODUCTION

A composite material is described as a mixture of two or more insoluble components that come together to form a new, usable material having attributes that the component parts do not have like airplane structures, marine bodies, and lightweight armor for ballistic

protection in military applications. This is because of their exceptional mechanical qualities, adaptability in design, simplicity in manufacture, and strong resistance to corrosion, wear, and impact [1-3].

When two or more materials that are significantly dissimilar in terms of their physical and chemical makeup are combined, composite materials are produced. The interaction between the several elements produces the particular characteristics of the composite. By laminating a fibrous material with fibers that are oriented alternatively to give the material strength and stiffness, an advanced composite material is created Composite materials fall into one of two categories [4]:

1. Particle-Reinforced Composites

The reinforcement of particle is one of the types of composite materials, which has great importance through its effect on most of the final properties of the products such as the reinforcement of epoxy by graphene [5].

This kind is one way to create a composite material with good mechanical and isotropic qualities by randomly dispersing it throughout the underlying material and reinforcing it. Filling in the gaps relies on several factors, including the dimensions of the main particle, the surface area, and the interaction between the base and filler molecules as well as their interface. [5].

The addition of minuscule particles to a brittle matrix is accompanied by an increase the toughness due to the difficulty of growth crack through the added particles, in the case of adding particles that high rigidity to the flexible matrix will increase the hardness of matrix and decrease flexibility of adding carbon black to rubber [6].

2. Fiber-Reinforced Composites

It is one of the types of composite materials where phase reinforcement is fiber, it is filament structures with distinctive shape and special properties that strengthen the matrix phase. Fiber-reinforced composites have exceptionally high ratios of stiffness to weight and strength to weight. Excellent fatigue behavior, corrosion resistance, durability, and dimensional stability are additional noteworthy advantages of composites. steadiness. Materials for reinforcing fibers are frequently made of carbon, ceramics, metals, and glasses. The fiber may exist in forms that are discontinuous or continuous [7]. The composite's aspect ratio, fiber orientation, and processing state all affect its performance, in general that the key to the success of composite materials is the transfer of stress from the base material to the reinforcement phase, this depends on the adhesion between the fiber and the base material [8].

Because of its excellent thermal properties, including high Tg and thermal stability, and good dynamic energy absorption characteristics, Kevlar is used in ballistic protective clothing to ensure the safety of the ballistic structure at a relatively high temperature in the

event of a ballistic impact. [9].

Scientists are working on developing liquid armors, which would have fewer layers yet still be just as strong as existing armors, but with more flexibility and less weight. Shear thickening fluids are impregnated into these textiles to generate liquid armors. [10].

A subclass of smart fluids known as shear thickening fluids (STFs) exhibit non-Newtonian fluid behavior, and have increasing viscosities with shear stress applied. Even at the highest levels, the fluid exhibits solid-like behavior due to shear stress. Fluids return to their original liquid behavior after the tension in the medium is removed, as seen in figure (1) [11–12].

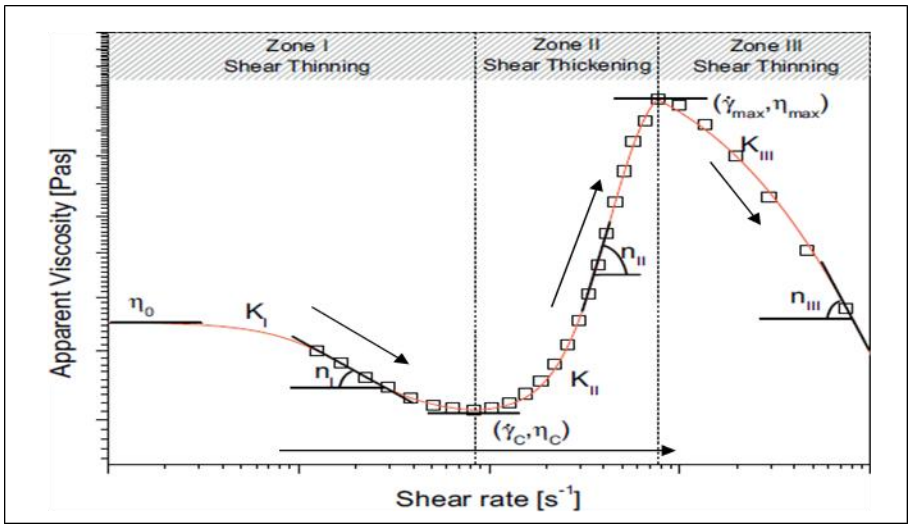


Fig. (1) Typical Viscosity Curve of A Shear Thickening Fluid [13]

Because of their distinct rheological reactions, STFs exhibit certain mechanical qualities, which makes them perfect for damping and shock-absorbing applications. Because of this capability, STFs are employed to enhance impact-resistant materials, such liquid armor or sporting goods. [14].

STFs are essentially made by combining a liquid polymer with a filler that is nanoscale in size. The typical materials utilized in STF manufacturing is corn starch and polyethylene glycol(PEG) with Nano fumed silica which have high surface area when compared with silica [15].

Polyethylene glycol works as carrier fluid for filling material in shear thickening fluids, the rheological properties of shear thickening fluids can be controlled by adding carrier fluids. As illustrated in figure (2), polyethylene glycol can adsorb onto the filling material's surface through adsorptions, increasing the hydrodynamic diameter of the colloids and the suspension fluid's viscosity. [16].

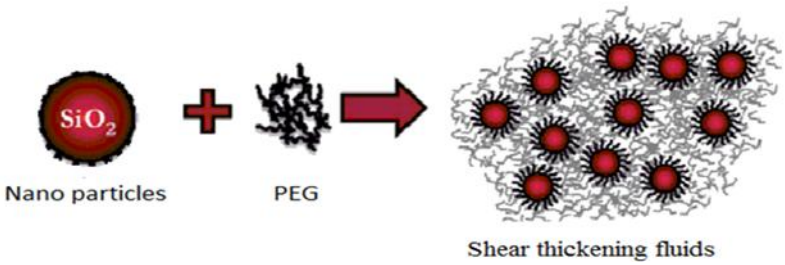


Fig. (2) Show The Adoption of PEG on Surface of Nano Silica [15]

In the manufacturing of impact-resistant materials, including as coatings, reinforcing, and STF formulations, fumed silica particles are employed. It is created when silicon tetrachloride is hydrolyzed in an oxyhydrogen gas flame. Through this process, silicon tetrachloride fused into the fundamental particles that will eventually agglomerate—those that are branched and chain-like. Primary particles are bonded to one another through hydrogen bonding as a result of the surface chemistry and chain-like morphology, which creates a network structure. [16].

Figure (3) depicts the untreated fumed silica, an amorphous, hydrophilic material with a high surface area and a very low bulk density. Because of the hydroxyl (-OH) groups that make up about 40% of its surface, it is hydrophilic. The fumed silica's special shear thickening ability is also a result of these groups. [17].

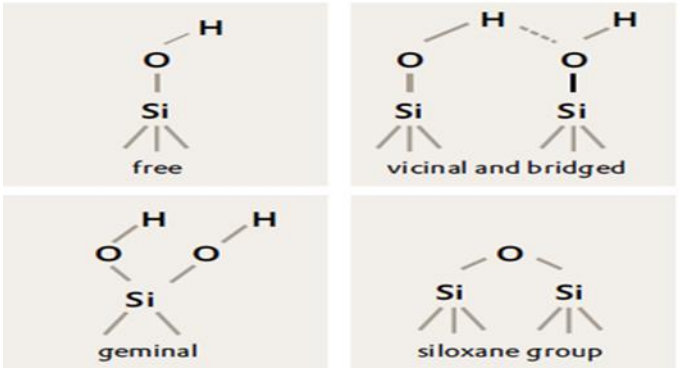


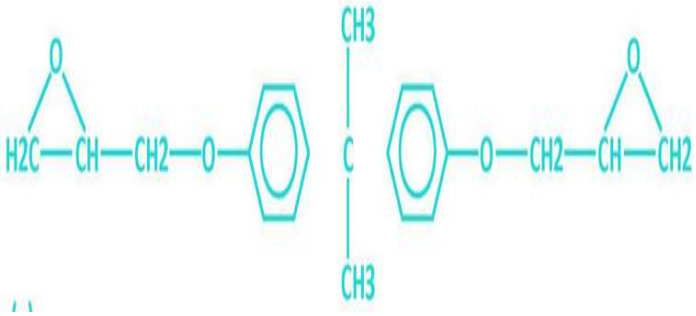
Fig. (3) Possible Surface Groups of Hydrophilic Silicas [15]

1. Experimental work

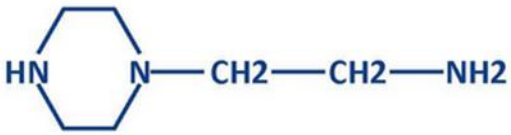
2.1 Materials Used and equipment

Epoxy resin (Renksan - Renfloor HT 2000) with a density of 1050(Kg/m^3), hardener to it with a ratio of 2:1, and Graphene about (6-8)nanometers in thickness, Polyethylene Glycol (PEG) , silica fume , keveler fibers ,Sensitive balance, Magnetic stirrers, mechanical stirrers, ultrasonic waves and ultrasonic bath.

(a)



(b)



(c)

"Fig. 4", Materials Used ((a) kevelar fiber (b) Epoxy, (c) hardener.

2.2 Preparation Epoxy/Graphene/Kevelar nanocomposites

Graphene powder was utilized as a filler material to create epoxy/graphene nanocomposites. weight percentages of Gnps (1,2,3)wt% were added to epoxy resin to reinforce it. Gnps were first weighed before being distributed in acetone at a ratio of 1(g): 50(ml) (Gnps: Acetone). At room temperature, the mixture was agitated for 15 minutes using an ultrasonic wave, and for another 30 minutes, it was churned using an ultrasonic bath. After adding epoxy resin to the mixture and mixing it for six hours at a low rotor speed of 300 rpm with a mechanical mixer, the mixture was heated to 78 C to eliminate any remaining acetone. In order to eliminate the bubbles, the mixture was lastly degassed in a vacuum chamber at ambient temperature for five minutes after the hardener was added and manually stirred for two minutes.

Then Cutting the Kevlar neat as square pieces, Greasing the mold to prevent adhesion of epoxy with mold, The resin is prepared from an epoxy and graphene mixture, Pour the mixture into the mold by Using a glass mould, Leave the sample to dry for 24 hours, and then heat it inside an oven at 70 C^o(curing of epoxy) After drying samples, cut them according to ASTM & ISO standards to use in tensile, hardness, , and impact tests.

(a) (b)

"Fig. 5", equipment and sample (a) final sample, (b)tensile sample

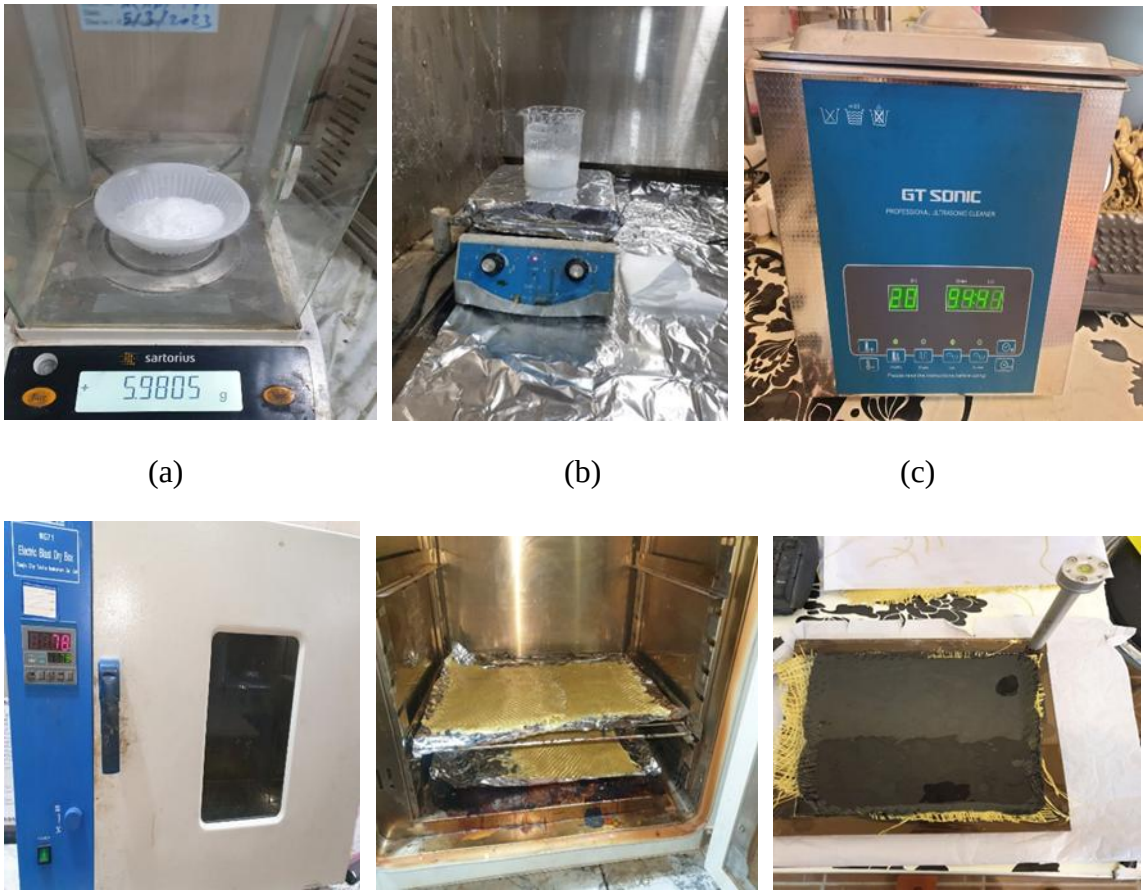
2.3 Preparation of Aramid Fabric/ STF Composites

Initially, the process of preparation of STFs is dispersing silica fume in ethyl alcohol". The particles mixing in a plenty of alcohol (ethyl alcohol: silica fume, 6 ml:1 g) to obtain a stable and dispersed solution, as well as alcohol to reduce the surface tension of the STFs and increase the impregnation of the fiber. Initially mixed by a magnetic stirror for 3 hours to dispersion of silica fume and absorption of ethyl alcohol by silica and then placed in the ultrasonic path device for 5 hours at 60% amplitude.

The ultrasonic mixer works to complete the dissipate silica and gives a better homogenization of the solution "Following this, PEG is included into the solutions at weight fraction so as to fix the fumed silica/ PEG concentrations (25,30, 35)w/wt % and The ultrasonic disperser was used for four more hours.". "The dishes were filled with the solution. and placed in the drying oven with a temperature of 78oC until remove all the ethyl alcohol from the solution and get the STFs.

The temperature was maintained at 78 oC, which is ethyl alcohol's boiling point, in order to prevent distortions in the STFs' microstructural system and to guarantee quasi-static drying. By expanding the surface area of the dishes, the evaporation time was shortened. "Preparation of fibers saturated with STFs, to begin STFs were diluted with ethyl alcohol to improve the fabric coating. The use of STFs with 35 weight percent silica concentration was shown to yield the optimum impact resistance characteristics, based on the rheological data. Aramid textiles were divided into 20 x 20 centimeter sections. "Each of the seven layers of fabric was soaked in the diluted STF solution to saturate it for

twelve hours. "After that, fabrics were baked to dry." And then composite production of aramid fabric /STF After the fibers were treated with STF, we use the same previous method to obtain the composite material with a 2% graphene percentage because we obtained the best properties at this percentage. After drying samples, cut them according to ASTM & ISO standards to use in tensile, hardness, and impact tests.



(a) (b) (c)

(d) (e) (f)

Fig. (6): Preparation of Aramid Fabric/ STF Composites ((a)weigh the silica fume (b) magnetic stirrer, (c) dispersing silica fume in ethyl alcohol, (d) drying oven ,(e) drying fibers (f))final sample

3. Results and Discussion

3.1. Tensile Test Results

Curves of stress and strain for samples of the composite plate with and without Nano graphene platelets are seen in figure (7). This figure shows that an increase in the Nano graphene will enhance the tensile behavior of the material and the best behavior of the stress – strain diagram is for a sample that is includes 2% of graphene platelets. This improvement in tensile properties is because of Nano graphene's excellent tensile characteristics which gives more strength and stiffness to the material after curing

complete.

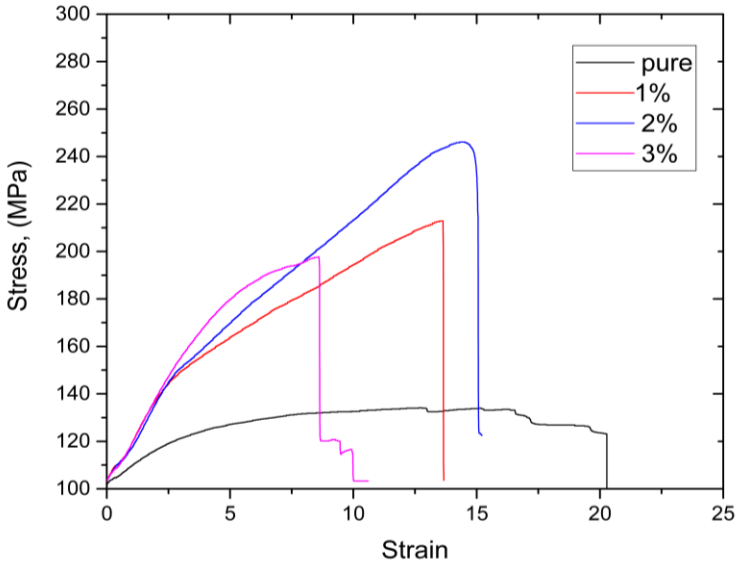


Fig.7 stress-strain curve

Were The tensile strength of composite samples represented by the table 1

Table (1) show Tensile Strength Results

No.	Sample type	Experimental results(Mpa)
1	With out graphene	105
2	1% graphene	218
3	2% graphene	260.2
4	3% graphene	199

After conducting tests on the 2% percentage after treating it with STF, it is noticed an increase in the mechanical properties, stress-strain curve as shown in the Fig. 8

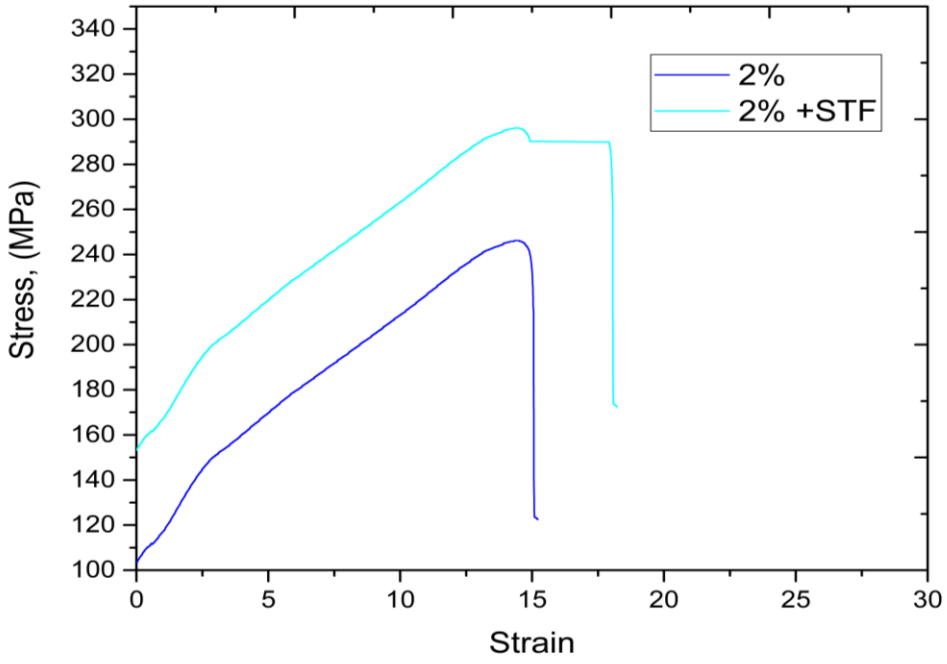


Fig. (8). curve of(stress-strain),(2%,2%+stf)

Table (2) show the tensile strength results

No.	Sample type	Experimental results(Mpa)
1	2% graphene	260.2
2	2% graphene+stf	280.5

3.2. Impact Test Results

Table (3) show the Impact results, the impact strength of the tested sample at various ratios of Nano graphene. These results showed an increase in the impact strength for composite samples with an increase in the Nano graphene platelet's ratio,The impact strength was 51.194 kJ/m2 for 2% Nano graphene. The effect of Nanographene's existence to improving the impact strength is attributed to the high impact strength property of platelets.

Table (3) show the Impact results

No.	Sample type	Experimental results KJ/m^2
1	With out graphene	23.24
2	1% graphene	46.324
3	2% graphene	51.194
4	3% graphene	34.055

After conducting tests on the 2% percentage after treating it with STF, it is noticed an increase in the mechanical properties

Table (4) show the impact results

No.	Sample type	Experimental results kJ/m^2
1	2% Graphene	51.194
2	2 % Graphene+stf	79.34

3.3.hardness Test Results

Table (5) show the hardness results that the sample's Shore-D hardness value increased significantly. It was observed that there was high surface finish. The samples of pure epoxy and nanocomposites epoxy with graphene had a hardness value of 50.3, but at 2 weight percent, it rose to 69.5. This suggests that greater graphene supply leads to improved bonding and durability, which is consistent with Ref [16]

lowering the hardness levels to 58 at a 3 weight percent ratio The brittleness of the sample may be the cause of the observed fall in hardness

Table (5) show the hardness results

No.	Sample type	Experimental results KJ/m^2
1	With out graphene	50.3
2	1% graphene	63.3
3	2% graphene	69.5
4	3% graphene	58

After conducting tests on the 2% percentage after treating it with STF, it is noticed an increase in the mechanical properties

Table (6) show the hardness results

No.	Sample type	Experimental results kJ/m^2
1	2% Graphene	69.5
2	2 % Graphene+stf	78.80

3.4.viscosity test

The best concentration of fume Silica is 35 % for STFs because it give high viscosity and low shear critical, therefore it is suitable to rise the mechanical properties of fabrics , Table (7) displays the maximum viscosities of all synthesized STFs as well as their viscosities at critical shear rates.

Table (7) “Steady Rheological Specifications of STFs

Sample	Critical shear rate	Viscosity at Critical shear rate(pa.s)	Max. Viscosity(pa.s)
PEG25%	34		65.24
PEG30%	23		192.12
PEG35%	17		5710

Conclusion

Adding of Nano graphene of 2%wt. will increase the impact strength for the composite about 50% ,The presence of Nano graphene will enhance the tensile properties of composite such as tensile strength, modulus of elasticity, with ratios of 40%,50%, respectively.

By incorporating graphene into epoxy resin, we were able to significantly enhance The epoxy composite's mechanical and thermal properties. The results of the tensile, impact, and hardness tests increased to 2%wt graphene before declining once more. The brittleness of the material may be the cause of its reduced impact strength and hardness at 3%graphene.Our results further show that compared to pure epoxy, the synthesized epoxy composites include more stable Nano-graphene.

After conducting tests on the 2% percentage after treating it with STF, we notice an increase in the mechanical properties, tensile strength increase to280.5, impact 79.34 and hardness78.80.

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