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Study the Effect of the Shape of the Laser's Path on the Mechanical Properties of Acrylic Layer

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Abstract

The study examined the reinforcement of the mechanical properties of acrylic by using a laser's path following three different functions without additives. The laser Paths are created by using a laser ray at different power and speed. The shapes of the path of laser Paths are designed according to different functions and investigate their effect on the acrylic micro-structure. The study investigated the influences of the crack shape caused by the laser, the laser's power, and speed on the mechanical characteristics of the acrylic layer. The study predicted mathematical equations of crack shape functions f_1, f_2, and f_3 while the equation F(z) described the empirical results as a relationship of laser power and laser speed with tensile stress. The maximum increase of stress due to the crack shape functions f_1, f_2, and f_3 was 22.94 %, 19.08%, and 28.24 % at the different laser power and laser speed.

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Keywords: Mechanical properties, Laser ray, Crack functions, Laser power, Laser speed..

Nomenclature

e :Engineering strain
L: Is the initial measuring length (mm).
ΔL:The variation in length's gage (L_f- L_o) , (mm).
L_f :The final length, (mm).
L_o : The initial length, (mm).
F: The tensile force (N)
A:is the initial crosssectional area (mm^2).
f_1:The laser path's function has a slope (41°).
f_2:The laser path's function has a slope (29°).
f_3:The laser path's function has a slope (24°).
f_4, f_5 *and,* f_6: The equations describes the relationship of the empirical results at different laser speed and power.
CW: Clockwise motion.
O : Original acrylic samples of tensile test without crack.
A: is the samples with crack shape function (f_1) at various laser power of 40 watts, 50 watts, and 60 watts, and various laser speeds of 15 mm/sec, 30 mm/sec, and 45 mm/sec.
B : is the samples with crack shape function (f_2) at various laser power of 40 watts, 50 watts, and 60 watts, and various laser speeds of 15 mm/sec, 30 mm/sec, and 45 mm/sec.
C : is the samples with crack shape function (f_3) at various laser power of 40 watts, 50 watts, and 60 watts, and various laser speeds of 15 mm/sec, 30 mm/sec, and 45 mm/sec.
τ_{max} : Maximum shear stress (MPa).
σ : The stress (MPa).

1. Introduction

At present, Acrylic material is one of the essential materials that will be used in many future applications. On the other side, laser applications have taken a wide range in industry, structures, and technology field processes, in addition to using of lasers for polymers and heat treatments. They showed the influence of the laser beam on NiTi at the midline that achieves better transmission in the microstructure, which leads to acceptable mechanical properties without introducing interlayers [1]. Cladding techniques are widely used to modify the surface microstructure and properties of alloys [2,3],including the cladding using the laser, which showed some useful future properties [4-6]. First, it is a simple, green, economical, and efficient process, which can improve the corrosion resistance of the surface coating [7, 8]. Second, it can improve the metallurgical bond between the coating and the substrate [5, 9, 10], so that the size of the heat-affected zone (HAZ) is usually small [5, 11, 12].The study showed that increasing the laser scanning speed enhances the shift from planar crystals to dendrites and purifies the grains simultaneously[13]. They studied the optimal conditions for the desired microstructure on the surface of the H13-TiC composite at a scanning speed of 12 mm/sec, a pulse width of 9.96 ms, and an operating distance of 5.94 mm[14]. They examined the improvement of the mechanical properties of the coating by changing the composition of the alloy powders by studying the improved internal structure and mechanical properties of the nickel-based composite coatings[15]. Laser cutting of metal and non-metallic materials depends on the energy of the laser ray focused on a specific point in the material to be cut. The laser ray is 0.1 to 0.4 mm in diameter and the ray energy required for cutting depends on the thickness of

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the material, in which the material is heated to the melting or evaporation temperature. [16-18]. Examined to get better of the mechanical characteristics of acrylic through variation of the speed and power of the laser at one specific path. They investigated the influence of the laser's ray energy and speed on improving the mechanical features [19]. They studied mechanical features under high-pressure conditions and high-temperature conditions and needs to the reinforcement of the mechanical features through the laser[20]. The study used Taguchi's method for optimum cutting conditions for acrylic material, cutting speed, feed rate and cutting tool angle [21]. The study carried out a finite element analysis that was adopted to simulate penetrating welding using a polycarbonate laser ray to facilitate the selection of appropriate process parameters to obtain suitable welding [22]. The study analysis was based on building a digital model for the welding process using a type (CO_2) laser ray for the thermoplastic polymer material to determine the appropriate factors for practical testing [23]. They investigated the preparation of a mathematical model for selective laser sintering (SLS) for a polymer material that has good strength properties that can be achieved taking into account the processing factors (laser speed, density, and energy)[24]. The study analysis of crack initiation on plates is limited by variable hole dimensions. The researchers performed the analysis for the crack initiation of the panels involving variable perforations (circular, ellipsoid, and rectangular). The study concluded that the influence of the hole shape and its dimension that must be taken into account when calculating the fracture factors [25]. The study investigates the improvement of the impact energy of acrylic by a core of composite material reinforcement consisting of a metal mesh of different shapes with polyester resin of different diameters [26]. The investigation depends on composite material of natural fibers from agricultural waste with epoxy to improve mechanical properties such as tensile and flexural strength [27]. The study investigated the effect of fiber orientation reinforced by graphite and epoxy on improving mechanical properties such as dynamic transverse shear stress of the composite [28]. The study investigated the polyester composite material reinforced with fiberglass and the effect of temperature on the creep stress on the behavior of the viscoelastic of the composite material and the measurement of the Poisson ratio, which indicates the amount of improvement in the properties of the composite material [29]. Compared to the previous papers that focus on improving the properties, what characterizes the present study is adopting specific laser paths to work on the dispersion of the stress concentration in the material under stress as in the study of Raed N. and Ahmed S. [19], which saves time and cost instead of using the laser to harden the entire surface of the sample's material. Adopting specific laser paths opened the horizon to focus on designing laser paths to disperse internal forces and improve the failure resistance of these products without any additives. The aim of the present study is to upgrade the mechanical features of acrylic by depending on the influence of the laser's ray on its internal structure and without additives by depending on the design of three new lasers' paths and their influence on the dispersion of the internal concentration's forces at different laser speeds and powers.

2. Theoretical methodology

The uniform stress intensity exposed to the body leads to internal stress in it. To illustrate these internal stresses, we will take a hypothetical section of the body in which the stress changes according to the cutting angle of the body, the stress in perpendicular cutting as in Figure 1-a is equal to [30]:

$$\sigma_1 = A_1.F \tag{1}$$

while, when changing the angle to45 degrees to cut off the body as in Figure 1-b, the stress will be redistributed again to be[30]:

$$\sigma_2 = A_2.F \tag{2}$$

And since $A_2 = A_1.\sqrt{2}$

The stress will decrease to be equal to [30]:

$$\sigma_2 = \frac{F}{A_2.\sqrt{2}} \tag{3}$$

The tensile force is recorded as an indicator of the increase in gauge length when drawing the relationship between the tensile strength and the tensile elongation, which has a small value, if they were not normalized with the dimensions of the sample. Engineering stress, or nominal stress, (σ), is defined as [31]:

$$\sigma = \frac{F}{A} \tag{4}$$

The engineering strain, is defined as,

$$e = \frac{\Delta L}{L} \tag{5}$$

The total elongation is, $\Delta L = L_f - L_o$. A stress-strain curve; an identical curve in the figure can be drawn with the force elongation curve. The dependence on the stress-strain curve is an alternative to the forces-elongation curve because the stress-strain curve is independent of the sample dimensions. With failure due to fracture, new surfaces are created (i.e. fracture surface) with the start creating of the crack at surfaces. The kinematics cannot be described simply, and therefore, depend on the empirical results to describe them [31]. According to the Tresca theory, it is now considered a different kind of failure. As the material deforms in a more complex manner with the development of the measurement

of slip deformation of visible bands. The bands are called Lüders (slip) bands which apply to ductile steels and other types of metals so that shear bands of more brittle materials. These bands or slips appeared in a material that is subjected to tensile stress at about 45° to the loading direction. The failure occurs in the type of failure to shear when the material is sheared along with those slips at those planes. The assumption is that failure occurs when the shear stress exerted at these slips at the plane is large enough for shear to occur along these planes. In the tensile test, let the applied tension be *(σ)* at the point when the elastic limit (or the yield stress) is reached. In Figure 2, the shear stress is applied to the samples to reach the maximum shear stress that occurs at

an angle of 45 degrees from the loading axis according to the equation below [31]:

$$\tau_{max} = \frac{\sigma}{2} \tag{6}$$

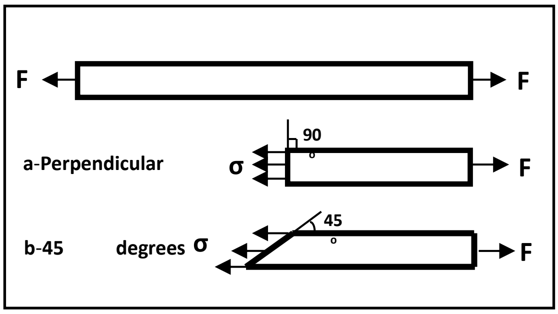


Figure 1-a and b. Illustrate the internal stresses Perpendicular angle and 45 degrees angle of a hypothetical section of the body

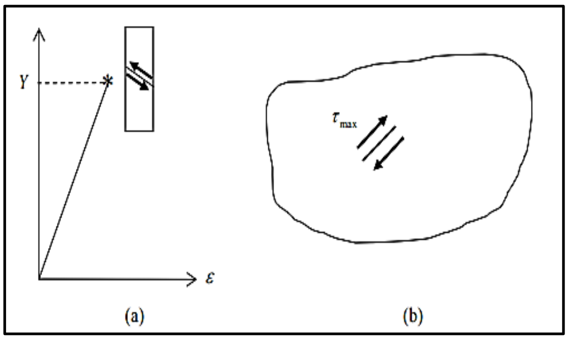


Figure 2. Failure through shear; (a) stress-strain curve in a tension test, (b) shear failure in a three-dimensional component [31]

In the present study, Figure 3 shows the stress concentration in the test sample and the influence of the curve of the laser path. The curve contributes to the analysis of the forces on it and its dispersion along the path of the laser ray. The dispersion of forces strengthened the material's resistance to breakage, which is in agreement with the behavior of the material described by Piaras Kelly [32] .

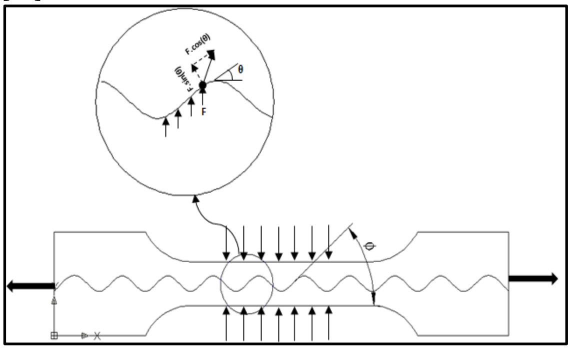


Figure 3. The stress concentration on the tensile sample and the dispersion of the forces on the curve of laser path

Figure 3 shows the idea of the study in dispersing the stress on the curved paths of the laser path, which affected the internal structure of the sample, which contributes to reducing the vertical stress that leads to failure and thus enhancing the sample's resistance to fracture. So, the study takes into account Tresca's theory assuming that the movement of a slide in the direction of a shear stress plane at an angle of 45o in the microstructure of the material., and investigates changing the direction of movement of slides by using different laser paths according to specific equations. The slope of the equations specified for the slit of the laser with the tensile stress axis at angles 24°, 29°, and 41°. Changing the direction of these slips increases the material's resistance to failure, which means increasing the material's resistance to failure without reinforcing it with another material. The research has adopted three crack path functions f_1, f_2, and f_3 produced by a laser ray as follows:

$$f_1 = 3 * Sin\left(\frac{x}{1.7} + 6.3\right) \tag{7}$$

Where the equation's wave of laser path (f_1) has a slope with an x-axis angle of about 41°

$$f_2 = 3 * Sin(\frac{x}{3.2} + 6.3) \tag{8}$$

Where the equation's wave of laser path (f_2) has a slope with an x-axis angle of about 29°.

$$f_3 = 3 * Sin(\frac{x}{3.6} + 1.5) \tag{9}$$

Where the equation's wave of laser path (f_3) has a slope with an x-axis angle of about 24°.

The length of the path of laser path is determined by the following equation [33]:

$$L = \int_a^b \sqrt{1 + (\frac{dy}{dx})^2} \, .dx \tag{10}$$

The length of the path of the laser follows the laser's path shape functions f_1, f_2, and f_3 determined by the following equations:

$$L_{f_1} = 3.5 * \int_0^{2\pi} \sqrt{1 + (f_1'(x))^2} \; dx \tag{11}$$

$$L_{f_2} = 2 * \int_0^{2\pi} \sqrt{1 + (f_2'(x))^2} \; dx \tag{12}$$

$$L_{f_3} = 1.6 * \int_0^{2\pi} \sqrt{1 + (f_3'(x))^2} \; dx \tag{13}$$

Where, the laser's path lengths of f_1, f_2, and $f_3$are approximately equal to57mm, 47mm, and 42 mm respectively.

3. Material and Methods

The samples were made from acrylic layers used in the industrial field and cleaned with alcohol to prepare them for tests to measure mechanical properties at different parameters such as variation of the laser's path, the speed of the laser, and its power.

3.1. Materials

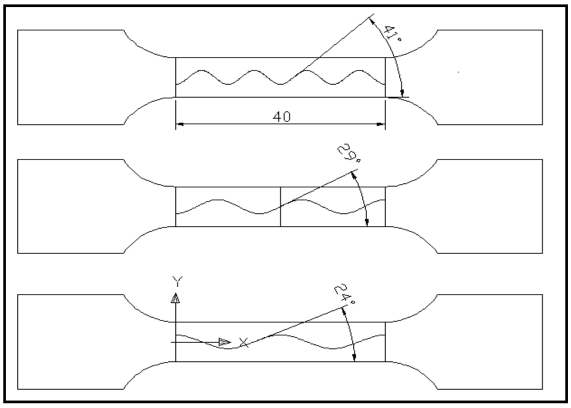
The empirical test used an acrylic layer with properties as shown in Table 1 to prepare tensile test samples for studying the influence of the functions of the laser's path on the mechanical properties. Acrylics are used widely in typical applications due to being lightweight, rigid, weather resistant, and more impact-resistant than glass, etc. [34] and tourist submarines [35] The shape functions of the laser ray have adopted three different functions for contributing to the re-distribution of the stresses in the samples through subjecting the tensile. The tensile test samples are prepared according to different laser path functions by using the (CNC) laser machine. The laser rays power is used to form different crack functions at different laser power with continuous ray type CO_2 at 40 watts, 50 watts, and 60 watts. The laser Machine properties consist of work dimensions (140 cm *190cm), maximum power of 80 watts, and a distance from the laser lens to the sample of 6.5mm.The laser speed of creating the crack functions by laser ray for tensile samples according to three different functions of the laser's path at different speeds 15 mm/ sec, 30 mm/sec, and 45 mm/sec.

Table1. The characteristics of Acrylic layer [21].

Properties	Therm. Expan. μ^{-6}/K	Thermal. Conductivity W/m.K	Specific heat J/kg.K	Glass transition temp. °C	Density kg/m^3	Shrinkage %	Friction coefficient	Refractive Index
Value	50-90	0.167- 0.25	1466	105	1170 - 1200	0.3 - 0.8	0.54	1.42

3.2. Methods

Tensile testing is important for many reasons, including the results of tensile tests of different materials used for engineering applications. The tensile test is the tool to determine the specifications of materials used for quality assurance of the material, in addition, measuring the tensile properties of different materials is used for developing different engineering materials and to predict the behavior of the material during a tensile test [36]. A laser ray is characterized by having photons of the same frequency, wavelength, and phase, as compared to a normal ray. Hence, the laser has higher energy density and better focusing properties. These unique features of laser rays are useful in the material processing of many industries, types of research, and other fields. The laser ray realizes the possibility of processing various materials and manufacturing processes such as creating cracks, engraving, cutting, heat treatment, and others. The current study depends on generating the crack's paths according to three specific functions which are equations 4, 5, and 6, in which the wave's inclination achieves a variable angle of 24, 29, and 41 degrees as shown in Figures.4-a,b, and c. The tensile samples are prepared from acrylic depending on the ASTM D412 standard. [36] standard of thermoplastic polymers which are commonly produced and distributed in the form of pellets and shaped into the final product form by melting, pressing, or injection molding. Figure 5 shows the drawing of the standard tensile samples by depending on Auto-cad software by transforming drawing files to the (CNC) laser machine for cutting the tensile samples according to their dimensions so that creating the laser's path on samples. Many microscopic images are obtained by microscopic type (Bel) at (X1600). The study used a laser machine to create three types of cracks according to three functions f_1, f_2, and f_3 on one side of the acrylic samples.



Figures. 4 :a- Crack shape according to(f_1), b- Crack shape according to (f_2) and c-Crack shape according to (f_3)

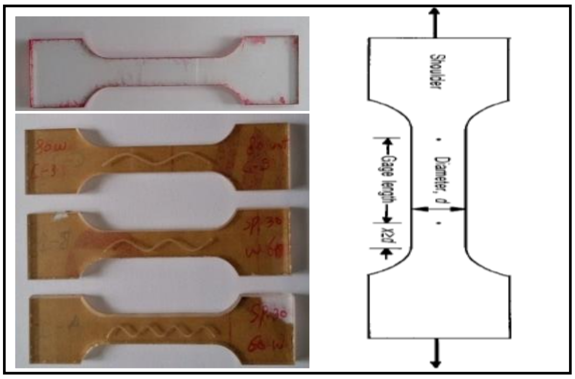


Figure 5. The standard sample typeASTM D412 [36].

4. Results and discussion

The heat generated from laser rays causing to create the crack's edge and its effect on the microstructure in the laser's path zone. The laser path zone works as a reinforcement region to prevent the occurred failure in the acrylic, which has affected the sample's resistance to failure compared to the samples that didn't have a laser path. The various functions of the laser's path shape have slopes at different angles with the loading axis to change the direction of growth of crack failure. The laser paths are achieve the following different functions that contribute to the redirection of the crack's failure for increased material resistance. The equations f_4, f_5, and f_6 describe a relationship between the empirical results at different factors affecting the creation process of the crack's path achieved through the laser ray, such as the laser's power of 40 watts, 50 watts, and 60 watts, and laser speed at 15,30 and, 45 mm/sec respectively on the tensile stress.

$$f_4 = 42420.728 - 8882.325 . z + 767.875. z^2 - 35.07 . z^3 + 0.893 . z^4 - 0.012 . z^5 + 6.664E\text{-}5 . z^6 \quad (14)$$

$$f_5 = 3325.661 - 724.486 . z + 64.847. z^2 - 3.0387 . z^3 + 0.0786 . z^4 - 0.001 . z^5 + 5.892E\text{-}6 . z^6 \quad (15)$$

$$f_6= 4875.614 - 789.812 * z + 52.613 . z^2- 1.839 . z^3 + 0.0356 . z^4 - 0.00036. z^5 + 1.5E\text{-}006 * z^6 \quad (16)$$

The empirical results are described in the general function :

$$F(z)=f_a+ f_b .z+f_c . z^2+f_d . z^3+f_e . z^4+f_g .z^5+ f_h . z^6 \quad (17)$$

4.1. Laser ray effect on crack zone

A topographic scan of the three-dimensional laser path zone is shown in Figures 6,7, and 8 which form an edge extending along the laser path. The images in Figures 6, 7, and, 8 of the topographic scan got by using the PHYWE Atomic Force Microscope device of different paths and conditions of the laser beam. Heating by the laser beam led to a change in the internal structure of the acrylic material due to the effect of laser beam heat along the edge of the tensile samples in the laser path that appear in a microscopic as a form cantilever's shadow is an area that enhances resistance of the growth of the crack, which means an increase in the resistance to failure. Figures 6, 7, and 8 show the effect of the laser paths on the internal structure at different functions of the f_1, f_2 and f_3 crack laser paths generated on acrylic samples, at conditions of power 50 W, speed of 15 mm/sec. The protrusions formed are differently shaped in the microstructure of the acrylic material by the effect of the laser beam in the region of different laser paths at the same conditions of power and speed of the laser beam. The images of the laser paths have zone dimensions (49.5 µm * 50 µm) and have variable depths due to the change in the laser path. The three dimensions images at a speed of 15 m/sec and laser power of 50 watts showed that the maximum protrusion relative to the neutral line was 54.2 nm and the lowest drop was 45,8 nm at f_1 so that at f_2 the maximum protrusion was 161 nm and the lowest drop 96.4 nm while the maximum protrusion is 110 nm and the lowest drop 162 nm at f_3.

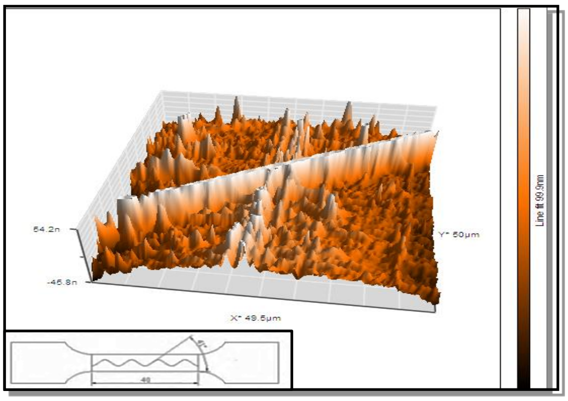


Figure 6. 3D topography scan of the laser's path according function (f_1) at 50 watts and 15 mm/sec.

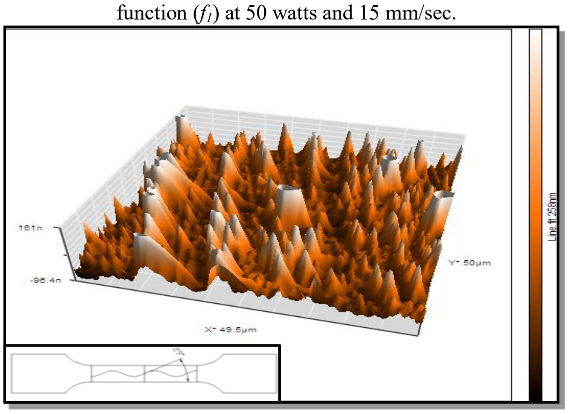


Figure 7. 3D topography scan of the laser's path according function (f_2) at 50 watts and 15 mm/sec.

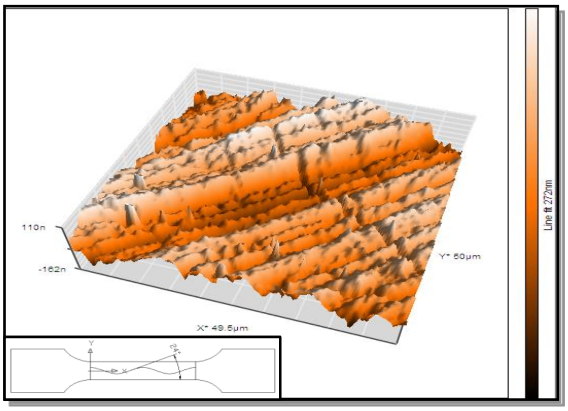


Figure 8. 3D topography scan of the laser's path according function (f_3) at 50 watts and 15 mm/sec.

4.2. Influence of laser's path functions (f_1, f_2,and f_3)

The empirical results in Figure9 showed an increase in the stress with a ratio of 14.66%, 14.45 %, and 14.01 % of samples type A, B, and C of the laser's path according to functions f_1, f_2, and $f_3$at 40 watts and 15 mm/sec. The samples type A, B, and C of the laser's path according to functions f_1, f_2, and $f_3$at 40 watts and 15mm/sec increased at ratios15.01%, 12.33%, and 18.02% respectively compared to samples type (O) as shown in Figure10.

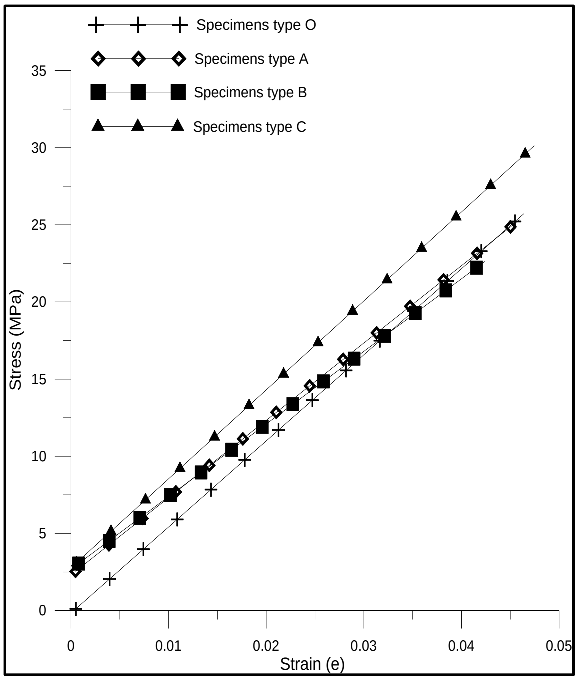


Figure 9. The effect of crack shapefunctions on the tensile testat 40 watts and 15 mm/sec

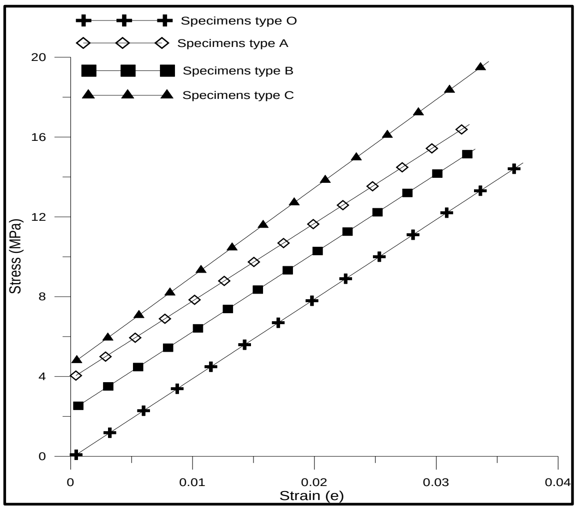


Figure 10. The effect of crack shape functions on the tensile test at 50 watts and 15 mm/sec

The variable influencing the increase in the stress value of Figures 11, 12, and 13 was the increase of the laser's power with the fixing of other factors such as the laser speed and the functions of the crack's path shape. The variation in the microstructure caused by heat-producing from the laser ray along the region of the crack's path formed a zone of resistance to stress concentration. The increase in the stress is a result of the influence of the crack's path function which was created on one surface in tensile samples due to tensile stress resistance by redistributing the stresses resulting from the tensile test along the edge side of the crack. Figure 11 shows the samples type A, B, and C of the laser crack's path shape according to functions f_1, f_2, and f_3 at 60 watts, and 15 mm/sec which increased the stress with ratios of 12.69%, 16.44%, and 18.91% respectively compared to samples type (O) while Figure 12 offers the samples type A, B, and C of the crack's path shape according to functions f_1, f_2, and f_3 at 40 watts and 30 mm/sec which increased the stress with ratios 12.91%, 14.8%, and 19.31% respectively. So, the tensile stress increased with ratios of 14.12%, 11.54%, and 21.91% due to increasing the laser's power by 50 watts as in Figure 13 while increasing at ratios of 14.18%, 19.08%, and 20.39% due to increasing the laser's power 60 watts as shown in Figure 14which compared to the sample type (O).

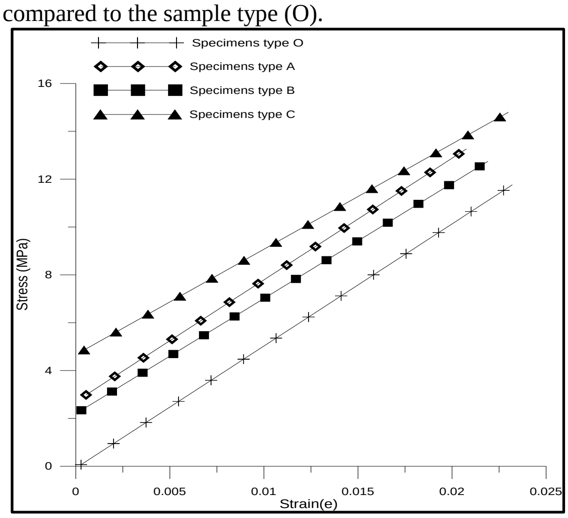


Figure 11. The effect of crack shape functions on the tensile test at 60 watts and 15 mm/sec

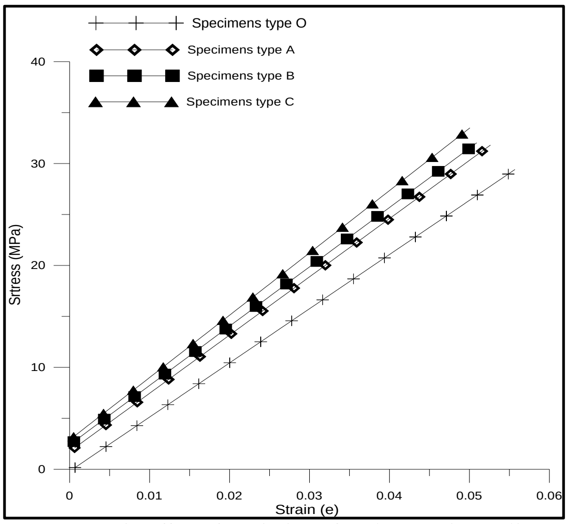


Figure 12. The effect of crack shape functions on the tensile test at 40 watts and 30 mm/sec

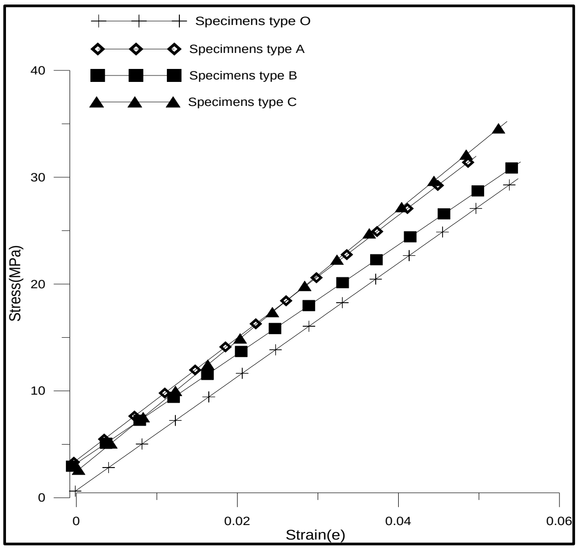


Figure 13. The effect of crack shape functions on the tensile test at 50 watts and 30 mm/sec

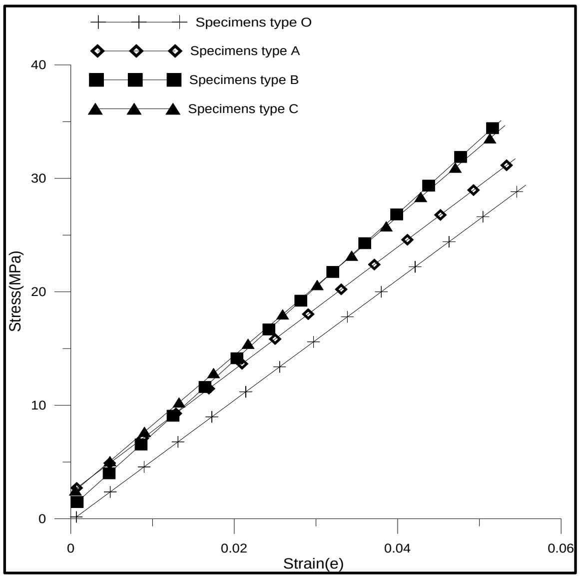


Figure 14. The effect of crack shape functions on the tensile test at 60 watts and 30 mm/sec.

Figures 15, 16, and 17. shows the influence of an increase in the laser's power at a laser speed of 45 mm/sec on the tensile stress which increases the stress with ratios of 17.14%, 20.97 %, and 21.16% due to increasing the laser's power at 40 watts, 50 watts, and 60 watts when compared to sample type (O). Figure 15 shows that at a laser speed of 45 mm/sec and laser power of 40 watts the kind of samples A, B, and C of the laser slit shape according to the functions f_1, f_2,and, f_3 tensile stress increases by 6.94%, 16.26% and, 28.42% respectively compared to the type of sample (O) while increasing by 14.12%, 11.54% and, 21.91% respectively when the laser's power is increased to 50 watts as in Figure 16 In addition, the laser's power increased to 60 watts due to an increase the tensile stress by 22.94%, 16.23% and 24.33% as in Figure 17.

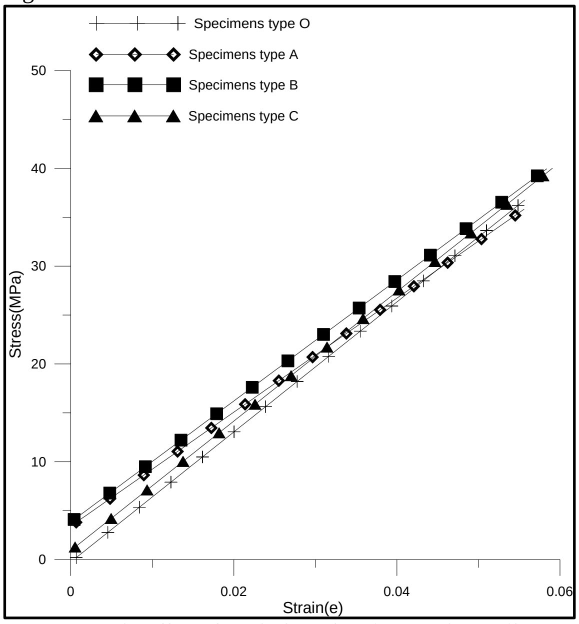


Figure 15. The effect of crack shape functions on the tensile test at 40 watt and 45 mm/sec.

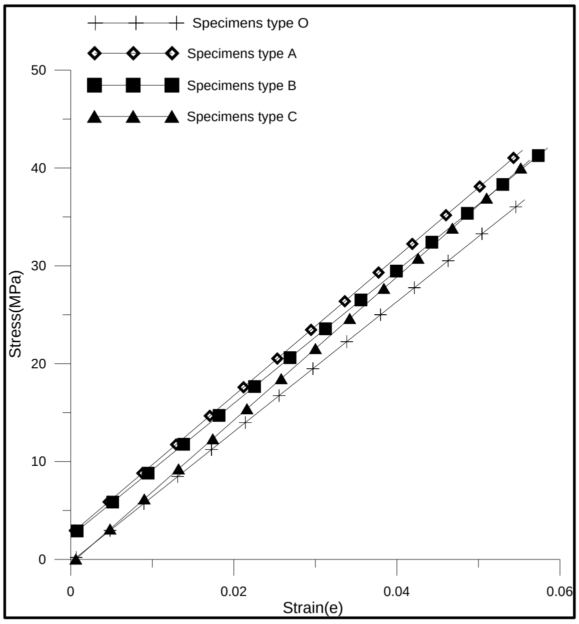


Figure 16. The effect of crack shape functions on the tensile test at 50 watt and 45 mm/sec

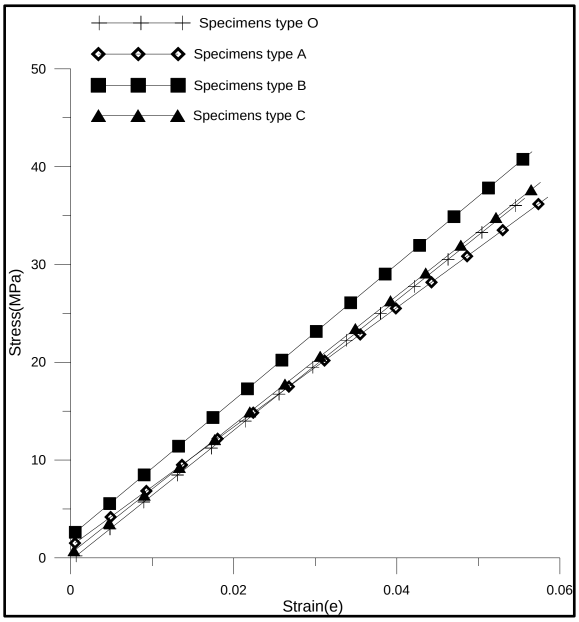


Figure 17. The effect of crack shape functions on the tensile test at 60 watt and 45 mm/sec

4.3. Effect of laser speed on the tensile stress

Increasing the laser speed from 15mm/s to 30mm/s indicates a decrease in the time of exposure of the samples to the laser ray that is focused on the crack zone at a ratio of 50%, which reduces its effect on the microstructure due to the heat produced by the laser ray. Also, the constant speed of the laser ray with the increase in the laser's power on the tensile samples for creating the crack according to specific functions indicates that an increase in the laser's power on the crack zone caused to generate more heating in it, which has a more effect on the micro-structure of the crack zone. Increasing the laser speed from 15 mm/sec to 45 mm/sec increases the stress at different crack's path functions f_1, f_2, and f_3 with an average ratio of 50.44%, 11.12 %, and 48.42% respectively at the power of 40 watts and increasing at a ratio of 13.62%, 30.8%, and 34.71% respectively, at power 50 watts, while the laser's power increases the tensile stress at average ratio 44.66%, 14.94%, and 22.29% respectively at power 60 watts compared to samples type (O). The empirical results offer the influence of the crack shape function through the angle of the path's slope with stress axis and the path's length, where the increase in the laser speed shows an increase in the stress ratio at a wave function f_1 has an angle of 24 degrees compared to a function of type f_2 and f_3 which have a wave that has a higher slope angle and greater length of the wave path. Figures 18, 19, and 20 produce the influence of the conditions of the laser speed at a laser power of40 watts, 50 watts, and 60 watts on the micro-structure of the tensile samples of acrylic.

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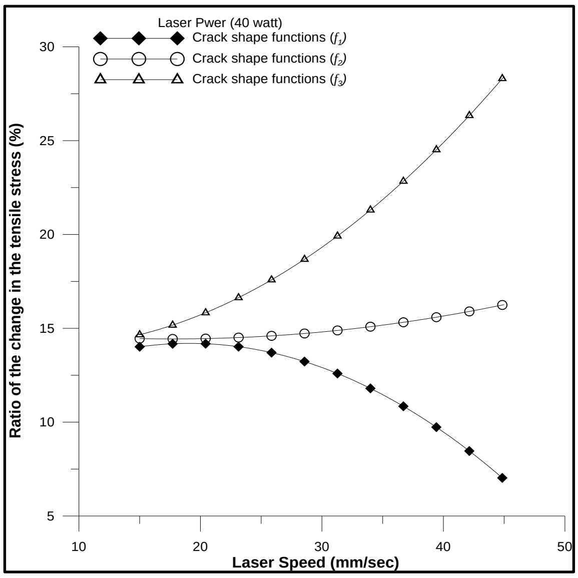

Figure 18. The laser speed and average change in tensile stress of crack shape functions (f_1, f_2, and f_3) at laser power (40 watt)

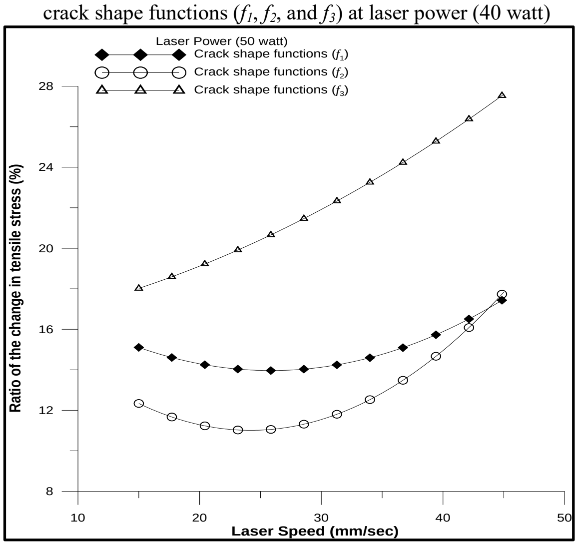

Figure 19. The laser speed and average change in tensile stress of crack shape functions (f_1, f_2, and f_3) at laser power 50 watt

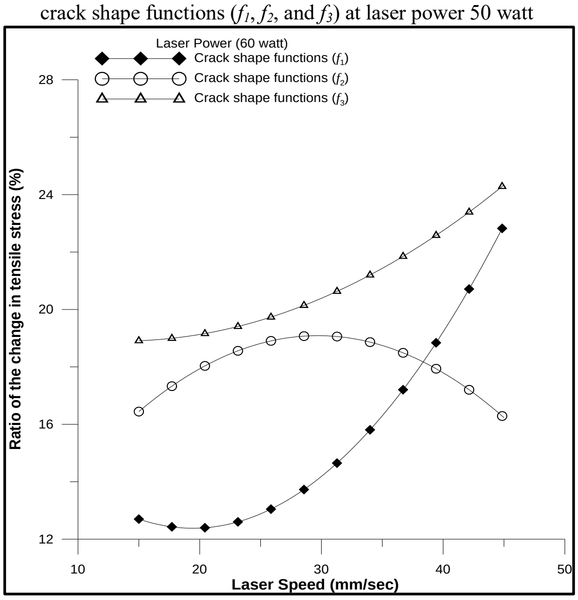

Figure 20. The laser speed and average change in tensile stress of crack shape functions (f_1, f_2, and f_3) at power 60 watts

4.4. Effect of laser power on the tensile stress

Increasing the laser's power from 40 watts to 60 watts indicates an increase in the heating of the crack zone at a ratio of 33.3%, causing to increase in its effect on the microstructure. Also, the specification of the influence of laser power on the tensile stress by taking other factors such as (laser speed and crack shape functions) be constant. The laser's power increases the stress of crack shape functions f_1, f_2, and f_3 with an average ratio of 9.39%, 12.1%, and 22.47% respectively at a laser speed of 15 mm/sec, and increasing at ratios of 8.97%, 22.42%, and 5.26% respectively, at laser speed 30 mm/sec, while the laser's power increasing the tensile stress at average ratio 69.73%, 8.97%, and 14.37% respectively at laser speed 45 mm/sec compared to samples type (O).

The empirical results in Figures21, 22, and, 23 clarify an increase in the ratio change in the stress of a function of type (f_1) with an increase in the laser energy, with a relative confirmation of the change in the stress ratio of the maximum effect in the microstructure composition of the tensile sample of acrylic at the lowest velocity of the laser ray and the type of function crack (f_1) that has the longest path. It increases in the ratio change in the stress until the laser's power50 watts, then it decreases to high laser power 60 watts because it causes a weak point in the structure of the samples and then a structure to the tensile stress due to the high energy and the low velocity of the laser ray which has a longer wave path, While it decreases in the low energy ranges, it increased as there is an implicit factor which is the angle of inclination of the wave 29 degrees, and the path length of the wave is less.

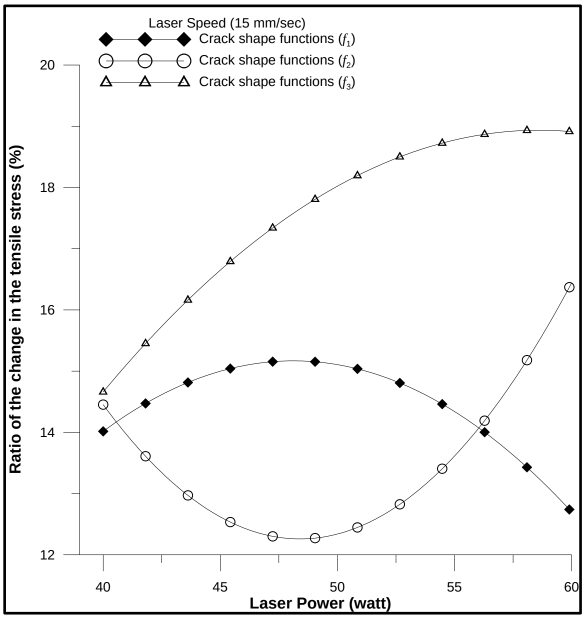

Figure 21. The laser's power and average change in tensile stress of crack shape functions (f_1, f_2, and f_3) atspeed 15 (mm/sec)

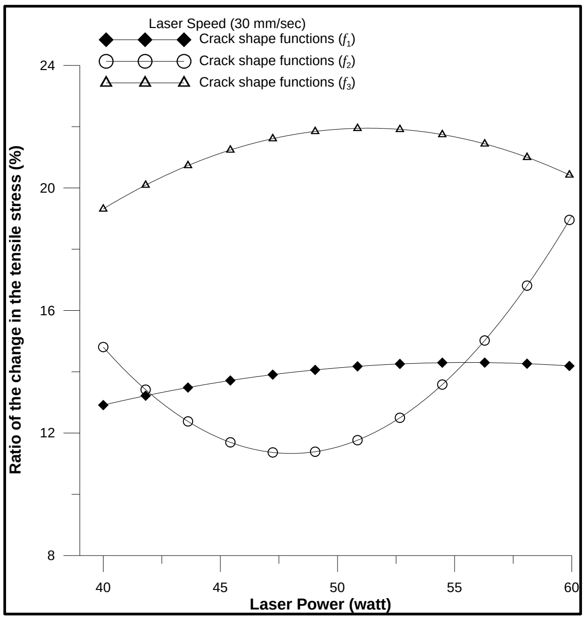

Figure 22. The laser's power and average change in tensile stress of crack shape functions (f_1, f_2, and f_3) at speed 30 (mm/sec)

So, clarify decreasing the influence of rising the laser energy at high speed on the ratio change in tensile stress due to the decrease in the period exposure of the tensile samples at the crack zone to the laser ray power.

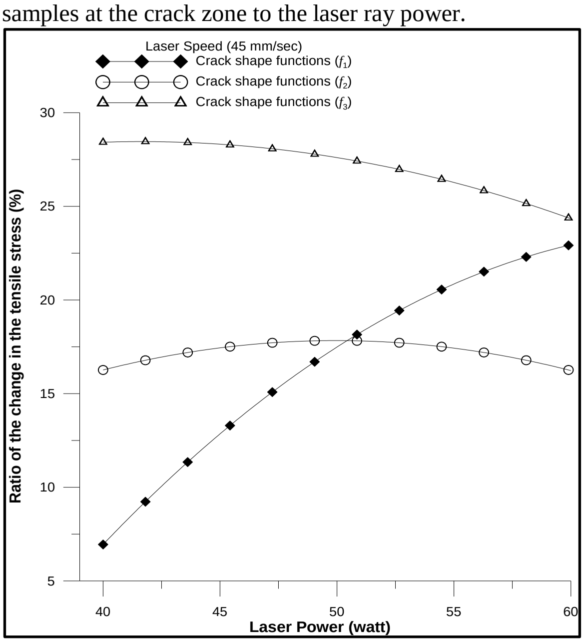

Figure 23. The laser's power and average change in tensile stress of crack shape functions (f_1, f_2, and f_3) at laser speed 45 (mm/sec)

The maximum influence of the crack's path of function's type (f_1) at a laser speed of 45mm/sec and laser power of 60 watts leads to an increase in the tensile stress with a ratio of 22.94 %. The crack function's type (f_2) achieved a maximum increase in the stress at a laser speed of 30 mm/sec and 60 watts with a ratio of 19.08% while the maximum influence of the crack's path of function's type (f_3) at laser speed 45mm/sec at laser power 40 watts caused to increase the stress with ratio 28.24%. The increased stress caused by the influence of the laser's path function and created on the one surface in tensile samples is due to increasing the resistance by redistributing the stresses through tensile test along the edge side of the laser crack's path. The disparity ratio in the stress of different types of the path of crack function f_1, f_2, and f_3 at different boundary conditions of creating crack by using a laser ray. The average ratio of disparity of tensile stress at the different shapes of crack function in which type (f_3) gets maximum average disparity at a ratio of 32.31% and the average disparity of the function shape type (f_2) gets a ratio of 24.91%, while the average disparity ratio in increasing of tensile stress in the shape crack function type (f_1) get ratio 22.82%. The results confirmed the influence of the crack shape functions and have slope angles of 24°,29°, and 41°of f_1, f_2, and f_3 respectively, the influence of the slope of the crack's path is to redirect the concentration of the stress produced through the tensile test far away from the slope of the shear plane.

5. Conclusions

The study found that the maximum stress affected by the laser path function type f_1 increased by 22.94% at 45mm/sec laser speed and 60W power, for f_2 it increased by 19.08% at 30mm/sec and 60W, while f_3 increased by 28.24% At a laser speed of 45 mm/sec and a power of 40 watts, therefore, these represent the ideal conditions for each type of laser path to optimize mechanical properties.

The study concluded that the effect of the speed of the laser beam on improving the mechanical properties varies by (0.7 - 1.41%) compared with the laser power effect at a variation of the sample's type, where increasing the laser speed of samples types A, B, and C increases the stress with a ratio of 15.99% and 17.16% and 18.35%, respectively, while the laser power increases the stress by 15.27%, 16.47%, and 19.76%, respectively. It is concluded that heat produced by the laser ray affected the microstructure of acrylic in the crack zone and enhanced the sample's resistance to tensile stress while the crack function (f_3) with a slope angle of 24° achieved maximum resistance to tensile stress with a ratio 28.24% due to the change direction of the crack's growth of failure far away from shear angle 45°. The mathematical equations for the crack path through the functions f_1, f_2, and f_3 are described by fitting the empirical results equation F(z) where the results are described as a relationship between laser power and laser speed with tensile stress to analyze their ability to disperse stresses away from the failure path. Finally, the study presents a new field for improving industrial product stress resistance by using laser power's influence on the microstructure according to paths designed to dissipate the concentration of internal forces in those products. The future scope of the study is to use high laser power at different paths to investigate its effect on the mechanical properties of metals and stress concentration regions in industrial products to enhance their resistance to failure.

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