Roughness Factor and its Implications, with Respect to Some Pressure Sensitive Adhesives, A Case Study of 3 Different Adhesives on 5 Mild Steel Plates with Varying Degrees of Roughness at the Surfaces

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Abstract: *The presents the effect of some physical properties like droplet height, droplet diameter, contact angle and surface tension on pressure sensitive adhesives (PSA) acting on a rough surface, a case study of 3 different adhesives on 5 mild steel plates with varying degrees of roughness at the surfaces. A camera of high speed and resolution was used to capture the droplets of the adhesives as it makes contact with the mild steel plate and the results were analyzed in a computer to determine the contact angle, the height of fall etc. the values of the results were tabulated and plotted against the varying degrees of roughness. It was discovered that the higher the diameter of droplet, the more the roughness factor as seen by first degree roughness and 2nd degree roughness in evolstic PSA, it was equally discovered that araldite has more bonding force than top gum and evolstic, while top gum is the least bonding when height droplet is applied. And this shows that evolstic at 157.217^o contact angle and 4th degree of roughness has more bonding force than other substance with araldite at 53° and 5th degree roughness having the least bonding strength. It could be deduced that Evostick at a value of $19.549 \mu N/m$ has the highest surface tension at zero degree of roughness and top gum has the least at the same condition.*

Keywords: PSA, degrees of roughness, contact angle and bonding

1. Introduction

1.1 Preamble

Pressure Sensitive Adhesives (PSAs) are materials which stick to different surfaces with low application of pressure, within a short time of contact. The characteristic property of PSA'S (Pressure Sensitive Adhesives) to perform this function is called TACK. The PSA's can adhere to surface without change of temperature or chemical reactions. This makes it safer and easier for usage. The distinguishing tack properties include low elastic modules, ability to wet adhering surfaces, cohesive capacity to sustain minimum level of strength on debonding Creton et al, (2001). Most PSA's are polymers as such possess low glass transition temperature, high molecular weight and weak cross linking.

The research work seeks to find out the relation between the various substrate surface roughness, tack, debonding capacity, contact angles at the adhesive/substrate interface and the tack propensity of the investigated PSA used in the study.

To this effect the probe track test was employed. The tack test is carried with a universal testing machine which aided in measuring the debonding capacity of the various PSA at the substrate/adhesive interface, the exact force at which the debond takes place is arrived at with the aid of the computerized meter in the universal testing machine. The other properties like the surface contact angle and the vectoral forces which act at the surface of the liquid boundary, surface-air boundary, liquid to air boundary was calculated with the aid of the software math lab. From Capimo (1998), the contact angle is calculated when the drop analysis of each adhesive on the various surfaces, with different roughness is carried out and with the aid of CCD camera snapshots are taken at the exact point of drop with later simulation analysis carried out using various computer software's.

Following Grassia (2011), these test helped to keep track of the cavitations process wettablity capacity, cavity growth and effects of constituent composition in the investigation of various TACKS of these adhesives.

An analysis is conducted, comparison is done against a model PSA, graphs are plotted and reasonable results and conclusion evaluated from values gotten.

1.2 Statement of Problem
- The contact angle of various PSAs on the surfaces of various materials is undefined and therefore, hinders the usability of such PSAs.
- The effect of roughness factor, contact angle and the free energy of the substrate on the tack of PSAs has remained a problem to many researchers.

1.3 Aim and Objectives of the Research

To experimentally determine the roughness factor and its implications, with respect to some pressure sensitive adhesives, a case study of 3 different adhesives on 5 mild

steel plates with varying degrees of roughness at the surfaces.

To achieve this, the following objectives will be pursued;
- To establish a relation between of an adhesive and the roughness factor at the interface.
- To study the impact of roughness factor on the contact angle of the adhesive.
- To find out the relation between the roughness factor and the contact angle at the adhesive substrate interface

2. Literature Review

2.1 Introduction

Among the different classes of adhesives, pressure – sensitive Adhesives (PSA)s are perhaps the most common type found in consumer products Giuseppe et al (2013)? Self-adhesive tapes and labels of all kinds are ubiquitous in everyday life. However, until recently, the understanding of the materials science and engineering of PSAs and in particular, the specific role played by the different components in them was very limited outside of the companies involved in their manufacture, and the interested reader had to refer to general technological text Fethers et al (1994). PSAs are typically used as nonstructural adhesives; they do not compete with epoxies for structural application. Secondly, PSAs typically stick to a surface upon contact without any chemical reaction. It is interesting to note that the term pressure-sensitive, really should be pressure-insensitive, and since PSAs do not need the application of much pressure to stick and the measured adhesion is then rather insensitive to the compressive pressure applied upon bonding. This property makes PSAs particularly easy and safe to use, sure no solvent evaporation or chemical reaction takes place and bonding can be done at room temperature.

Similar to all classes of adhesives, PSAs must be able to form a bond, that is, establish molecular contact [even on a rough surface] and then sustain a minimum level of stress upon debonding. All other classes of adhesives, however form the bonds in the liquid state, with the transition occurring by chemical reaction, change in temperature, irradiation, or another change in the structure of adhesive. By contrast modern PSAs are soft, viscoelastic solids that obtain their unique properties simply from the hysteresis of the thermodynamic work of adhesion. That is, there is a difference (adhesion hysteresis) between the energy dissipated during the fracture of these bonds Marin (2006). At least for short contact times, the only interfaces active in PSA adhesion are Van der Waals forces. In order to possess these unique characteristics, however, the mechanical properties of these adhesives must be much more finely turned those of conventional adhesive (MRS 2003).

2.1.1 Surface Free Energy
The Surface Free Energy (SFE) is defined as the work needed beyond the magnitude of the forces holding the surface together to separate two surfaces. The SFE is given in units of energy per unit Area, is often referred to as surface tension, and may be expressed in units of dynes/an (a surface tension, of / dyne /am or 1mN/m is equivalent to a

SFE of $1mJ/m^2$/. The SFE depends on the interfacical inter molecular forces and comprises the contributions from non-polar (e.g Van der Waals) and polar (eg. Hydrogen bonding) components Kendall (1994). The polar components can be further broken into electron acceptor/donor components strengths, and in many regions, one component will be much more significant than the others. The SFE of a social can be determined only indirectly by measuring the dynamics or static contact angles of various liquids in combination with appropriate theoretical approaches. The main methods used to determine the SFE of a solid are the methods of Zisman, Owens-Wendt (OW) and relatively new method of Vaness-Chaudhury-Good (VOCG).

2.1.2 Methods of Calculating Surface Free Energy
This method is used to determine the critical Surface Free Energy γ_c that differs from the quantity γ_s. According to Zisman, the value of γ_c of a solid is equal the value of γ_i of a liquid being in contact with this solid and for which the contact angles zero. The γ_c value is determined from empirical investigations, consulting of the contact angle measurements for the studied solid and the liquids of a homologous series of organic compounds Hoofar and Neuman (2004). Then, a plot is constructed in a coordinate system with the Y-axis corresponding to cosine values of the contact angle E and X-axis relating to the γ_i values for the applied liquid. The value of Cos θ for the liquids of a series of n-alkanes form approximately a straight line. Extrapolation of the line to the point of Cos $= \theta1$ yields the values of γ_c equal to γi at this point.

The measurement results can be described with a following relationship according to ASRM D570-98 (1998) being a straight line in the coordination system discussed.

$$\text{Cos } \theta = 1 + b (\gamma_c – \gamma_c) \qquad (2.1)$$

Where b is the tangent of an angle between the X-axis and the straight line being the approximation of the measurement results. The relationship between γ_c and γ_s

$$\gamma_s = (b\gamma_c + 1)2/(4b) \qquad (2.2)$$

The Zisman method made a significant progress with respect to understanding the phenomena associated with the wettability and determination of the SFE of polymeric materials.

2.1.3 Owens-Wendt Method
In the Owens-Wendt method, there have been made assumptions to those in the Fowkes method. The two methods, being identical in the mathematical aspect, differ slightly in the way of calculating the SFE Grassia et al (2011). The combination of equation below

$$\left(\gamma_s^d \ \gamma_i^d\right)^{0.5} + \left(\gamma_s^d \ \gamma_i^d\right)^{0.5} 0.5\gamma_i\left(1+\cos\theta\right) \qquad (2.3)$$

In the above equations there are two unknowns, γ_s^d and γ_1^p this two unknown are insufficient to determine the Surface Free Energy. The contact angle has to be measured using two measuring liquids, which would yield two equations like the ones mentioned above. The result is that the two linear equations is obtained from

$$x + ay = b(1 + \text{Cos } \theta_1) \qquad (2.4)$$
$$x + cy = d(1 + \text{Cos } \theta_2) \qquad (2.5)$$

where x = $\left(\gamma_s^d\right)^{0.5}$, y = $\left(\gamma_s^p\right)^{0.5}$, θ_1 and θ_2 are the contact angle values for the two measuring liquids, and a, b, c, d are the coefficients dependent on the kinds of these liquid. The liquid with a dominant polar component should be chosen as one of the measuring liquids and the dispersion liquid as the other one. Then the solution of the system of EQNs (iv & v) would be affected as slightly as possible by the errors accompanying the determination of the components γ_1^d and γ_1^p. Such conditions are well fulfilled by the pairs of liquids selected from the following set: Water (W), Glycerol (G), Formamide (F), Diiodomethane (D), and α-bromonaphthalene (β). For example, the pairs of liquids like WD,WB, GD, GB, FD, and FB can be used for the contact angle measurements.

The Owens-Wendt approach is one of the most common methods for calculating the SFE of polymeric materials, water and diodomethane being used most frequently as measuring liquids.

2.1.4 VAN OSS-Chaudhury-Good Method
Taking into account that the component is equal $2(\gamma^+ \gamma^-)^{0.5}$ and combining with Young Equation/Lifshitz Van Der Waal. Young Equation states

$$\gamma_s = \gamma_{sl} + \gamma_1 \cos\theta \qquad (2.6)$$

From the Lifshitz – Van der Waals

$$\gamma_{sl} = {}^s l \left(\gamma_s lw\right)^{0.5} - \left(\gamma_1^{lw}\right)^{0.5}\}^2 + 2\{\left(\gamma_s^+\right)^{0.5}\}.\left(\gamma_s^-\right)^{0.5} - \left(\gamma_1^-\right)^{0.5}\} \qquad (2.7)$$

The combination of equations (vi) and (vii) we obtain a relationship

$$\left(\gamma_s^{Lw}\gamma_1^{Lw}\right)^{0.5} + \left(\gamma_s^+\gamma_1^-\right)^{0.5} + \left(\gamma_s^-\gamma_1^+\right)^{0.5} = 0.5(1 + \cos\theta) \quad (2.8)$$

There are 3 unknowns in the equations above γ_s^{Lw}, γ_s^+ and γ_s^- and this results in 3 independent linear equations, analogous to equations (iv) and (v), which is required to determine these quantities. One non-polar and two bipolar liquids should constitute the set of the 3 measuring liquids.

The Van Oss-Chaudhury-Good (2001) method makes use of 3 equations represented above, even though they are not always proper and unequivocally interpreted. This follows from the assumed conditions and limitation, associated with both the kinds of selected measuring liquids and the ways of determination of SFE (Surface Free Energy) components such as γ_s^{Lw}, γ_s^+ and γ_s^-.

2.1.5 Contact Angle
When a liquid is dropped on a solid substrate, a contact angle (θ) is formed which is defined according to Zosel (1989) as the angle between two of the interfaces at the three phase line of contact as shown below.
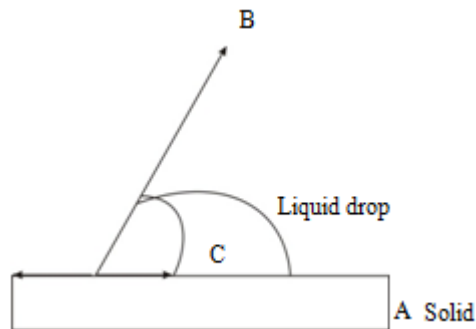
Figure 2.1: SFE vectors at equilibrium and contact angles

These three phases are solid, liquid, gas (air usually). If water drops are used, contact angle values give information about the hydrophilicity and hydrophobicity of the solid surface. Contact angle of a liquid is the angle between the vectors A and B as shown above. Simply the angle of tangent to the circle of the liquid drop drawn from the point where the liquid drop touches the surface. In the diagram above vector A shows γ_{sl}, which is the interfacial tension between solid and liquid, vector B shows γ_{lv}, which is interfacial tension between liquid and vapour and vector C shows γ_{sv}, which is interfacial tension between solid and vapour. Contact angle value of a liquid may range between 0 and 180 degrees. Zero contact angle means the surface is completely wetted by the liquid and are compatible to each other. When two different liquids drop on the same polymer surface, the one that spread more (liquid B) has lower SFE than the other (liquid A) and has lower contact angle Zarrlli et al (2006). Which means the attraction forces between the surface molecules and the liquid B molecule are higher than that of liquid A and the surface molecules. As a general trend the contact angle becomes lower when the SFE of the solid and liquid become closer.

When contact angle is to be measured, a given amount of liquid drop is usually deposited on the surface Winding and Hiat (1961). If one continues to pump the liquid on the surface instead of placing a constant amount of liquid, the drop would start to grow on the surface and it would be exhibiting an advancing contact angle on the surface. If that drop is pulled back from the surface the liquid would be receding. Contact angle made by an advancing liquid (θ_a) and that made by a receding liquid (θ_r) may not be identical. These results in these called contact angle hysteresis. Contact angle hysteresis is the difference between θ_a and θ_r. The reasons of contact angle hysteresis may arises from roughness and heterogeneity of the solid surface. Compound with chemically identical smooth surfaces, very roughness surfaces given different contact angles which do not reflect material properties of the surface rather, they reflect topographical properties Kwok et al (1998)

2.1.6 Contact Angle Measurement
Contact angle measurements are usually carried out by goniometers which are based on taking a high quality photo of the liquid drop and measuring contact angle with the help of certain computer programs. This method is called DROP SHAPE ANALYSIS. If the surfaces are rough or chemically heterogeneous, then contact angle measurements with drop

deposition are meaningless for an ideal surface on which no roughness and heterogeneity exists there will be no contact angle hysteresis and the experimentally observed contact angle is equal to real Yang et al (1996).

2.1.7 Goniometer Methods

Contact angles between liquid drops and surfaces can be measured directly from the angle formed at the contact between the liquid and the flat surface. Measurements can be made with manual goniometer, an inexpensive instrument. The drop is illuminated from behind and viewed through a lens focused on the silhouette of the drop A reference line is manually positioned to read the contact angle. The drop may also be projected onto a screen to view the contact angle. Low cost hand held instruments are available, based on digital camera technology, where the drop is imaged onto a built-in LCD screen using a CCD chip to produce an image that is easier to measure than the traditional magnifying eyepiece instruments.

2.1.8 Automated Contact Angle Measurement

Manual ganiometer measurements can be prone to operator subjectivity but this can be removed from the process by image analysis of the drop shape and contact using a computer programme. There are many commercially available automated contact angle measurement instruments where the image of the drop is viewed using a video camera and captured on computer. An image analysis programme detects the edge of the drop and the surface. Numeric algorithms are run to establish the 'shape' of the drop and the slope of the edge in contact with the surface. The software will also analysis the shape of hanging pendant drops to measure surface tension of liquids. Axisymmetric Drop Shape Analysis (ADSA) is one example of a computer program that uses digital image analysis to detect the edge of a static drop and accurately determine the interfacial tension and contact angle (Hoorfar M Ibid 2003)[3]. ADSA is capable, under ideal condition of determining contact angles to very high accuracy with uncertainties of less than 0.10. Through careful control of the position of the syringe plunger it is possible to make the drop advance and recede on the surface. Images of the drop can be captured in real time allowing measurement of contact angle hysteresis through the advancing and receding contact angle.

2.1.9 Contact Angle Determination by Sessile Drop

The state contact angle can be measured by observation of a drop of test liquid on a solid substrate either on a goinometer or by projection, either directly or using video imagine. Determination of the contact angle can be carried out using automated images fit techniques. In the packaging industry, contact angle is measured according to Tappc Methods for papers (Tappc T458cm 94). However, this technique tends not to be employed commonly as it is perceived as being time consuming and requiring a degree of interpretation of the results.

2.2 Issues in Contact Angle Measurement Drop

The sessile drop method requires the observation of a drop of test liquid on a solid substrate. The technique is associated with the challenges of swelling of the solid surfaces, roughness and porosity as discovered by Wool (1995). Cohesive hydrogen bonding with the test liquids and the solution pH may also influence the measured surface energy. The surface tensions of many liquid (particularly water) change dramatically with the absorption of small quantities of surface-active impurities (from surface) or (the atmosphere). Caution must be taken in the handling and storage of probe liquids Tobung and Klein (2000). Water is normally freshly de-ionised or distilled before use. Commonly used probe liquid for measuring contact angle include distilled water, glycerol, and ethylene iodine (typical drop size is 2 to 20Nl) Penco et al (2000). For porous materials the observed contact angle will reduce with time as the probe liquid penetrates the surface Bruce et al (2005)

2.2.1 Tack of Pressure Sensitive Adhesives

Tack or Quick stick is one of the most vital properties of pressure sensitive Adhesives (PSAs). The definition of tack is the property of a pressure sensitive adhesive that allows it to adhere to a surface under very slight pressure. It is determined by the ability of the adhesive to quickly wet the surface it contacts.

There are four standard test methods that are used globally to evaluate a pressure sensitive Acrylic tack. They are Loop Tack, Probe Tack, Rolling Ball Tack and Quick stick. Although these test methods do not result in the identical values for a fixed PSA, they can distinguish relative adhesion performance for different PASa. The descriptions of various test methods are listed below.

2.2.2 Loop Tack

has recently become the most reliable method because it can generate reproducible and consistent data. Most tapes and label manufacturers now prefer reporting loop tack data only on their published brochures. Micro-processor controlled loop tack testers are now commercially available.

2.2.3 Probe Tack

is very similar to the finger test tack. The deviation of test data results from this method can be high because of small contact area. The probe tip has a diameter of only 5.0mm. Tack performance determined by probe tack tester is too sensitive to the consistency of coating weight, smoothness of coating surface, and sample preparation.

2.2.4 Rolling Balltack

test is very simple, cheap and the test result cannot be used to compare with other tack tests. Very tacky adhesives do not impart good rolling ball tack. In practice, rolling ball tack is excellent for online. Quality control testing at the production site. The consistency of a coating on a web is easy to determine immediately after coating by means of this simple test.

2.2.6 Finger Test

This is commonly used in the real world evaluation and does not require equipment. Many people believe Finger Test is more realistic than others mentioned above. It is too subjective but also very unscientific. No PSAs, except skin contact PSAs, are bonded on human skin. Many variables such as skin roughness, temperature, grease and thread perspiration etc will significantly affect the feeling of finger tack. Finger tack may misled adhesive user when they try to select an appropriate PSA.

2.3.1 Surface Characterization

Large numbers of techniques have been developed to probe the different aspects of the physics and chemistry of surfaces. However, X-ray photoelectron spectroscopy (XPS) and Fourier transform infrared spectroscopy are used to study the surface chemical composition. Similarly, scanning electron microscopy (SEM) and atomic free microscopy (AFM) are used to investigate the surface morphology of the material at the atomic scale. These methods require relatively expensive equipment, skilled technicians and quite sophisticated techniques to interpret the data. A good understanding of the surface properties of a solid may be obtained relatively inexpensively from the measurement of the surface free energy. Therefore contact angle measurement has been used in the study of surface free energy materials. The surface free energy of a solid is an important parameter, useful in studies absorption and wettability processes which play important role in many industrial applications of the material Nwajage and Ugwu (1997). Measurement of contact angle of liquid with the solid surface permits a rapid and qualitative evaluation of surface free energy of polymers. The surface free energy in this context has been made on the basis of dispersive and components. Surface free energy (γ_s) and its polar (γ_s^p) and non-dispersion (γ_s^d) components here are determined from two sets of contact angles (water and glycerine) according to Owen-Wendt-Kaelble equation:

$$\gamma_l(1 + Cos\,\theta) = 2[\gamma_l^d \gamma_s^r]^{\frac{1}{2}} + 2[\gamma_l^p \gamma_l^p]^{\frac{1}{2}} \quad (2.13)$$

Where γ_l, γ_l^p and γ_l^d are the total surface free energy of the components

3. Methodology

The experiment involved in the research work, includes;
- The determination of the surface free energy of the three (3) different adhesives on 5 degrees of roughness of particular surface (mild steal).

Material requirement for the experiments are as follows

For the surface free Energy and contact angle measurement:
1) Araldite
2) Top gum
3) Evostic (polyurethane)
4) Mild steel plate

Testing Methods

For the test to determine the surface free energy of each adhesive type making use of 5-degree of roughness, through measurement of the contact angle for each situation in the mild steel surface.
1) Each drop of the adhesive for the experiment will be measured at 2ml/unit from a syringe
2) The drop will be made to fall on each steel plate substrates as shown in Fig 3.1
3) At the point of drop the CCD camera, takes a snap shot of the drop before it starts receding
4) From the drop snapshot, 3 snapshots were taken at each instant, with a view to choosing the best.
5) The experiment was repeated for all the plates with varying degree of roughness
6) The drop shape for each roughness surface was analyzed with the aid of computer and the CONTACT AGLE of each adhesive/substrate was determined.
7) The roughness factor was equally sorted for.
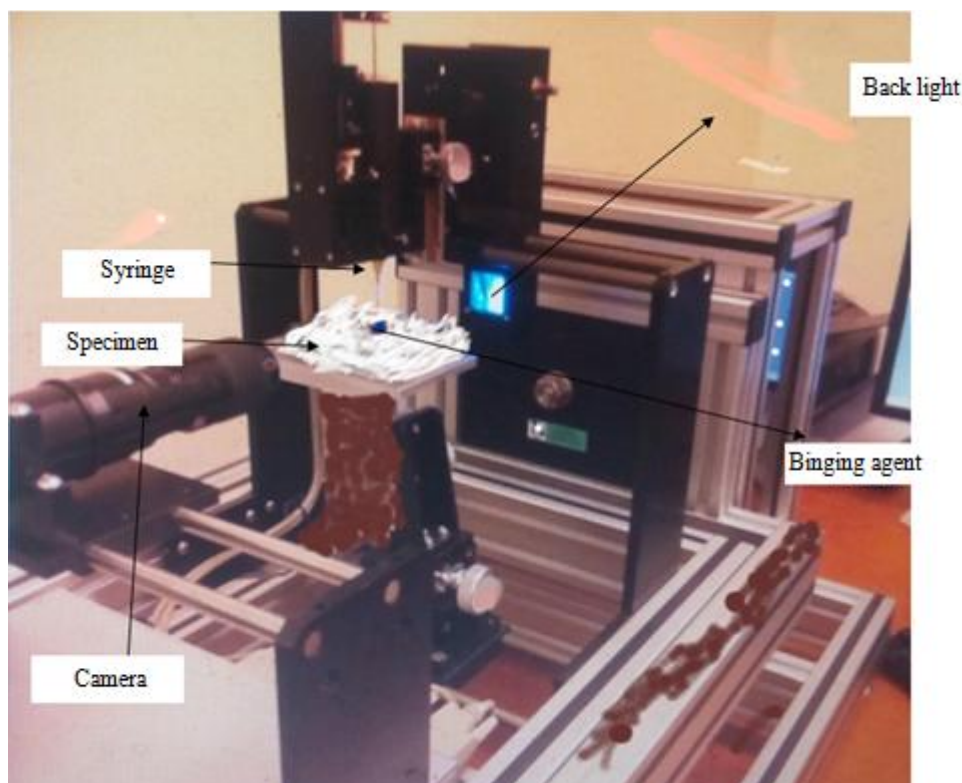
3.5 Roughness Factors and Degrees of Measurements

The analysis of roughness factors and degrees of measurements of the effects of droplet diameter(d), height droplet (h), radius of droplet (R), contact angle (b), surface tension at Interface (Rsl), spreading coefficient (S) and work of Adhesion (Wa) are presented in chapter four for different substances of araldite, top gum and evostick tangit are discussed in chapter four of section 4.3. These were measured with high speed video camera and analyzed with Image-J Software

4. Analysis

The experiment was carried out for five specimens and data was recorded as shown below;

Five member substrate materials of mild steel plates 130mmx130mm with thickness 12mm were subjected for both roughness and degree of roughness measurement. The classes of roughness texture used were; superfine of Ra 0.09µm for zero-degree determination. In addition, fine ground of Ra 0.18 µm, was followed. Thereafter, medium ground of 0.4 µm, coarse ground of 0.79 µm, and fine of 1.7

µm respectively were used. The values of various Ra were used for corresponding determination of zero degree; first, second, third, fourth and fifth degrees. The results are presented in section 4.3.

4.1 Roughness Factors and Degrees of Measurements

The analysis of effects of droplet diameter (d), droplet height (h), degrees of roughness, contact angle (b), surface tension at Interface (Rsl), are presented in Figs. (4.1- 4.4).

4.1.1 Implication of droplet diameter on adhesives of varying degree of roughness factor

The effect of droplet diameter on Adhesive at different degree of roughness factors is shown in table (4.1) and Fig. (4.1).

Table 4.1: Droplet diameter on adhesive (araldite) of varying degree of roughness factor

Avg. droplet diameter (mm)	13	8	6	7	6.5	8.1
Degree of roughness (µm)	Zero th	1st	2nd	3rd	4th	5th
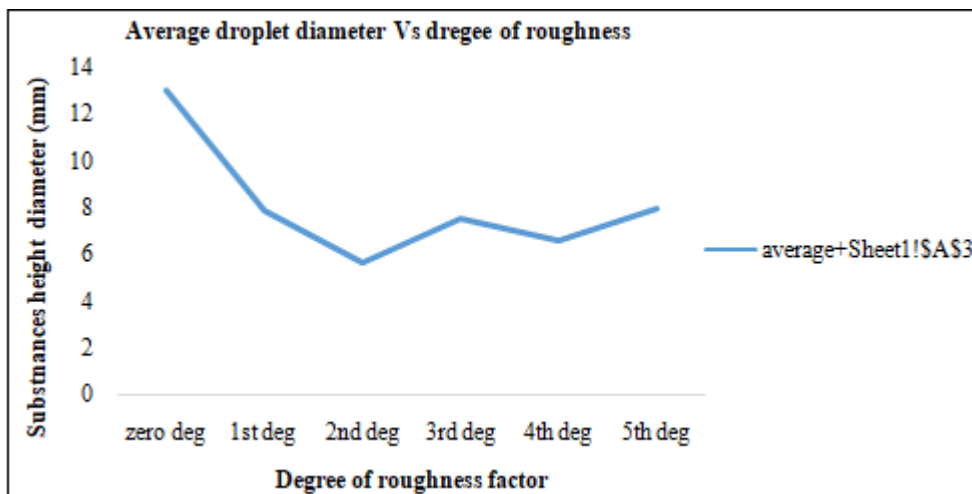
Figure 4.1: Degrees of Roughness factors due to Droplet Diameter of araldite adhesive

4.2 Effect of height droplet (h) on adhesives at different degree of roughness factors

The effect of height droplet (h) on adhesives at different degree of roughness in Table (4.2) and Fig (4.2)

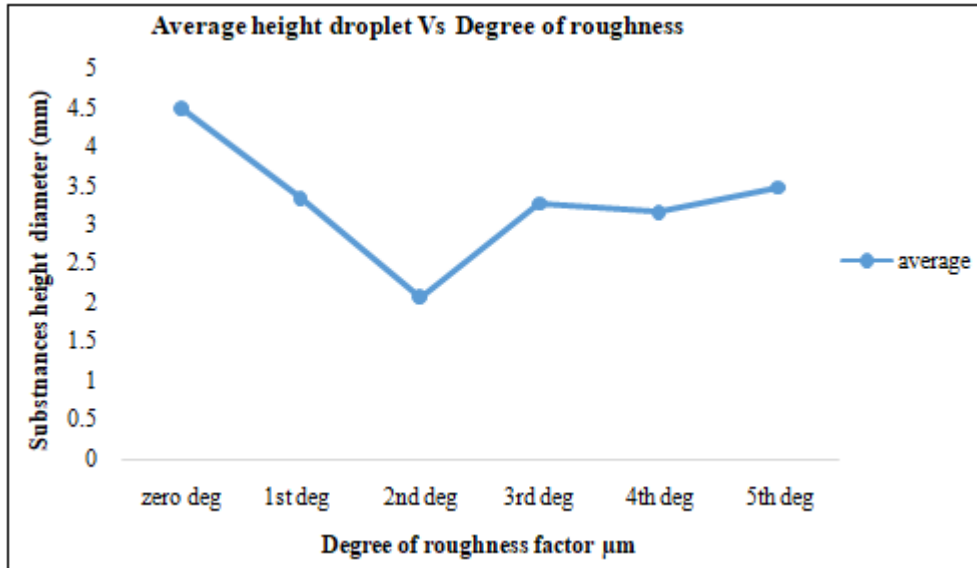| Avg. droplet height (mm)	4.5	3.3	2.1	3.3	3.1	3.4
Degree of roughness (µm)	Zero th	1st	2nd	3rd	4th	5th

Figure 4.10: Substance (araldite) and degrees of roughness factors due to height droplet

4.3 Effect of angle of contact (θ) on adhesives at different degree of roughness factors

The effect of contact angle (ө) on adhesives at different degree of roughness factors are presented in Table (4.3) and Fig. (4.3).

Table 4.3: Angle of contact (θ) on adhesives at different degree of roughness factors

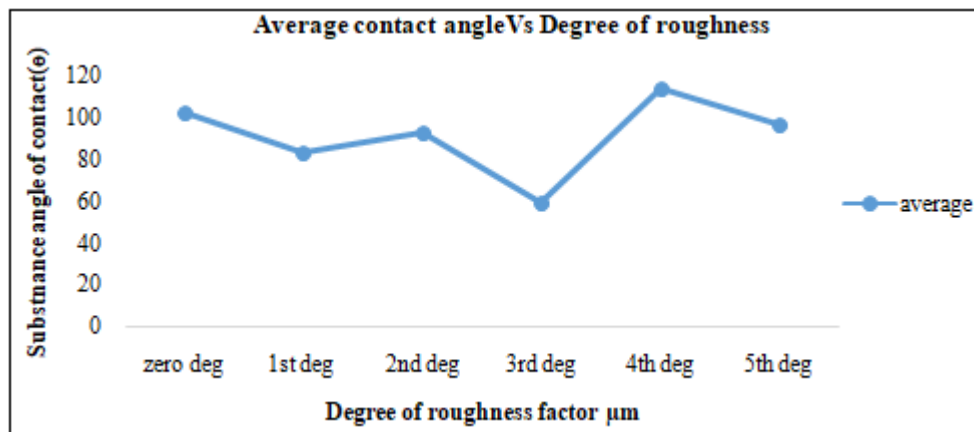| Angle of contact (ө)	104	80	90	53	118	108
Degree of roughness (μm)	Zero th	1st	2nd	3rd	4th	5th

Figure 4.3: Effect of angle of contact (θ) on adhesives at different degree of roughness factor

4.4 Effect of surface tension at interface (rsl) on adhesives at different degree of roughness

The effect of surface tension at interface on adhesives at different degree of roughness is shown Table (4.4) and Fig. (4.4)

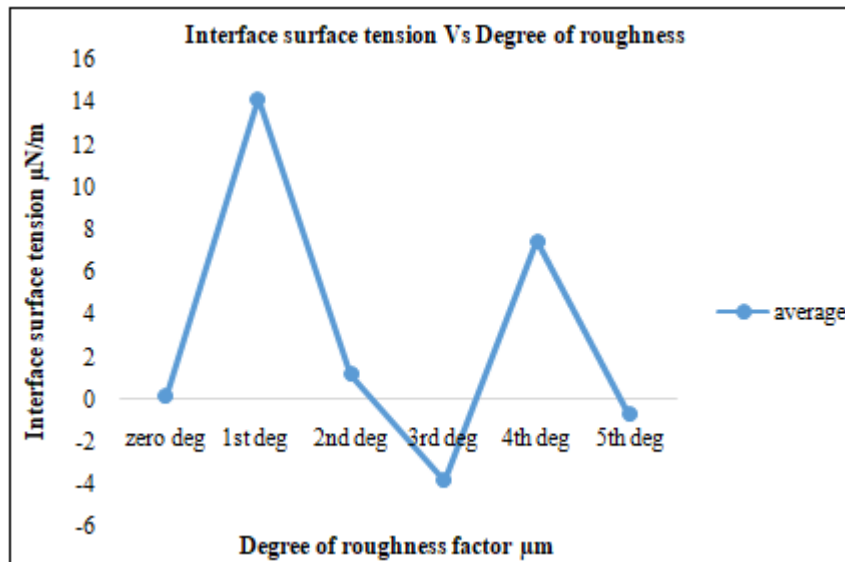| Surface tension (μN/m)	0.00	14.03	2.00	-4.03	6.02	-1.12
Degree of roughness (μm)	Zero th	1st	2nd	3rd	4th	5th

Figure 4.4: Substances and degrees of roughness tension at interface due to surface

5. Discussions

The analysis above could further be explain as follows; At Fig. 4.9, shows the degree of roughness on the diameters. At roughness factors of zero, the average diameter is highest at 13.0mm, followed by 5th degree roughness factor of average diameter 8.1mm. The least average diameter 6.0mm roughness factor occurred at 2nd degree This shows that higher the diameter of droplet, the more the roughness factor as seen by first degree roughness and 2nd degree roughness. However, the experiment was conducted for other two samples and it was discovered that evostic has highest droplet diameter of 24.7mm when the roughness factor is at zero degree, while the least is araldite of 1.593mm droplet diameter when the roughness factor is at 3rd degree. This shows that evostic has more bonding force that other substance with araldite as the least bonding when the case is with diameters droplet.

At Fig. (4.2) shows that height of droplet is highest at the same zero degree at a droplet height of 4.5mm while the least occurred at 2.1mm droplet height at 2nd degree roughness factor. It tends to increase but stopped at 3.4mm droplet height at 5th degree roughness factor. This shows that the higher the height droplet is more at zero-degree roughness factor followed by 5th degree and least at 2nd degree. However, after the same experiment was conducted for other two adhesives, araldite has highest droplet of 4.5mm when the roughness factor is at zero degree, while the least is the top gum of 0.41mm droplet height when the roughness factor is at 3rd degree. This shows that araldite has more bonding force than other substances with top gum as least bonding when height droplet is applied.

At Fig. (4.3) shows that average angle of contact 104° occurred at the 4th degree roughness factor while the least 53° occurred 3rd degree roughness factor. This shows that evolstic 157.217^o at 4th has more bonding force that other substance with araldite 53° at 5th degree roughness factor having least bonding when angle of contact is applied in roughness factor.

At Fig. 4.4 shows that at zero degree of roughness, the araldite has a high surface tension of 14.03 μN/m and at 3rd degree of roughness, surface tension is -4 μN/m. following other experiment, it could be deduced that Evostick at a value of 19.549 μN/m has the highest tension at zero degree of roughness and top gum has the least at the same condition.

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