Analysis of Variation in Surface Roughness and Adhesive Bond Strength With Adherend Surface Roughness

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Abstract— **As the diversity of the manufacturing materials is increasing we need to find effective joining techniques. Adhesives are one of the efficient means of joining such kind of materials where conventional joining techniques are not suitable. The biggest challenge in such joining processes is to sustain stiffness and rigidity under application of higher and dynamic load. It is observed that the enough quantity of suitable adhesive makes sure the higher stiffness and rigidity,. In the present work it has been tried to analyze the effects of surface roughness on adhesive bond strength in the case of aluminium. It has been found that bond strength increases with the surface roughness up to a certain point; however further increment in surface roughness causes gradual decrement in bond strength.**

Keywords— **Adherend surface roughness, centre line average Breaking load, Surface Treatment.**

INTRODUCTION

As the new manufacturing techniques are introducing, it becomes necessary for industries to enhance their adaptability for these techniques to achieve higher customer satisfaction. It is no more the case where only traditional manufacturing materials are sufficient enough to fulfill all the expectations. So, with changing manufacturing materials it becomes imperative to find new joining techniques, as we have standard techniques of joining like welding, brazing and riveting etc.are not suitable for joining materials like polymers, different types of fiber materials and plastics. Adhesives are one of the efficient means of joining such kind of materials where conventional joining techniques are not suitable. The biggest challenge in such joining processes is to sustain

Roughness:

Roughness is a measure of texture of surface. It is a deviation of real surface from its ideal form. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. If the deviation is large, the surface is called rough; for small deviation, the surface is termed smooth.

Roughness plays an important role in determining how a real object will interact with its environment. Surface roughness determines friction and wear rate of interacting surfaces. Rough surface usually wear more quickly and have higher friction coefficient than the smooth surface. Roughness is often a good predictor of the performance of a mechanical component. Thus, the optimum surface roughness values are decided based on the area of application. There are many parameters in use for roughness measurement. Some of the commonly used ones are defined here.

Experimental Details:

Initially, aluminium sheets were used as an adherend, keeping in mind that it is generally used in structural applications because of its light weight and easy availability. The sheet-thickness was 5 mm. An epoxy resin, commercially known as Araldite, was taken as the base adhesive.Aluminum plates of size 100 ×□ 30 mm were cut by shearing from the commercially purchased sheet. Adherend surfaces were prepared by abrasion. The surface roughness of the aluminium adherends was varied by mechanical abrasion using emery paper. Different grades of emery paper identified by P120, P50, and P30 were used to produce different levels of surface roughness in the range of 0.44- 3.76μm and as-purchased aluminium plate roughness was itself used as one grade. The residual particles remaining after mechanical abrasion were removed by cleaning the surface with a soft clean cloth.

Roughness measurement:

After surface-treatment, the surface roughness of both type of adherend was measured using a profilometer The measuring range of the profilometer was 0.03-6.35μm while the sensor traversing length for all cases was 2.4 mm. Measurement were performed in different areas, along two different mutually perpendicular directions, longitudinal and tangential. Over the 10cm×3 cm area 9 readings of Ra (Center Line Average) and Rz were measured and the representative value was calculated as the average of all nine readings. Measured values of Ra and Rz are given in Table below:

TABLE I
VALUE OF RA AND RZ

Surface Treatment	Ra value (μm)	Rz value (μm)
No treatment	0.545±0.15	3.65±1.35
Grinding P-120	1.880± 0.14	10.29±2.4
Grinding P-50	2.599± 0.17	17 ± 1.56
Grinding P-30	3.660± 0.13	23.5 ± 2.0

Testing :

The samples were tested in a Universal Testing Machine. All test were carried out under the monotonic loading at room temperature with applying load step of 10N. The UTM was interfaced with a computer for automatic data acquisition and storage. The gripping length was kept at 30 mm at both ends, while the Gripping width was over the whole width of the specimen.

Specimens for each surface condition were tested to achieve an average result. After each test failure load and displacement was recorded by data acquisition system from data panel of UTM

Result:

It is observed that there is change in bonding strength with change in adherend surface roughness value. Joints with adherends having surface roughness value of 0.5417 ± 0.15 and their corresponding bond strength was taken as the reference. The relative change in adhesive bond strength is calculated on this basis.

As it can be seen from the table, there is an initial increase in bond strength value as the surface roughness of adherend increases from 0.5417 ± 0.15 µm to 1.680 ± 0.14 µm.

Thereafter, it is observed that there is a decrease in bond strength as the adherend surface roughness value increases. Significant increase in bonding strength i.e. 26.70% is achieved by maintaining roughness values in the range of 1.680 ± 0.14. As far as the variation of adhesive bond strength with change in adherend surface roughness is concerned, it is clear that an optimum surface roughness value exists that gives the maximum strength of adhesion .

TABLE II
VARIATION IN AVERAGE LOAD WITH ROGHNESS

Sr. No.	Roughness(μm)	Average load (kN)	Percentage increase in load (%)
1	0.5417 ±.15	4.98	
2	1.680 ±0.14	6.31	26.70
3	2.697 ±0.17	5.56	11.64
4	3.660 ±0.13	4.84	-2.81

The pattern of variation is shown in the graph below:

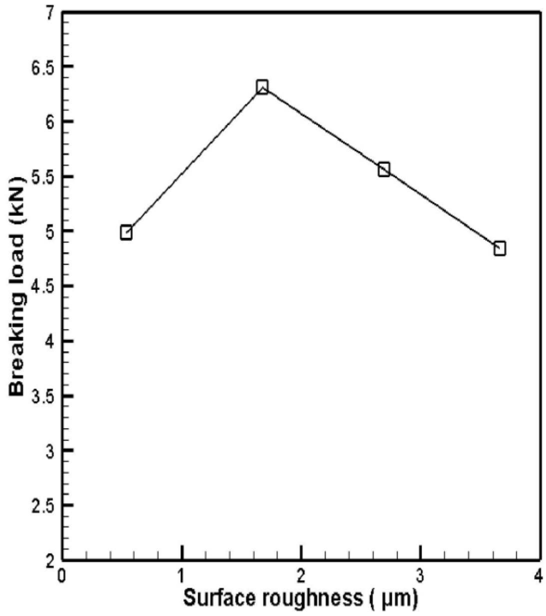

Fig. 1 Variation of Breaking Load with Surface Roughness

The entire data set was divided into two parts—one for low roughness values ranging from 0.410μm to 1.88μ m, the other for higher roughness values ranging from 2.49μ m to 3.64μ m. There were 14 pairs of data in the lower roughness group and 13 pairs of data in the other group. For both the data sets, it was observed that a cubic polynomial of the form:

$y = A + BX + CX^2 + DX^3$

gave the best correlation coefficient between the roughness and the breaking load. The correlation estimate R2 was 0.94144 for the first group of data, and 0.87484 for the second group.

The fitted equation is

$LB = (0.98963 + 13.03Ra - 12.161Ra^2 + 3.7382Ra^3$ for $(0.411\ \mu m \le Ra \le 1.78\ \mu m)$

LB = (88.745 – 72.826Ra + 20.938Ra2 – 1.9957Ra3 for (2.58 μm ≤ Ra≤ 3.74 μm).

where LB is the breaking load in kN and Ra is the surface roughness. The fitted curves are shown in Figures.

Fitting curve for first group of data is shown in figure

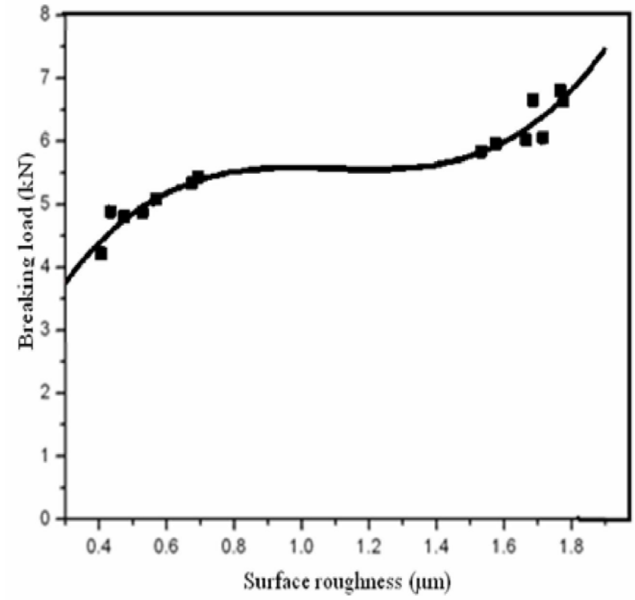

Fig. 1 Fitting Curve For First Group of Data

Fitting curve for second group of data is shown as below:

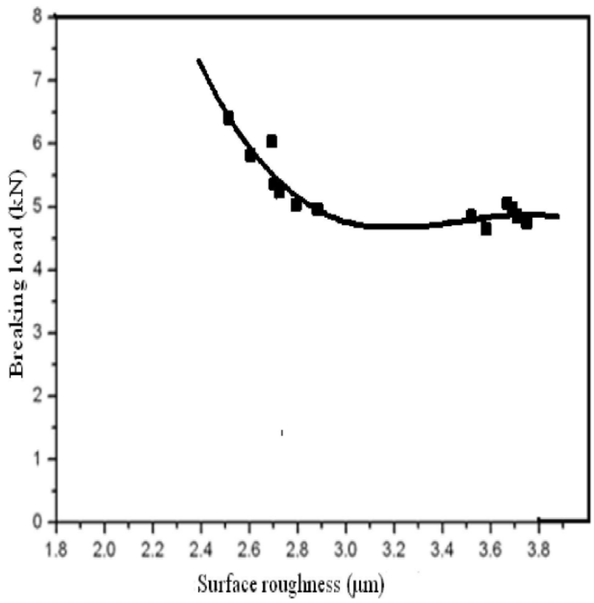

Fig. 3 Fitting Curve For Second Group of Data

Curve fitting of breaking load with surface roughness for entire experimental data is shown in figure 4.

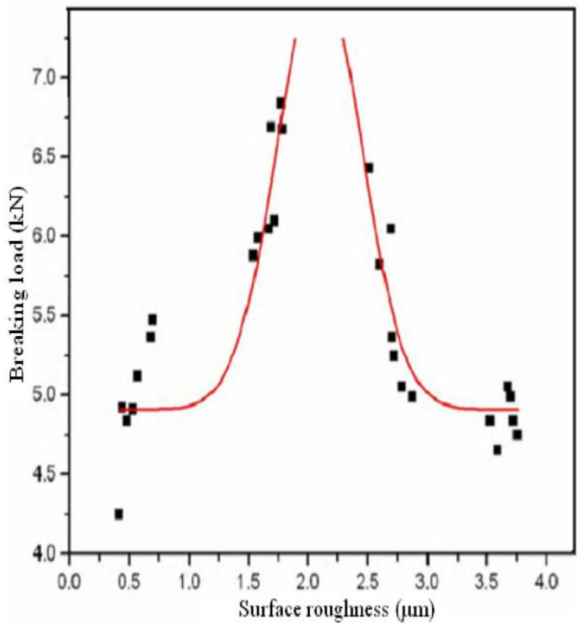

Fig. 4 Fitting Curve For Whole Data

From the graph, it shows the maximum strength is obtained in the range of 1.75 µm -2.5 µm roughness values. In this range there is one optimum point where will get maximum bonding strength. So as the roughness value increase, bond strength also increases with roughness up to 2.5 µm there after strength decreases with surface roughness

Conclusions

Bond strength between rough surfaces is higher than that smooth one. It is possibly due to-

1) Increase in surface area.

2) Mechanical locking adhesive between micro columns

3) Modification in the surface chemistry of the adherend

4) Consequent improvement in wettability of adherend interface.

5) Surface pretreatment process.

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