Adhesive strength improvement of epoxy resin with different reinforcing materials

Ahmed S. Abdulaziz Lecturer
Ahmed Nafie Rashid Lecturer
Yasir M. Al Hbaite Assist. Lecturer
Mosul University – Engineering College – Mech. eng. Dept.

Abstract

Abstract: This research was carried out by adding several reinforcement materials to the epoxy type (Henkel/pattex) then the shear strength was measured. It was noticed from experimental results that there is a significant improvement achieved by adding the reinforcement materials. Also the change of the percentage of the reinforcement materials was studied and its effect on the shear strength was considered. The reinforcement materials include iron filing, silicon carbide as weight percentages 10%, 20% and 30%. Also steel mesh, polymers mesh and fiber glass was used. The cling was carried out on standard specimens including galvanized steel, aluminum and brass. The results obtained shows that the shear strength was significantly improved by adding the reinforcement materials .The results were affected by the type of reinforcement materials and type of metals being glued. The maximum improvement obtained with brass/brass specimen using mixture of epoxy with 10% iron filing as a weight percentage.

Key words: Adhesives, Epoxy, Reinforcement materials, Shear strength.

تحسين قوة اللصق لراتنج الايبوكسي بواسطة مواد معززة مختلفة

احمد سعدون عبد العزيز
مدرس
كلية الهندسة/قسم الهندسة الميكانيكية
جامعة الموصل

احمد نافع راشد
مدرس
كلية الهندسة/قسم الهندسة الميكانيكية
جامعة الموصل

ياسر محسن الحبيطي
مدرس مساعد
كلية الهندسة/قسم الهندسة الميكانيكية
جامعة الموصل

الخلاصة

الخلاصة:تضمن البحث إجراء دراسة عملية حول تأثير إضافة مواد تقوية على إجهاد القص لمادة الايبوكسي نوع (Henkel/pattex) واشتمل البحث تغيير نسب الإضافة لمواد التقوية وتأثير هذا التغيير على إجهاد القص لطبقة اللصق .اختيرت مواد تقوية شملت برادة الحديد و كاربيد السليكون بنسب وزنيه (10% ، 20% و 30%). كذلك تم استخدام شبكة معدنية ، شبكة بوليمرية وألياف زجاجية حيث تم لصق نماذج قياسية معدنية من الصلب المغلون ،الألمنيوم والبراص . تم قياس إجهاد القص للنماذج التي تم لصقها باللواصق المصنعة ولوحظ من النتائج العملية حصول تحسن كبير في إجهاد القص وتباينت نسبة التحسن باختلاف مواد التقوية المضافة ونوع المعدن المستخدم وتم الحصول على اكبر نسبة تحسن في إجهاد القص لنماذج البراص/براص الملصوقة باستخدام ايبوكسي مضافا له برادة حديد بنسبة 10% كنسبة وزنيه.

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Introduction:

The study of the mechanical properties was the goal of many researches in the last few years. The epoxies have been widely used in high - performance structural adhesives especially in the automotive and aircraft manufacturing .Also epoxy resins are attractive for metal bonding adhesive system due to their low shrinkage [1].All the previous researches were carried out by adding different types of reinforcement materials to the epoxy in order to fabricate composite material which have better mechanical properties than that of the pure epoxy. S.M.Darwish et.al. found that the metal reinforcements added to the epoxy resins show increase in shear strength with increasing the weight percentage of reinforcement to a maximum after which shear strength drops [2].Makoto Nakazawa shows that adhesive joint of galvanized steels suffer adhesive failure between zinc coating and the adhesive and are poor in wet durability [3] also J. J. Chang, W.C. Yeih found that adding foreign particles to the epoxy may enhance the bond characteristics of coating. This may come from two reasons: one comes from the mechanical improvement by foreign particles and the other comes from the chemical reaction of foreign particles which yield to a better binding material [4] while M. Drak, L. A. Dobrzansk investigate the properties of composite material with epoxy matrix reinforced by Nd-Fe-B Particles with addition of iron powder they found that this kind of composite material can broaden the application of magnetic materials and reduce the cost of their manufacturing [5]. R. Kahraman et.al. found that the epoxy adhesive retains its strength up to 50 wt% with aluminum reinforcement content also the addition of reinforcement particles to the epoxy will improve its strength and reduce the quantity of resin, hence the total cost is reduced [6]. A. A. Aljoboree et.al. found that the impact strength, tensile strength and compression strength are significantly improved with addition of glass fibers to the epoxy type (EP-10) [7] .Finally A. I. Almosawi et.al. showed an improvement in the mechanical properties which include impact strength, tensile strength, compression strength and flexural strength for the resin (AY103) with addition of carbon fibers [8] .In this research a different reinforcement materials were used to improve the shear strength of the epoxy type(Henkel/pattex) .

Experimental work:

This work includes specimen preparation, additives preparation, adhesion process and the mechanical test. Different metallic sheets were chosen, they were galvanized steel, aluminum and brass all of (1) mm thickness. A Standard single lap joint (Figure 1) was used to evaluate the epoxy property according to Annual Book of ASTM standard [9] and according to this specification the adhesion area is equal to (12.7×25.4) square millimeter. Types of particles were chosen for the improvement of the epoxy, they were iron filing of mesh size (48-500) µm, silicon carbide of sizes (150) µm and (250) µm, also for this purpose a steel mesh, a polymer mesh and fiber glass were added as a reinforcement materials. The epoxy used was (pattex - henkel) type. The particles were chosen as (10%, 20% and 30%) percentages by weight, hence different types of epoxy mixtures were obtained to produce different sets of adhered specimens to compare with those adhered with pure epoxy. Each set consisted of two specimens of similar or dissimilar metals adhered by the epoxy mixture. A tensile machine WOLPERT type capacity of 50KN (Figure 2) was used to test the maximum shear load of the adhered specimens.

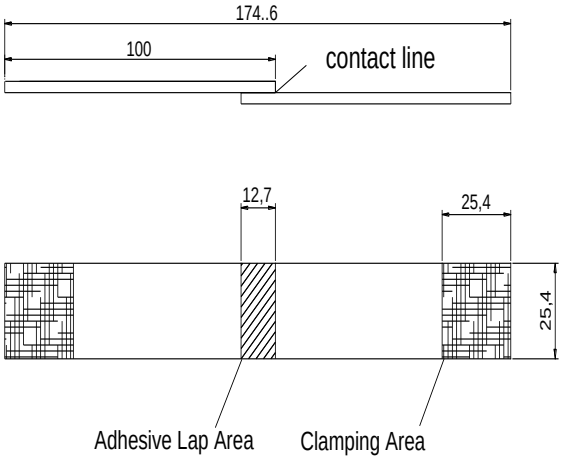

Figure (1): standard single lap joint (Dimensions in mm)

Figure(2):WOLPERT tensile testing machine

Results and discussion:

From the experimental results, it was noticed that there is a significant improvement in the shear strength for most of the specimens adhered by the epoxy mixtures compared with those adhered by the pure epoxy .i.e. epoxy without reinforcement materials. This improvement is related to the type of reinforcement materials and the type of specimens adhered. The result obtained was organized by tables and figures. Figure (3) shows the change in shear strength of galvanized (steel/steel) using different iron filing percentages. At (10%) iron filing, maximum shear strength is obtained. Using iron filing of (20% & 30%) as weight percentages cause a drop in the shear strength this is due to the relative large quantity of iron particles which affects the wetting property of the epoxy which means that the iron particles prevent the epoxy from reaching significant parts of the adhered surfaces which decrease the adhesion area of the specimen . Silicon carbide (Figure 4) has a small effect on shear strength compared

with iron filing (10%) as a weight percentage. On using different kinds of meshes as reinforcement materials, the same type of steel mesh gives a highest shear strength (Figure 5) whereas polymer mesh and fiber glass has almost same effect on shear strength .However a significant improvement was achieved in shear strength compared with pure epoxy. A (10%) weight of iron filing was found to have the greatest effect on shear strength in all specimens (Figure 6) hence it was recommended as an optimum case .Also steel mesh has the highest effect on shear strength compared with polymer mesh and fiber glass.

The same work was applied on brass/brass and aluminum/aluminum specimens. On adhesion of these specimens it was found that the addition of iron filing to the pure epoxy has a better effect on the shear strength of the adhered specimen more than the other epoxy mixtures, (Figure 7) and (Figure 8) explain these results. About the adhesion of dissimilar metals (Figure 9) it was found that the brass when adhered with aluminum has a better improvement in the shear strength more than the other metals using epoxy mixture including iron filing (10%) as a weight percentage, whereas brass/ galvanized steel couple (Figure 10) adhered by epoxy mixture including steel mesh has the highest shear strength among the others. (Figure11) represents a comparison between different types of adhered specimens .It was found that the brass/brass specimen which was adhered using epoxy mixture consisting of iron filing (10%) gave the highest shear strength as compared with others.

From the results obtained, a significant improvement in mechanical properties of epoxy was obtained by adding different types of reinforcement materials which coincides with the work of the researchers S. M. Darwish, A. A. Aljoboree and A. I. Almosawi.

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Table (1): Comparison between the effect of percentage of iron filing on shear strength of galvanized (steel / steel) specimens.

% Iron filing	shear strength(N/mm²)
0	4.2
10	5.6
20	4.7
30	5.5

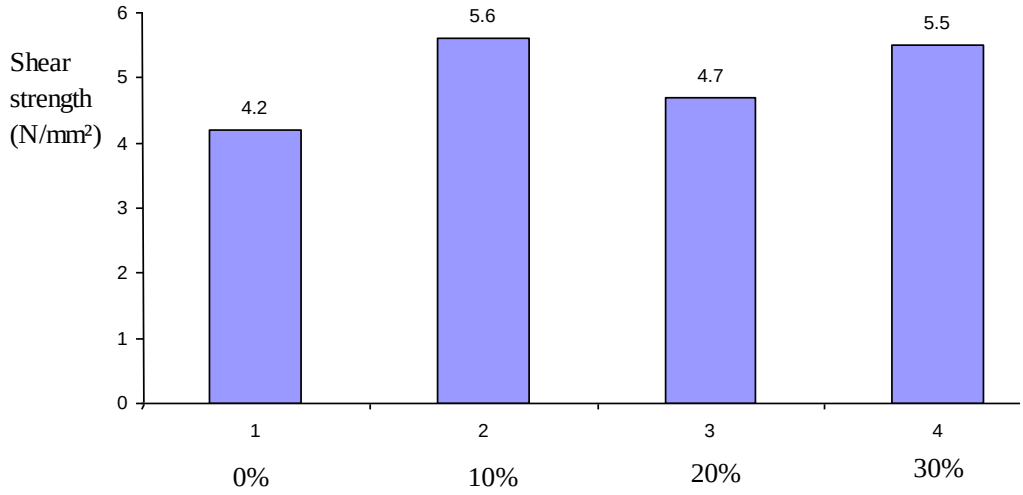

Figure (3): Effect of iron filing percentage on the shear strength of galvanized (steel / steel) specimens.

Table (2): Comparison between the effects of different particles on shear strength

reinforcement materials	Shear strength(N/mm²)
10% SiC(150µm)	4.6
10% SiC(250µm)	4.7
10%Iron filing	5.6

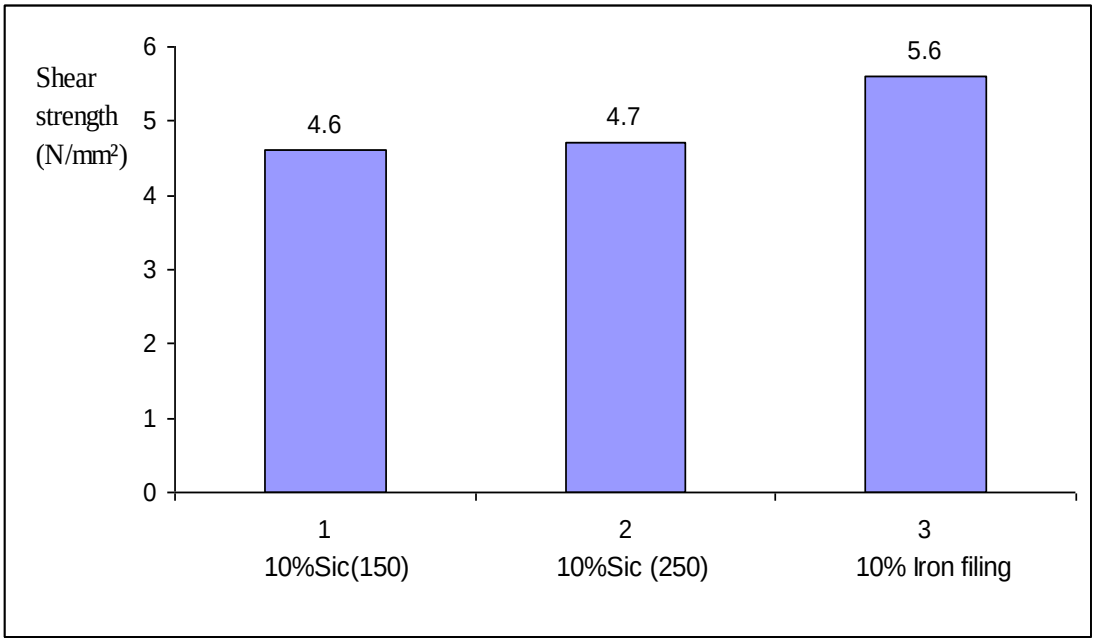

Figure (4): Comparison between the addition of (10% Sic) particles and (10%) iron filing on shear strength of galvanized (steel / steel) specimens.

Table (3): Comparison between the effect of different meshes on shear strength of galvanized (steel / steel) specimens

Reinforcement materials	Shear Strength(N/mm²)
steel Mesh	6.3
polymer mesh	5.6
fiber glass	3.9

Table (4): comparison between the best results in adhesion of steel / steel specimens

Reinforcement materials	Shear Strength(N/mm²)
Pure epoxy	4.2
10%Iron filing	5.6
Steel mesh	6.3

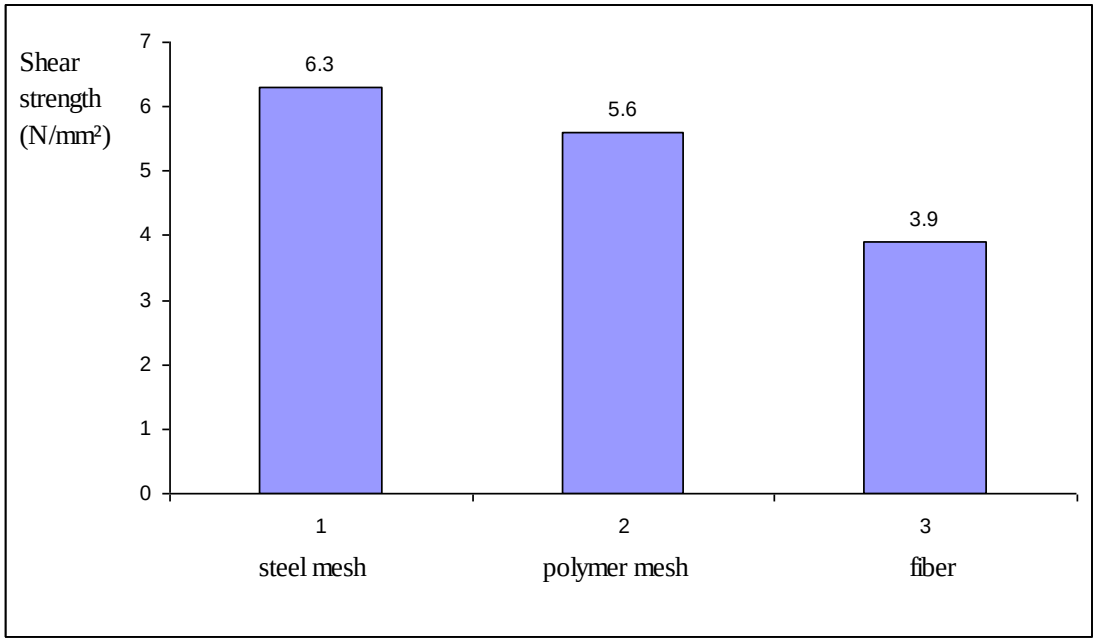

Figure (5): Effect of mesh type added to the epoxy on shear strength of galvanized (steel / steel) specimens.

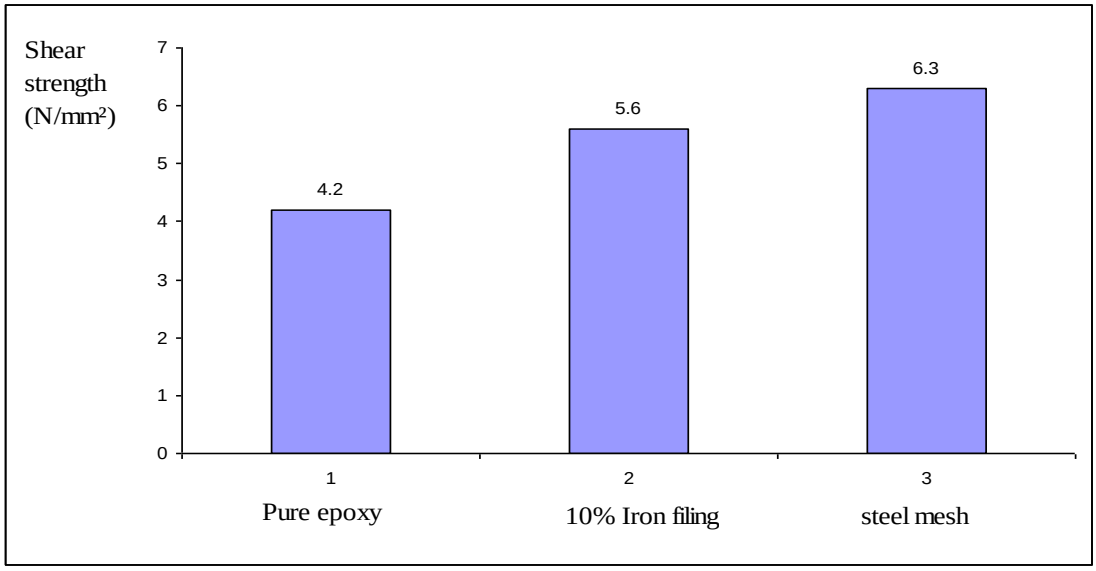

Figure (6): Comparison between the best results of adhesion steel / steel specimens

Table (5): Comparison between the effect of different reinforcement materials on shear strength of brass / brass specimens.

Reinforcement materials	Shear Strength(N/mm²)
10%Iron filing	7.5
Pure epoxy	5.7
Steel mesh	4

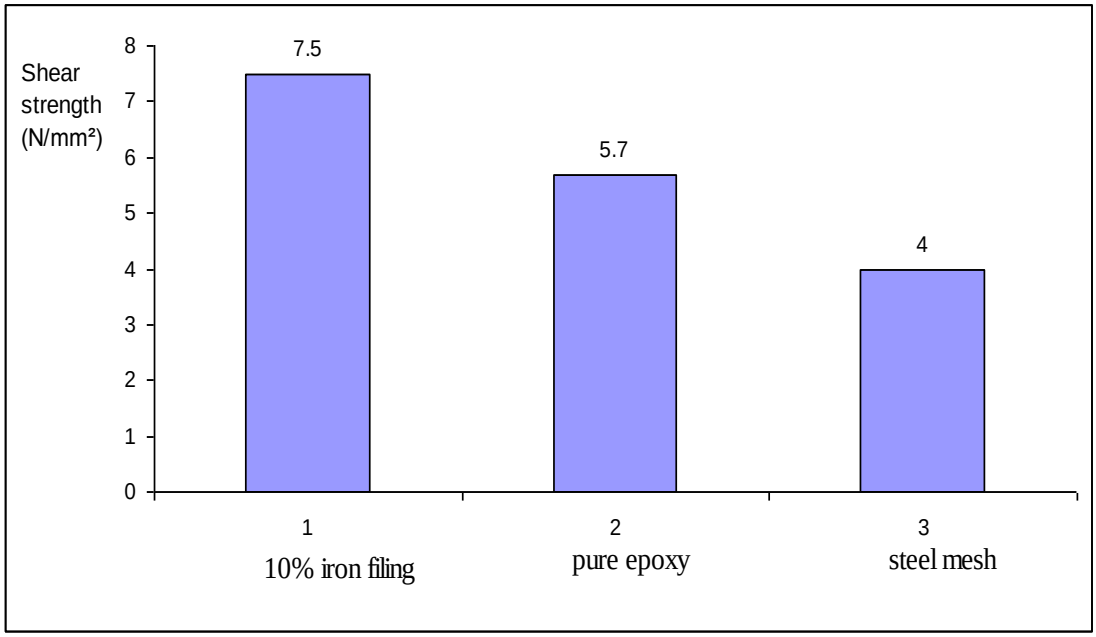

Figure (7): Effect of reinforcement materials on shear strength of brass / brass specimens.

Table (6): Comparison between the effect of different particles on shear strength of aluminum /aluminum specimens

Reinforcement materials	Specimen no.	Shear Strength(N/mm²)
Pure epoxy	1	3.7
10%Iron filing	2	4.6
Steel mesh	3	3.8

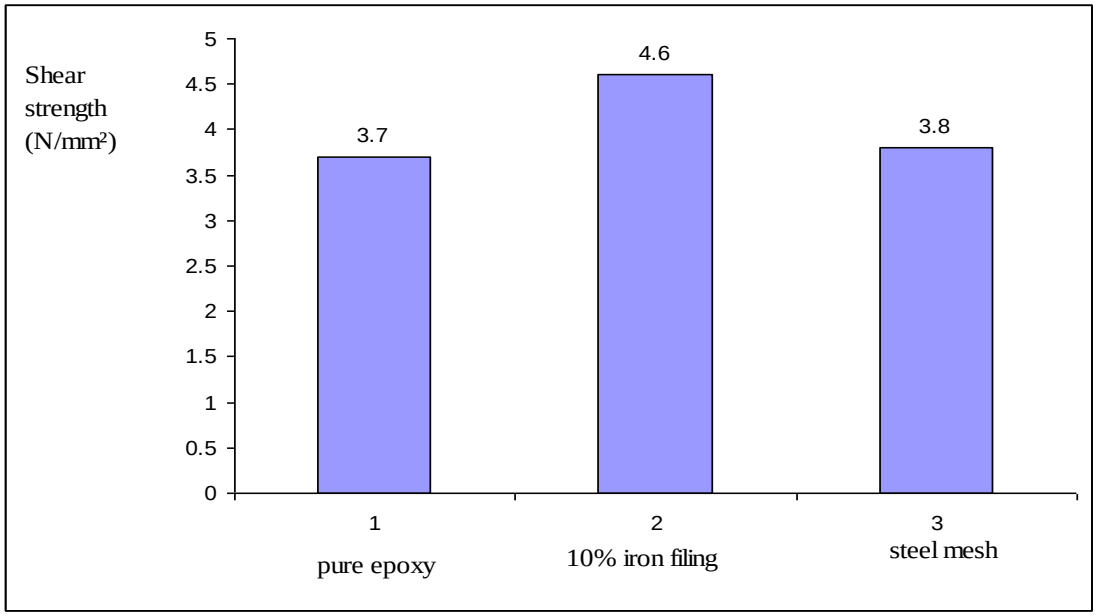

Figure (8): Effect of s reinforcement materials on the shear strength of aluminum/aluminum specimens

Table(7): Effect of addition of 10% iron filing on the shear strength of dissimilar metals

Specimen	Shear Strength(N/mm²)
Al-Brass	4.7
Al-Steel	4.4
Brass-Steel	4.3

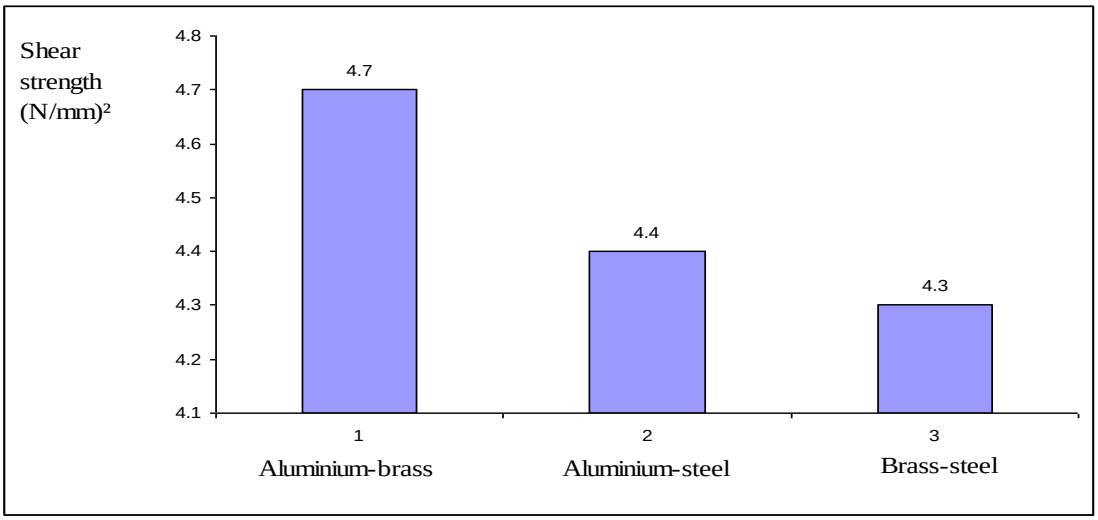

Figure (9): Effect of addition of 10% iron filing on the shear strength of dissimilar metals

Table (8):): Effect of steel mesh added to the epoxy on the shear strength of dissimilar metals

Specimen	Shear Strength(N/mm²)
Al-Brass	4.3
Al-Steel	4.0
Brass-Steel	5.8

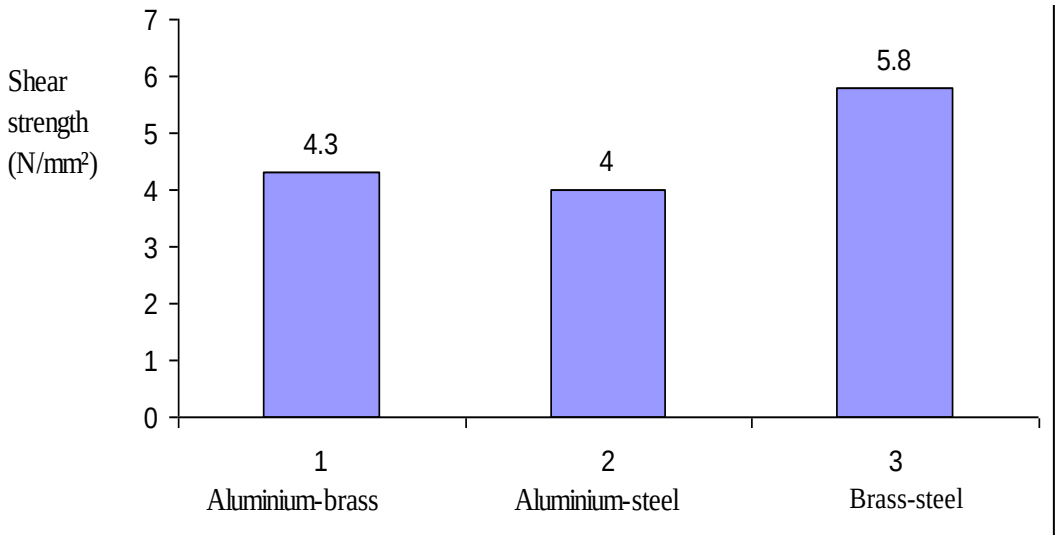

Figure (10): Effect of steel mesh added to the epoxy on the shear strength of dissimilar metals

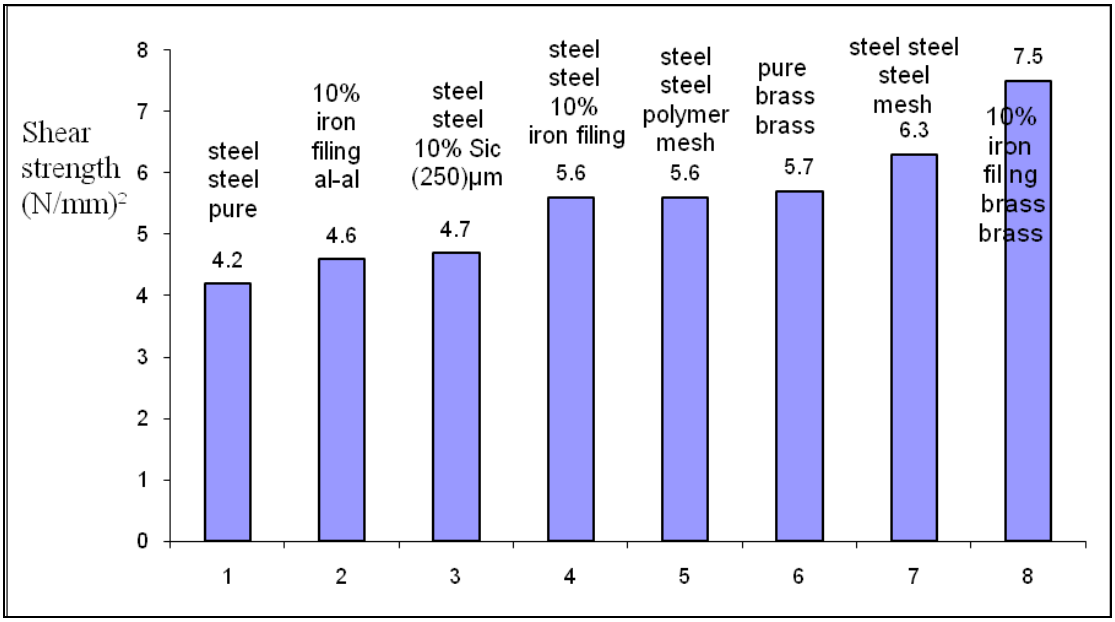

Figure (11): comparison between the shear strength of different types of the experimental results

Conclusions:

1- It is possible to improve the shear strength of epoxy type (pattex/ henkel) by the addition of reinforcement materials. The reinforcement materials used in this research included iron filing, silicon carbide, steel mesh, polymer mesh and fiber glass.
2- The steel mesh is considered to be the best reinforcement material used in adhesion of galvanized (steel/steel),about(33%and50%)shear strength improvement using (10%)iron filing and steel mesh respectively.
3-Epoxy including iron filing has a better effect on shear strength than that of pure epoxy when adhesion of brass / brass specimen. The highest value of shear strength was found in adhesion of similar metals type brass / brass specimen using epoxy mixture consists of(10%) iron filing as reinforcement to the epoxy, about (31%) of shear strength improvement.
4-In most adhered specimens it was found that the best percentage of iron filing added to the epoxy is (10%) compared with the other percentages (20% and 30%)of iron filing.
5- It was found that the particle size of silicon carbide has a slight effect on the shear strength of the epoxy mixture, about (12%) of shear strength improvement.

6- A reduction in the amount of expensive pure resin was obtained due to the addition of inexpensive reinforcement materials which lead to a reduction of total adhesion cost.

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