Spot Welding of Galvanized Steel ASTM A653 Using Oxygen Free High Conductivity Copper Interlayer

اللحام النقطي للفولاذ الكاربوني (ASTM A653) باستخدام نحاس عالي النقاوة كطبقة وسطية

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Abstract

The effect of spot welding parameters (Current and Applied Load) are studied in welding of galvanized steel specimens. Three values of current 9600, 11000 and 12300 AMP and load of 350, 400, 450 kg are used. The results indicate that the shear force improve with increasing the current and decreasing the load. The optimum shear force is achieved with current of 12300 AMP and load of 350 kg. Those parameters is used to weld steel (with and without galvanize layer) using the OFHC copper as interlayer with different thickness (0.1, 0.2 and 0.3mm). The results show that OFHC as interlayer reduce the shear force.

Key word: spot welding, galvanized steel, OFHC copper, DOE(Design Of Experiment

الخلاصة :

تم دراسة تأثير متغيرات لحام النقطة (التيار وحمل مسلط) على عينات من الفولاذ المغلون . اختيرت ثلاث قيم من التيار (9600، 11000، 12300 أمبير) وثلاث قيم من حمل مسلط (350 ، 400 ، 450 كغم) للحام العينات . اظهرت النتائج ازدياد قوة القص بزيادة التيار وصولا الى 12300 امبير وحملا مسلطاً عند 350 كغم. استخدمت هذه المتغيرات للحام العينات المغلونة وغير المغلونة (بعد ازالة طبقة الزنك) باستعمال طبقة رقيقة من النحاس عالي النقاوة كمعدن حشو وباسماك (0.1، 0.2 ، 0.3 ملم). بينت النتائج ان استخدام معدن الحشو ساعد على خفض قوة القص.

Introduction

Resistance welding is the simplest and most commonly used spot resistance welding, is carried out by overlapping the edges of the two sheets of metal and fusing them together between copper electrode tips at suitably spaced intervals by means of heavy electrical current. Many studies have been carried out on the resistance spot welding process, some of which are associated with effects of various process (welding parameters) conditions on weld quality Resistance Spot Welding (RSW) emerged in the 1950s, and is today the main assemblage method in the automotive manufacturing. RSW is considered as the dominant process for joining sheet metals in automotive industry. Typically, there are about 2000–5000 spot welds in a modern vehicle. Simplicity, low cost, high speed and automation possibility are among the advantages of this process **[1-6]**. **S. Zhange [7]** based on the fracture mechanics analysis of spot welds, approximate stress formulas of structural stress, notch stress, and stress-intensity factors are obtained for a newly proposed multiracial spot weld specimen that enables a spot weld to be tested under combined loads ranging from shear to tension. The formulas were validated by finite element simulations. **I. S. Hwang , et al [8]** studied the weldability of galvanized steel by the inverter DC resistance spot welding process and make comparison with the resistance spot weldability depending on testing of tensile strength and the testing of macro-section performed galvanized steel and uncoated steel, They found that :- tensile strength increases with the increasing welding current and time under all electrode force conditions.Under the same conditions, the uncoated steel is and weaker than galvanized steel in terms of nugget diameter and tensile strength. **Ugur Esme [9]** used Taguchi method for the optimization the parameters of resistance welding process on the tensile shear strength for AISI 1010 steel sheet. Four three – level process parameters have been selected, electrode force, electrode diameter, welding current, and welding time. The experiment was performed on two different thicknesses (1 and 2 mm).**Fisun Muftuoglu and Tunakeskinel [10]** examined the effect of coating thickness on electrode life in the resistance spot welding of galvanized steel. The materials used in the experiments were uncoated and hot dip Zn coated low steel sheets with 1.5 mm thickness. The electrode force used during spot welding operations was 7.3 KN under 6500 AMP and 2 second as welding time. They found that the electrode life is decreased by increasing the number of welds for all steels investigated. Also shearing strength is decreased by decrease in the number of welds, due to the reduction in nugget diameter.

Experimental work

In this work, the chemical composition and the mechanical properties of the material used have been examined (Table-1&2). Shear tensile test specimen is made in order to achieve the mechanical properties according to ASTM standard. The material used is galvanized steel ASTMA653 Type A G30 with 2 mm in thickness. The type of filler is OFHC C11020 in annealed condition (Table 3).

Table (1): Chemical composition of galvanized steel ASTM A653\A653 M

Element	C%	Mn%	P%	S%	Cu%	Ni%	Cr%	V%	Ti%
Nominal[11]	0.08	0.6	0.1	0.035	0.25	0.2	0.15	0.008	0.025
Actual	0.063	0.164	0.013	0.003	0.013	0.010	0.029	0.002	0.001

Table (2): Mechanical properties of galvanized steel ASTM A653

Mechanical properties	Yield strength (MPa)	Elongation%
Nominal [11]	170-410	>26
Actual	262	40

Table (3): Chemical composition of copper UNS OFHC C11020

Elements	Cu%	Si%	Mn%	Zn%
Actual	99.8	0.017	0.012	0.08
Nominal[12]	99.9	0.01	0.008	0.05

The welding process was implemented using the spot welding machine. It is rocker arm (Bay Kay), machine type (p1-Rectifier Press Spot Welding Machine Schlatter) with transformer capacity (15 KAV), and single phase (220 Volt).

A sheet of 2mm is used to made the specimen according to ASTM D1002. The dimensions of sample are (L=101.7mm, w= 25.4mm and t= 2 mm) as shown in figure (1) with overlap 12.7 mm.

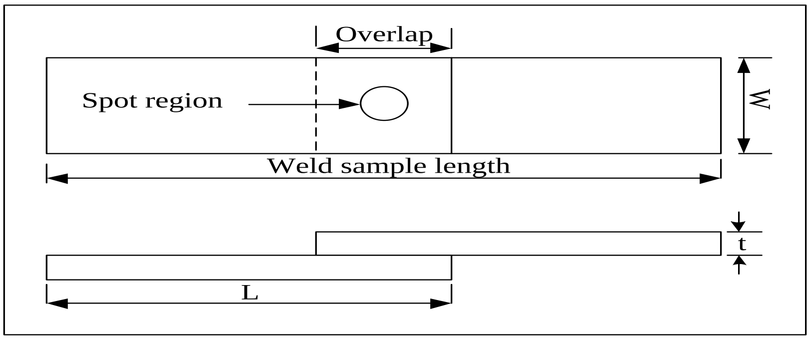


Figure (1): Spot welding specimen

The specimens are welded with different currents and applied loads (Table-4). From those specimens, the optimum conditions will be found which represents the maximum shear force.

Table (4): Welding parameters

Specimen Number	Current (AMP)	Applied Load (kg)
1	9600	450
2	9600	400
3	9600	350
4	11000	450
5	11000	400
6	11000	350
7	12300	450
8	12300	400
9	12300	350

Table (5) shows the constant parameters employing during welding all specimens.

Table (5): Parameters of spot welding

Weld time	Heat cont.	Up slope	Hold time	Off time	Squeeze time
25 cycle	3 cycle	2 cycle	12 cycle	9 cycle	2 cycle

OFHC with different thickness (0.1, 0.2 and 0.3 mm) is used then as interlayer between the lap joint for the samples those recording maximum shears force (Figure-4 & Table-6).

Figure (4): OFHC as interlayer

In order to examine the effect of foil thickness and the galvanize layer on the mechanical properties, more specimens are spot welding (Table-6).

Table (6): Spot welded specimen with OFHC interlayers

Specimen No.	1	2	3	4	5	6	7	8
Base metal	Un-galvanize	Galvanized	Un-galvanize	Galvanized	Un-galvanize	Galvanized	Un-galvanize	Galvanized
OFHC(mm)	0.3	0.3	0.2	0.2	0.1	0.1	0.0	0.0

The shear tests were performed at a cross head speed of 10 mm/min. The specimens were gripped as shown in Figure (5) with shims. Figure (6) illustrates the fractured welded specimens.

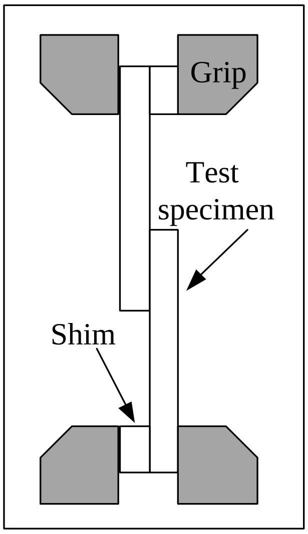
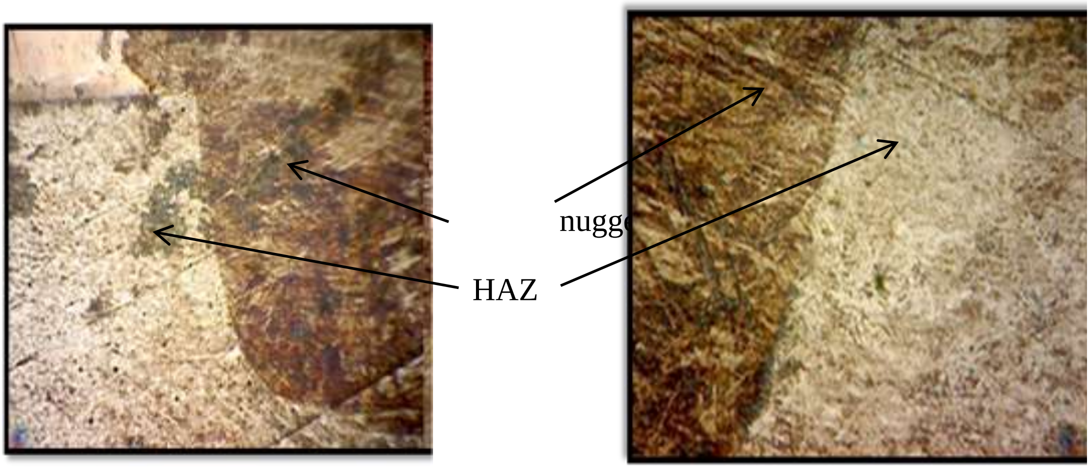


Figure (5): Tensile test grip assembly

Figure (6): Fractured shear test specimen

Results and Discussion:

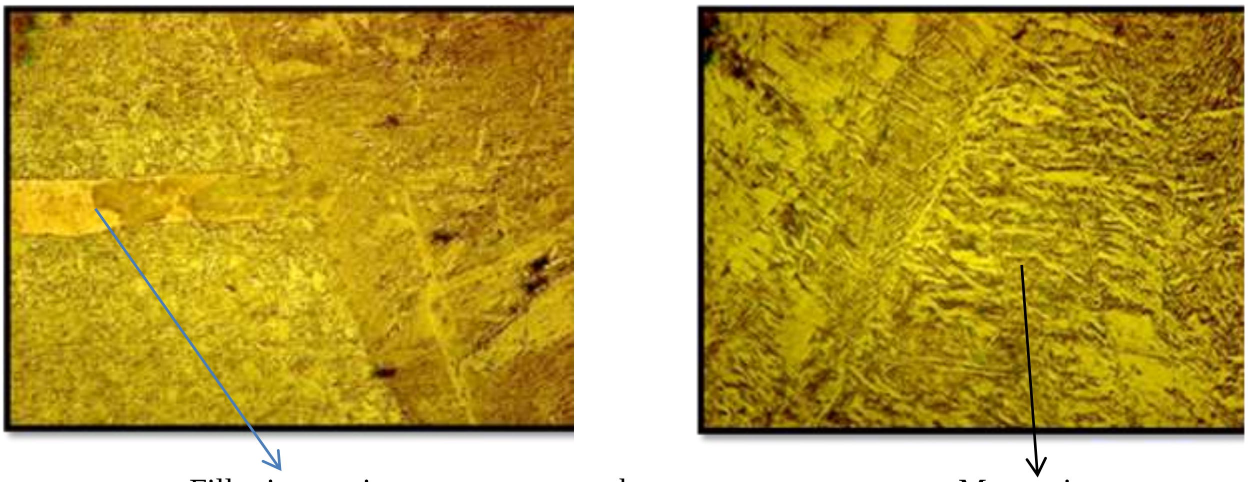
In spot welding process ,the microstructure of welded joint shows two zones in general , the nugget and the heat affected zones as shown in figure (7) , which clearly appears the all metallurgical aspects in this process.



a b.

Figure [7]: The microstructure of un-galvanize steel (X50)

Figure (8-a) shows the interaction between the nugget zone with the fused OFHC Copper. While figure (8-b) indicates the epitaxial grain growth when welding without filler. The structure of the nuget zone is mainly martensitic. The using of filler metal with spot welding sometime called spot brazing process.



a- Filler interaction b- Martensite

Figure (8): The microstructure of galvanize steel a. with copper b. without copper (X50)

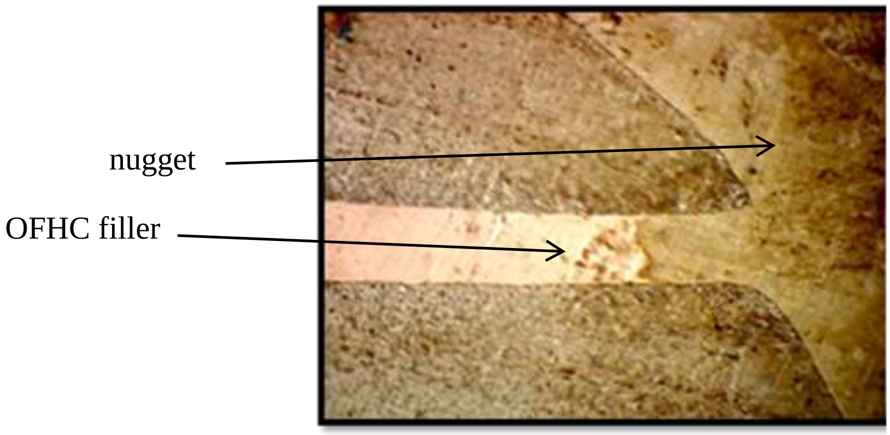


Figure (9): The microstructure of galvanize steel welded with filler metal (copper 3mm) (X50)

In order to obtain a good accuracy, three specimens for each case are tested. According to table (4) three values of current (9600, 1100 and 12300 AMP) and applied load (350,400 and 450 kg) are used. The result of shear force for welded specimen is presented in figure (10). As it has been observed, regardless of current, the shear force increased with decreasing the load. The presence of copper reduces the shear force of weldment, that means, the shear force increase with decreasing the applied load for specimens (1,2,3 at current of 9600 AMP) ,(4,5,6 at current of 11000 AMP) and (7,8,9 at current of 12300 AMP) . On the other hand, the shear force increase as the current increased. Whereas, the optimum results are obtained with welding of higher current (12300 AMP). For specimens (7, 8, 9) ,the optimum shear force is presented in specimen (9) which has been welded with maximum current (12300 AMP) and minimum applied load (350 kg) .

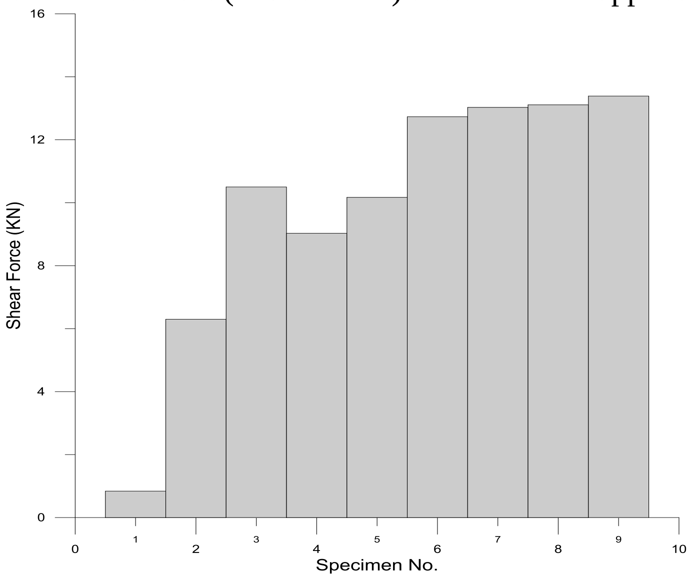


Figure (10): Shear force for galvanized specimens

In order to analyze the effect of welding parameters (Current, Applied load), A Minitab program is used by design of experiment method (DOE). A pareto chart present that the current have the most effect on shear force as comparing with the other factor (Applied load).

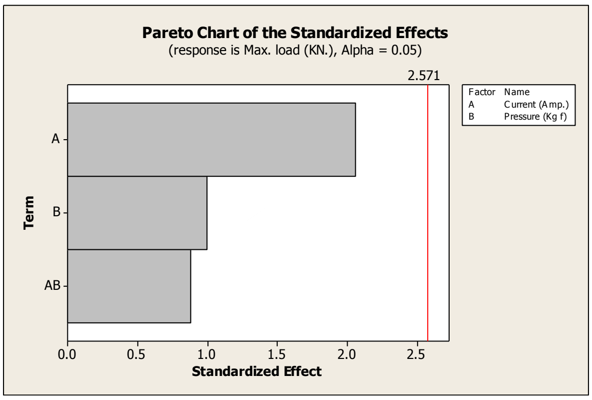


Figure (11) : Pareto chart of the standardized effects response

According to countor graph, the maximum shear force can be occurred through all range of the used pressure as in figure (12), such that the range of current is more than 6000 AMP.

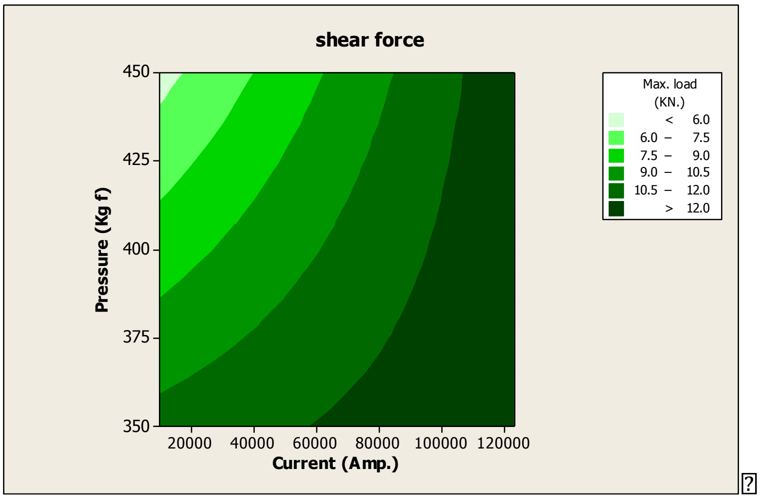


Figure (12): Countour diagram of pressure – current rate with maximum shear force

The optimum conditions for shear force is concluded at the values; current of 123000 AMP and load of 350 kg as it has been observed from the optimization of DOE results , figure (13).

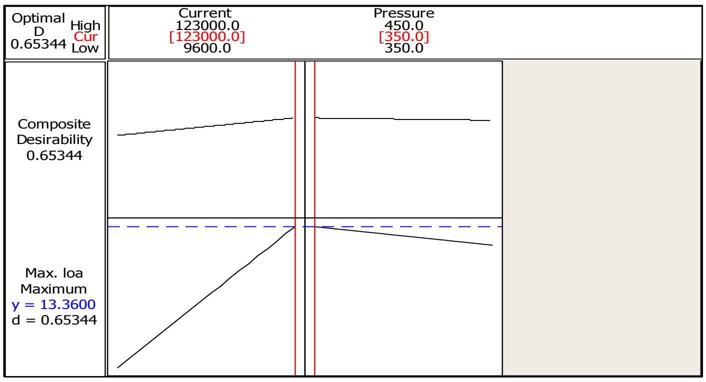


Figure (13): Optimal of maximum shear force

The main effect plot analysis proved the increasing in current gave an increasing in the maximum shear force on the other, the increasing in pressure decreased the maximum shear force, figure (14).

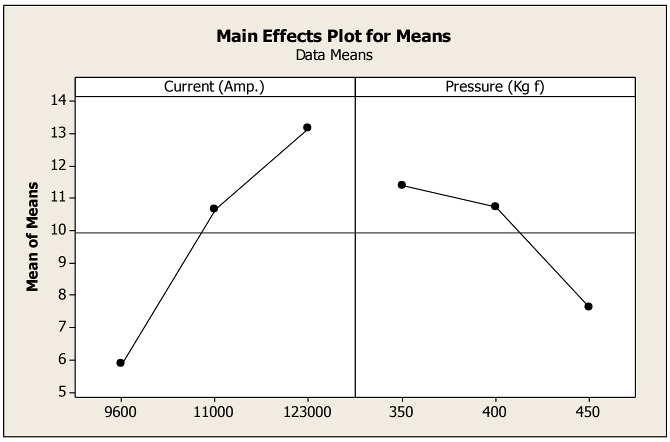


Figure (14): Main effect plot for means (Data Means)

A current of 12300 AMP and load of 350 kg is used to weld all specimens in table (6). Those specimens are classified into two groups. The first one represent the welded of galvanized specimen with three different OFHC thickness (0.1, 0.2 and 0.3mm). The other group represents the welded of steel without galvanize layers. The results of shear force are show in figure (12). The galvanized layers gave a higher shear force when the OFHC foil is used as comparing with specimen without galvanize layer. The presenceof copper reduce the shear force of weldment.

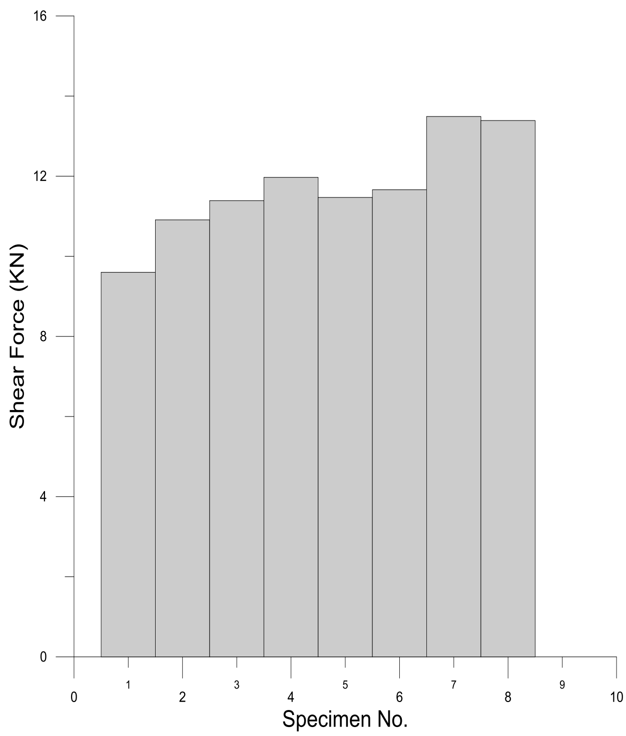


Figure (15): Shear force for specimen with intermediate (OFHC)

The result of DOE presents that a higher shear force is observed in the galvanized specimen than those of steel specimen. The increase in foil thickness reduce the shear force of spot region, figure (16).

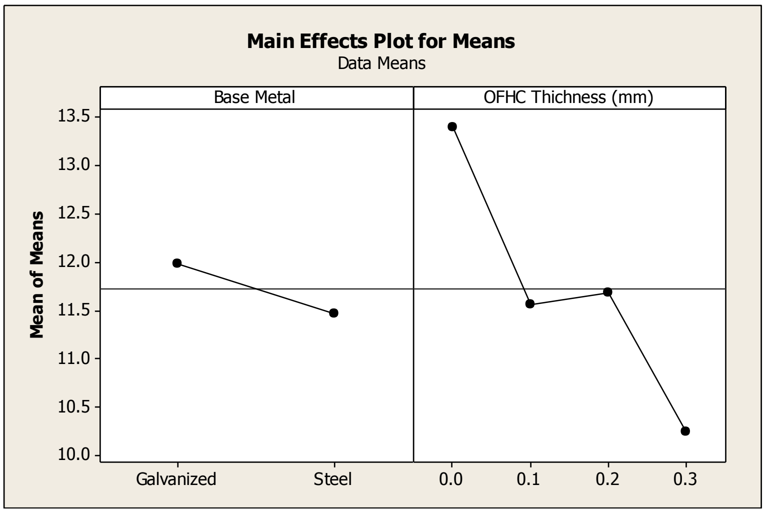


Figure (16): The main effect plot of shear force for specimen of with intermediate foil

In general, a weakness shear properties are found for un-galvanized steel as comparing with the galvanized one.

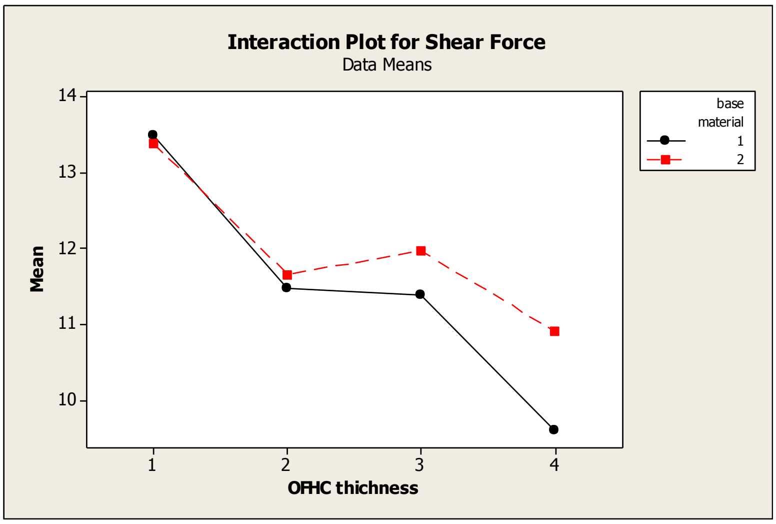


Figure (17): Interaction plot of shear force specimen with intermediate foil

Conclusions

1- Increasing the current results in increasing the shear force of spot weldment for galvanized steel, while increasing the applied load assosiated with decreasing the shear force.
2- Galvanized layer has postive effect on the shear force.
3- Using the OFHC layer results in decreasing the shear force.
4. The analysis of DOE corresponding with eperimental results to some extent.

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