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Soft Soldering of Steel DIN CK50 Using ASTM 50A and ASTM 63A

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Abstract.

The research presents some experimental data concerning the relation between the shearing strength of soldered joints and holding time. Two types of solders ASTM 50A (Sn50Pb50) and ASTM 63A (Sn63Pb37) were used to joint medium carbon steel type DIN CK50 of 3 mm thickness. Lap joint design was employed. Muffle furnace used for heating with holding (reflow or dwell) times of 10, 20, 30, 35, 40, 45 and 50min. Maximum shear strength was obtained when the eutectic solder (ASTM 63A) used with 35 min. as holding time. Clear intermetallic compounds were shown at the interface, whereas the X-ray detected the formation of many phases like FeSn and $FeSn_2$.

Keywords: soldered joints, solders, shear tests, intermetallic compounds.

Introduction

At the beginning of the twentieth century soldering came into use for jointing of thin metallic materials. Its next development is closely connected with the development of automobile, electrical and light industry. Today it is luxuriantly used not only for single-part production but in serial and mass production, too. Its optimal use is, e.g., at products of general and precision engineering, in electrical, chemical, light and aircraft industry, in cosmonautics, at production of imitation jewelry and in other fields. Properties of soldered joints are specific, e.g., joints can be gas proof, waterproof, electric conductible, corrosion proof etc. Joints are tough both at static and dynamic stress. In the same way as other methods of joining the soldering technology is of advantages and disadvantages and therefore of its optimal application fields. Among advantages less energy consumption, higher operating speed, high economy, higher labour productivity, possibility of mechanization and automation, possibility of almost all metallic materials jointing regardless of their size and thickness, only low stress in the joint, lower effect on jointed materials properties and at last a fair visual appearance can be enumerated. Disadvantages are, e.g., lower strength and heat resistance [1].

Steel can readily be soldered if the proper procedures and techniques are employed and if special attention is given to surface preparation and the selection of fluxes. There are few limitations on the types of solders that may be used on steel [2, 3]. Solder alloys are used extensively as interconnect materials and the combination of relatively low melting point, low coast, and high ductility are all attractive features of these materials. While the relatively low melting temperatures of Pb-Sn alloys minimize the risk of heat damage to devices [4-6]. Most often solders are classified according to their working temperature as soft solders (upper melting point < 450 °C) and hard solders (upper melting point > 450 °C) and compared with hard solders the working temperatures of soft solders are lower and mechanical properties are lower, too. Relatively new class of soft solders is the so- called leadless solders [1].

Mechanical properties of soldered joints are generally related to, but not equivalent to, the mechanical properties of the soldering alloy [7]. Jainbiao [8] concluded that the shear force of lead

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containing SnPb solder joints is higher than that of leadless SAC 305 solder joint. Molleda [4] demonstrated in his work that soldered joints, which can be considered as functional joints, have very good mechanical properties and can provide more than acceptable levels of leak tightness. When have been compared with those obtained from adhesive and hybrid joints. Suezawa [9] during their investigation about the relation between the shearing strength of soldered joint and the roughness of soldering surface of base metal, they cleared that the shearing strength of a soldered specimen having a small roughness value was greater than that of the one having a large roughness value. And also declared that the maximum shearing strength for the soldered specimens was obtained at the joint clearance of about0.2-0.3 mm. Knowing that Eutectic Sn-Pb solder is one of the most commonly used joining materials which serves as a mechanical and electrical connectors between printed circuit boards and components [10, 11].

Materials and methods:

However, there are a few limitations on the type of solders that may be employed for joining steel [2] and the choice of a solder that may be used on steel is governed somewhat by the intended end use of the assembly. The aim of present research was to state the strength of solder joints of steel DIN CK50 (tables-1and2). Soldering was carried out in a muffle furnace without using any protective gas and two most applicable lead content soft solder alloys (table-3) with lap shear joints (figure-1).Tensile shear specimens of 3mm thickness and 20mm width were used. The specimen grinding before soldering using emery papers ASTM Grade 120,220,320 and 400 respectively and cleaned by Alcohol before assembling. The solder alloys formed as foils of dimensions 10x6x0.14mm, were cut and fixed between two samples. Soldering flux was Rosin-type and soldering was carried out at temperature 55°C over the solder alloy liquidus temperature.

Table-1: Chemical composition of DIN CK50

Materials / Elements	Nominal chemical composition	Actual chemical composition
%C	0.47- 0.55	0.493
%Si	0.4	0.217
%Mn	0.6 – 0.9	0.832
%P	0.035	0.029
%S	0.030	0.017

Table-2: Mechanical properties of tensile test of steel DIN CK50

Property / Material	σy MPa	σu MPa	% Elongation
Nominal Mechanical Properties	520	750 - 900	13
Actual Mechanical Properties	638	875	14.5

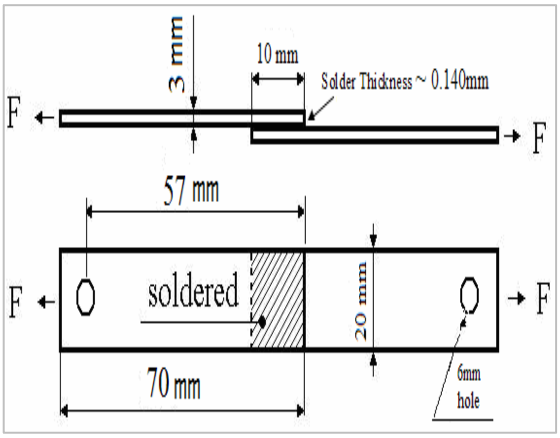
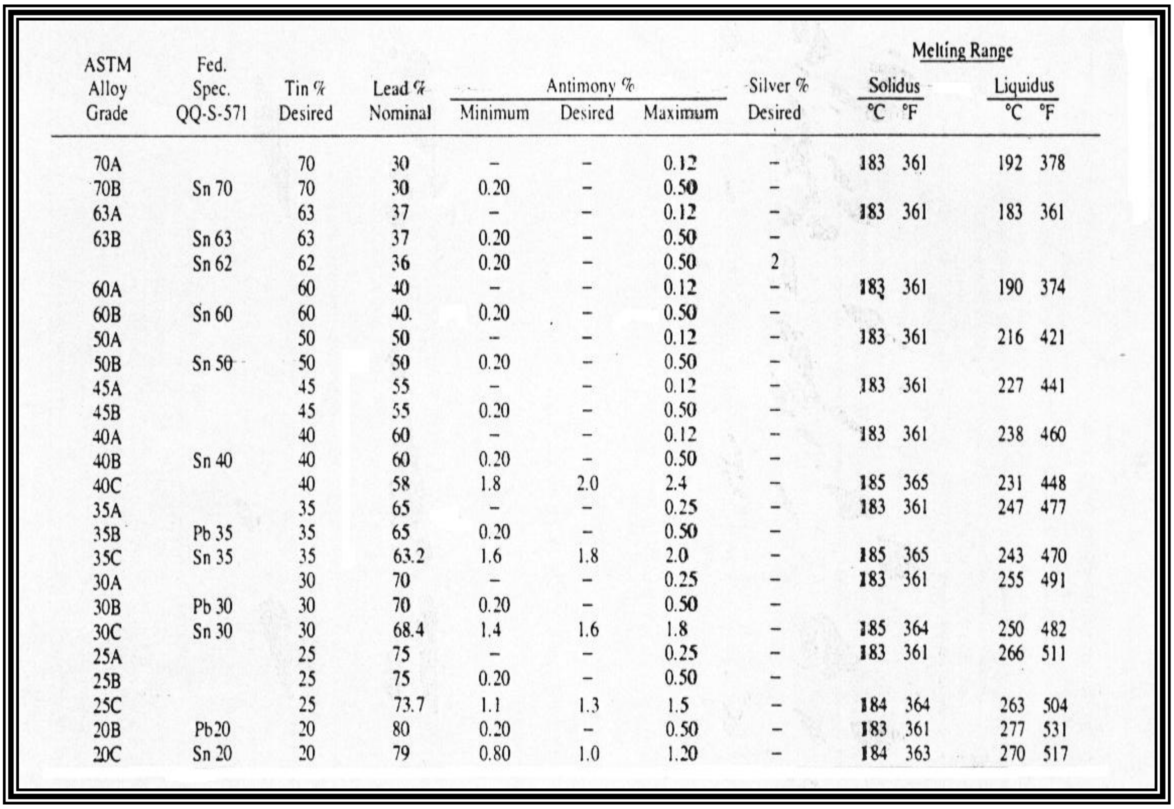


Figure-1: Dimensions of the assembly test specimen

Table-3: Classification of Sn-Pb alloy [12]



ASTM Alloy Grade	Fed. Spec. QQ-S-571	Tin % Desired	Lead % Nominal	Antimony %			Silver % Desired	Melting Range			
				Minimum	Desired	Maximum		Solidus		Liquidus	
								°C	°F	°C	°F
70A		70	30	–	–	0.12	–	183	361	192	378
70B	Sn 70	70	30	0.20	–	0.50	–				
63A		63	37	–	–	0.12	–	183	361	183	361
63B	Sn 63	63	37	0.20	–	0.50	–				
	Sn 62	62	36	0.20	–	0.50	2				
60A		60	40	–	–	0.12	–	183	361	190	374
60B	Sn 60	60	40.	0.20	–	0.50	–				
50A		50	50	–	–	0.12	–	183	361	216	421
50B	Sn 50	50	50	0.20	–	0.50	–				
45A		45	55	–	–	0.12	–	183	361	227	441
45B		45	55	0.20	–	0.50	–				
40A		40	60	–	–	0.12	–	183	361	238	460
40B	Sn 40	40	60	0.20	–	0.50	–				
40C		40	58	1.8	2.0	2.4	–	185	365	231	448
35A		35	65	–	–	0.25	–	183	361	247	477
35B	Pb 35	35	65	0.20	–	0.50	–				
35C	Sn 35	35	63.2	1.6	1.8	2.0	–	185	365	243	470
30A		30	70	–	–	0.25	–	183	361	255	491
30B	Pb 30	30	70	0.20	–	0.50	–				
30C	Sn 30	30	68.4	1.4	1.6	1.8	–	185	364	250	482
25A		25	75	–	–	0.25	–	183	361	266	511
25B		25	75	0.20	–	0.50	–				
25C		25	73.7	1.1	1.3	1.5	–	184	364	263	504
20B	Pb20	20	80	0.20	–	0.50	–	183	361	277	531
20C	Sn 20	20	79	0.80	1.0	1.20	–	184	363	270	517

Chemical analysis of CK50 carried out in the University of Technology; whereas the mechanical testing was doing in the Technical College of Sulaimani using (Universal Material Testing / WP300 / 20KN).The examination of microstructure of CK50 detects the presence of Ferrite and Pearlite (figure-2).

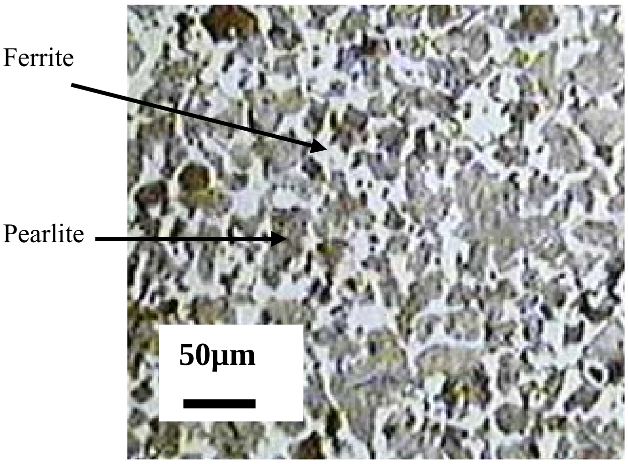


Figure-2: **Microstructure of steel CK50**

Results and discussion:

Tin-Lead solders are widely employed for joining mild steel. The two most applicable lead content soft solder alloys of (50A) and (63A) were used for joining medium carbon steel DIN CK50 at temperatures 271 ± 2 °C and 238 ± 2 °C respectively, and they hold at their temperatures for 10, 20, 30, 35, 40,45 and 50 min., then soldered specimens cooled in the furnace gradually. The relation between the shear strength and the holding times of the lap joints show in (Figure-3). It is evident that the results of tests of both solders are similar to some extend. It indicates that due to increasing of holding (dwell) time the shear strength of the joints are increasing to a maximum value then decreasing. The maximum shear strength of 50A solder alloy joint is 35.85 MPa at holding time of 30 min.The microstructure (Figure-4) indicates that clear intermetallic compound is forming. X-ray diffraction of maximum shear

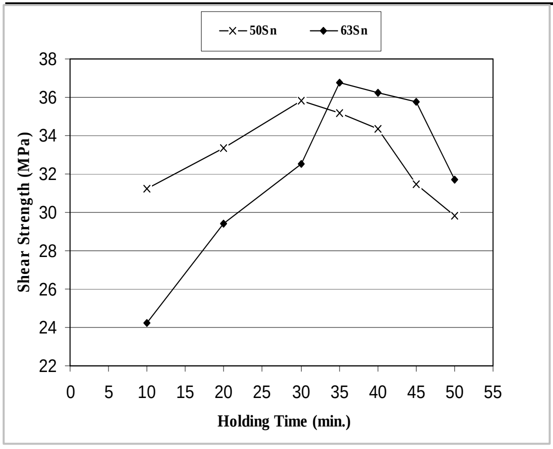


Figure-3: The relation between Shear Strength and holding time

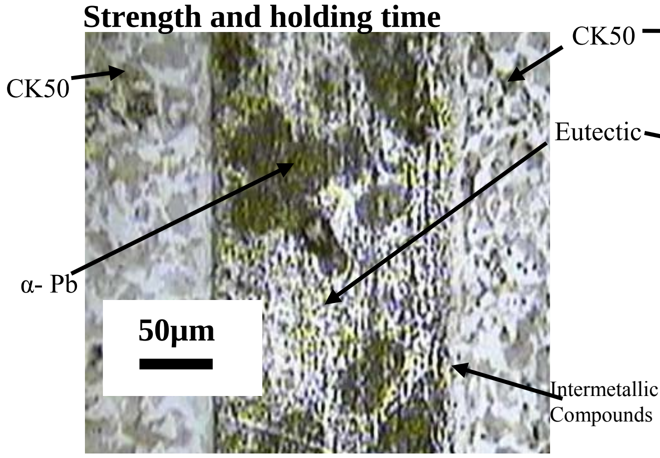


Figure-4: Microstructure of solder joint with 50A. Holding time, 30min

specimen shows the formation of intermetallic compounds FeSn and $FeSn_2$ and Alpha-Iron as well as the presence of solder phases; eutectic and Alpha-Pb. (Figure-5) is showing the structure of the joint for 63A at holding time 35min. in which the maximum shear strength of 36.75 MPa is obtained. FeSn and $FeSn_2$ and Alpha-Iron are forming, as well as the phases of 63A solder, eutectic and β –Sn.

Returning to (Figure-3) it could be noticed that the increasing of holding time from 10min. to 20min. causes the increasing of the soldered joints shear strength from 31.25 MPa to 33.35MPa when 50A solder type was used and from 24.25 MPa to 29.43 MPa when 63A solder alloy was used. The incrementing of shear strength will be continuous for the joints of both types of soldering alloys till it reaches its maximum value (30 min. holding time for 50A and during 35min. for 63A solder type). Certainly the increasing of shear strength of soldered lap-joints is belong to the formation of the hard phases of $FeSn_2$ and FeSn in the joint structure during soldering and the restricted increment of the shear strength of 63A solder joints is due to the increasing of Sn rate in 63A joint composition.

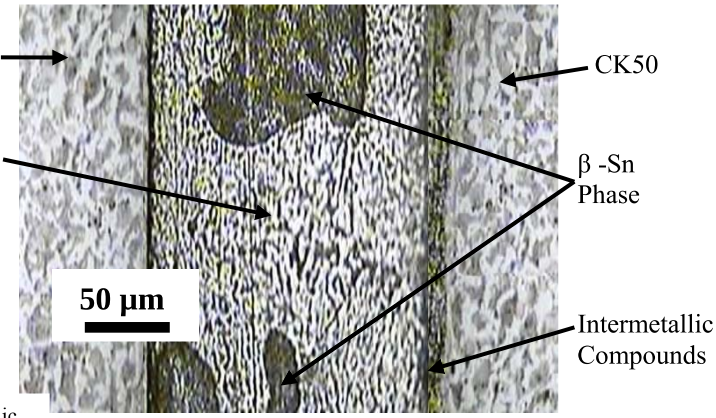


Figure-5: Microstructure of solder joint with 63A. Holding time, 35 min.

From the mentioned relation it could be observed that the difference between the shear strength of both solder types is small. 50A solder with 10min. holding time is achieving strength more than 30MPa, while this incrementing is not passing 6MPa when the holding time is increasing to 30min.

Conclusion:

1. Possibility of soldering DINCK50 by using 50A and 63A as solders.
2. A wide range variation of shear strength with time can obtained with maximum shear strength 35.85MPa for 50A and 36.75MPa for 63A.
3. No clear difference in shear strength when using 50A or 63A as solders with DINCK50.
4. FeSn and $FeSn_2$ are the mainly two intermetallic compounds forming with the two solders.

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گۆڤاری زانکۆی سلێمانی , ٢٠١٠, بەرگ١٣(١) بەشی A

بەبەکارهێنانی سۆڵدەری نەرم لە جۆری DIN CK50 لکاندنی پۆڵای جۆری ASTM50A و ASTM 63A

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پوختـــە

ئەم توێژینەوەیە کۆمەڵێك زانیاری سەلمێنراو سەبارەت بە پەیوەندی نێوان بەرگەگری دادڕان و ماوەی هەڵگرتن بۆ لکێندراوەکانی کاویەدەخاتە ڕوو. دوو جۆر سۆڵدەری کاویە ئەوانیش ASTM 50A (Sn50Pb50) **و** ASTM 63A (Sn63Pb37) **بەکارهێنراون بۆلکاندنی پلێتی پۆڵای کاربۆن ناوەند لەجۆری** DIN CK50 **کە ئەستوری یەکەی** (3mm) **ە. شێوازی بەستنی سوار(لەسەریەك دانان) بەکارهێنرا بۆ لکاندنی پارچەکان بە سۆڵدەر هەروەها فڕنی کارەبایی بەکارهێنرا بۆ گەرمکردن بۆماوە جیاوازەکانی** (10, 20, 30, 35, 40, 45 , 50min) **.دارِشتەی ئەیۆتکتکی سۆڵدەری** (ASTM 63A) **بەرزترین بەرگەگری دادڕانی لە ماوەی** (35 min) **دا تۆمارکرد . هەروەها پشکنینی تیشکی** (X) **دوو فەیزی نێوانی(** FeSn **و** $FeSn_2$ **) ی دەرخست.**

باستخدام نوعين من الحشوة الناعمة للمونة وهما DIN CK50 ربط فولاذ نوع ASTM 50A و ASTM 63A

رزگارمحمد عبدالرحمن

كلية التقنية السليمانية / قسم هندسة الأنتاج والمعادن

الخلاصـــة

يقدم البحث معلومات تجريبية تتعلق بعلاقة مقاومة القص بوصلات الربط بالمونة مع الزمن. استخدم نوعين من حشوة المونة وهما ASTM 50A (Sn50Pb50) **و** ASTM 63A (Sn63Pb37) **لربط صفائح من الفولاذ متوسط الكاربون نوع** DIN CK50 **بسمك** 3 mm **. استخدم الربط التراكبي في عملية المونة كما استعمل فرن كهربائي لغرض التسخين لازمان مختلفة** (10, 20, 30, 35, 40, 45 , 50min) **. سجلت سبيكة الحشو الايوتكتيكية** (ASTM 63A) **اعلى مقاومة قص عند زمن وقدره** (35 min) **. اظهر الفحص بحيود الاشعة السينية تواجد طورين بينيين هما (** FeSn **و** $FeSn_2$**).**

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وەرگیراوە لە ٩/١/٢٠١٠ پەسەندکراوە لە ٢٨ / ٦ /٢٠١٠