Research Article

The Study of Suitable Factors for Welding on Canned Food by Design of Experiment Method

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Received October 21, 2011; Accepted January 30, 2012

Abstract

This research aimed to study the factors that affected canned food welding and the suitable condition of the design of experiment that affected its quality and suitability which finally led to standard quality reference in real work place.

This research utilized the concept of experiment design and analysis to study 4 factors as follows; the electric current, a spring pressure, size of copper wire and overlapping area. By testing 3 response values of welding which were welding strength, welding flexibility, and welding thickness, we found the suitable factors and conditions of the experiment. The results indicated that electric current, spring pressure, and size of copper wire had stronger influence on welding strength and flexibility, whereas only electric current and spring pressure had influence on welding, welding thickness and welding flexibility. The overlapping area had less influence comparing to other factors. The study concluded that the suitable conditions for welding were 55 Amp of electric current, a spring pressure of 60 daN, wire diameter of 2.10 mm. and overlapping area of 0.7 mm.

Keywords: Suitable Factor; Design of Experiment; Welding; Canned Food

Introduction

Canned Food Containers are useful for food preservation. Nowadays, canned food packaging is commonly used in Thailand. There are about 900 million cans of canned food containers produced each year. Canned food and fruit manufacturing compete in quality and price to gain competitiveness in the global market.

The important steps that lead to producing qualified canned food depend on various suitable factors such as can welding, can coating, polyester-powder coating on welding line, and can sealing.

According to the manufacturing research data, it was found that the sample product with the size of "603x700" had highest defect in can welding and had highest risk among all heights of can products. The defect can be categorized into 3 types; hot weld, narrowed weld and cold weld by testing the 4 welding characteristics; welding strength, welding coherence, welding flexibility and welding thickness. All defect types cannot be fixed and returned to manufacturing process once they occurred.

Welding process is the process of forming connections between metal by the pressing of metal electrodes on both sides. Heat will be generated by electricity and transferred to the plates. Heat resistance of metal plate will be higher than electrode heat. Heat distribution is common in the normal welding process. E1 and E2 electrodes identify "I" (volume) required heat and welding capacity in accordance to rules of the Joule heat spots. Heat volume Q is balanced with the performance of W when welding electric current, welding power and welding time are correctly set. The heat will help weld the metal. The first process occurs between the plates' joint where the heat is distributed and some heat is lost to the water cooling system.

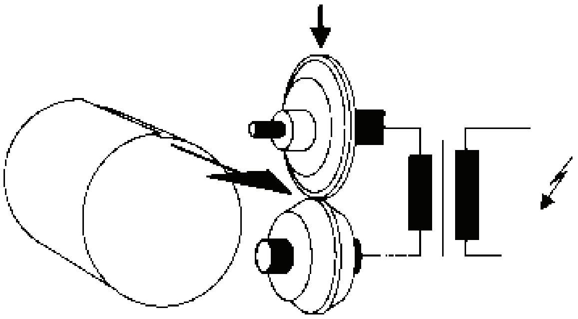

Figure 1 Welding roll

From Figure 1, tin plate was welded with copper wire electrode through the welding tin at the melting point of 230 °C where the wire was dissolved and prevented the contamination from welding roll. The wire strength affects the welding characteristics; therefore the copper wire should be periodically tested in order to maintain the highest quality. Normally, the design of wires has changed from time to time due to machine-design development; the change on single side of heat surface could result in heat transfer change. Even though the other value settings are normal, the heat will be easily noticed from the point where the heat has better flow.

The best amount of electricity from the power supply was measured by the flow based on the maximum number of beads on a piece of iron metal. The appropriate power supply depended on the can thickness that did not tear when tested by connecting them with the power supply set at 2 / 3 of the minimum value for the production.

Parames Chutima (2002) presented 3k Factorial Design that referred to the factorial design which each factor consisted of three design levels. The symbol of the factors was represented by a capital letter and the levels of each factor were low, medium, and high. The symbols could be substituted by k 0 (Low), 1 (Medium), and 2 (High). The experiment of 3k designs was substituted by the numbers of k. For example, to design 3^2 number 00 meaned the experiment which both factors A and B were low. 01 referred to experiment which factor A was low and factor B was moderate. The equation was defined as follow (Mayer and Montgomery, 2002) (Figure 2).

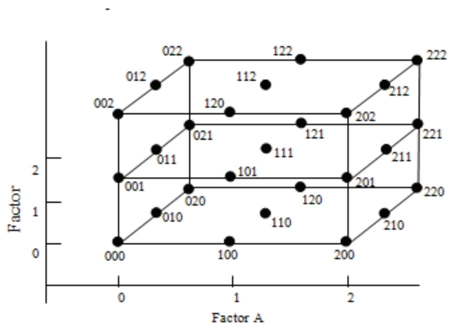

Figure 2 Co-factor for the experiment design 3^3

Equation	$Y_{ij} = \mu + \Gamma_i + \varepsilon_{ij}$
μ=	Average
Γ=	Influence factors
ε =	discrepancy

Most experimental designs set up the hypothesis when y (variable) is at a normal distribution. Therefore, to gain that kind of distribution, E needs to be set up as a normal distribution and independently as well $\varepsilon_{ij} \sim NID(0,\sigma^2)$.

The independence of distribution is verified by using a scatter plot to study the distribution characters. The distribution characters are then checked whether the distribution points are independent. For the variance stability, a scatter plot is also used to check whether the distribution points from each factor have the residual. If none of changes of the megaphone appears in a distribution shape of the information, the information displays variance stability.

Several researchers have studied in this area. "Finding the optimum conditions for coating of lacquer on a piece of tin coated steel by means of experimental design" by Tosapol Kieatchareanpol (1994) applied the concept of experimental design and analysis of the experiment to study the four factors i.e. types of lacquers, lacquer weight per area, incubation temperature, and incubation time. The experiment was conducted by testing six types of lacquer coating i.e. flexibility test, scratching test, rubbing resistance test, penetration of water resistance test, strength of adhesion between the lacquer and metal texture test and delaminating of the lacquer from the heating sterilization test. The results showed the optimum condition was **Z** lacquer weight 8-9 grams per square meter curing temperature 250 ^{o}C and 13 minutes for incubating. "A Study of the TIG welding that influences the properties of welding for stainless steel pipes type SUS 436L " by Sutiwat Mahakaporn (1996) experimented the welding according to three factors i.e. welding electric current, welding electric pressure, and welding speed. His experiment set the value of factors at high and low levels within the 8 experimental conditions in order to pilot the welding by using the specified factor values. The pipe produced by the welding process was used to conduct a mechanical testing and then measured the tensile strength of welding and expansion of the pipe diameter. This needed to be done together with the consideration of the welding structure. The result was then analyzed and trial used in real workplace. In "factors that were appropriate for polyester powder coating, spray cans on the welds" by Staporn Pimsarn (2004), the experimental design was conducted to study the appropriate factors for polyester spray on the can welding". Utumporn Pongudom (2010) studied the problem in radiator factory by studying the data from a prototype factory and found that there were several problems that needed to be solved urgently. However, waste problem had great influence on cost. According to the data from the prototype factory, it was found that most of the wastes were produced during the aluminum roll forming process to make raw material radiator. There were two main factors that caused this waste problem i.e. the performance of forming process and the value setting of a welding machine. The first problem occurred when material specification was incorrect such as the size of aluminum molding wheel. Moreover, the machine with broad scale caused an inaccurate reading. To deal with this matter, the researchers modified the procedure manuals in order to set the operational standard. According to the analysis, the second problem was pointed out that welding speed and welding voltage were the main factors of waste. The 3^2 factorial Design was used to find out the perfect conditions as a reference for machine setting. From experiments using the manual operation and setting the appropriate welding speed at 106.1 m/min with electrical power at 268 voltages, it was found that the waste was reduced from 9.62% to 2.71%. Consequently, this led to factory standard improvement.

This research studied the suitable factors for canned-food welding size of 603x700. Statistical analysis was used to calculate the suitable value. The significance of the study was the result of suitable factors that influenced canned-food welding. The suitable factors would help reducing waste which finally led to standard quality reference in real work place.

Procedure

This research studied the properties of the connection by rip test, ball test, post weld test, and stretch weld test. The experiment was divided into three levels i.e. medium, high and low. The three levels were used to study the impact, and compared with the manufacturing conditions at present. The range of each variable studied was related to the interesting point in manufacturing. (Table 1)

Table 1 The level of factors

Factor	State		
	-(low)	0(medium)	+(High)
Electricity Volume	45	50	55
Spring Pressure	50	60	70
Overlapping Area	0.5	0.7	0.9
Size of welding wire	2.06	2.08	2.10

Factors that affected various features of the testing can were electric current, spring pressure, size of welding wire, and the overlapping area. Therefore, these factors have influence on the testing result. The 4 types of results from response variables are shown as follows:

y Response Variables
μ Average
Γ Factors that influence the amount of electricity
β Factors that influence the pressure spring
γ Factors that influence the overlap
δ Factors that influence the the size of the copper wire
$\Gamma\beta$ Effects caused by the interaction of Γ & β
$\Gamma\gamma$ Effects caused by the interaction of Γ & γ
$\Gamma\delta$ Effects caused by the interaction of Γ & δ
$\beta\gamma$ Effects caused by the interaction of β & γ
$\beta\delta$ Effects caused by the interaction of β & δ
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$\Gamma\beta\gamma\delta$ Effects caused by the interaction of Γ & β & γ & δ
ε Errors

Experiment design plan (Table 2)

1. The main factors were electricity volume, spring pressure, overlapping area of steel sheet, steel sheet thickness.
2. Response variables were Rip test, Ball test, post weld test, weld stretch test
3. Reproductively, the numbers of experiments were 3x3x3x3 = 81 repeat for 2 times in total of 162 testing, and the response variables tested of 4 types in total of 648 testing.
4. Metric design.

Table 2 Experiment order

C		-						0						+					
D		-		0		+		-		0		+		-		0		+	
A	B	No.1	No.2	No.1	No.2	No.1	No.2	No.1	No.2	No.1	No.2	No.1	No.2	No.1	No.2	No.1	No.2	No.1	No.2
-	-	1*	82	2	83	3	84	4	85	5	86	6	87	7	88	8	89	9	90
	0	10	91	11	92	12	93	13	94	14	95	15	96	16	97	17	98	18	99
	+	19	100	20	101	21	102	22	103	23	104	24	105	25	106	26	107	27	108
0	-	28	109	29	110	30	111	31	112	32	113	33	114	34	115	35	116	36	117
	0	37	118	38	119	39	120	40	121	41	122	42	123	43	124	44	125	45	126
	+	46	127	47	128	48	129	49	130	50	131	51	132	52	133	53	134	54	135
+	-	55	136	56	137	57	138	58	139	59	140	60	141	61	142	62	143	63	144
	0	64	145	65	146	66	147	67	148	68	149	69	150	70	151	71	152	72	153
	+	73	154	74	155	75	156	76	157	77	158	78	159	79	160	80	161	81	162

Low - A Factor of electricity.
Medium 0 B The intermediate pressure spring
High + C Level factors, area of overlap of the plate.
D The thickness of the welding wire.

5. Analysis of statistical tests.

5.1 The analysis of variance (ANOVA).

5.2 To determine the accuracy

$\varepsilon ij \sim NID(0,\sigma^2)$

- Data were normally distributed.
- Data was independent.
- The stability of the variance.

5.3 On a response (Response plot)

Finding the optimum conditions from the experiment

From the welding condition experiment, the welding strength and welding are considered. Therefore it is vital to consider the suitable conditions of each factor by evaluating response values to find out the good quality of welding line.

The scale for each factor can be described in the table below.

Table 3 The weight rating of the results

Result	Character	% Character	Weight
Normal Weld	Nugget & Extrusion welds are smooth	70-100%	9
	Nugget & Extrusion welds are smooth	40-69%	8
	Nugget & Extrusion welds are smooth	1-39%	7
Hot Weld	Welding Burr	> 60-100%	6
	Welding Burr	> 30-59%	5
	Welding Burr	> 1-29 %	4
Cold weld	Red Welds	1-29%	3
	Red Welds	30-59%	2
	Red Welds	60-100%	1

Results

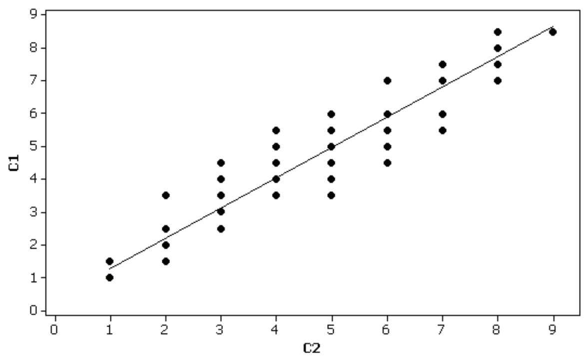

Figure 3 Error analysis of the normal distribution of the results of welding strength test

From the experiment data, it was shown that data variations were distributed evenly along the line indicating that data had normal data distribution.

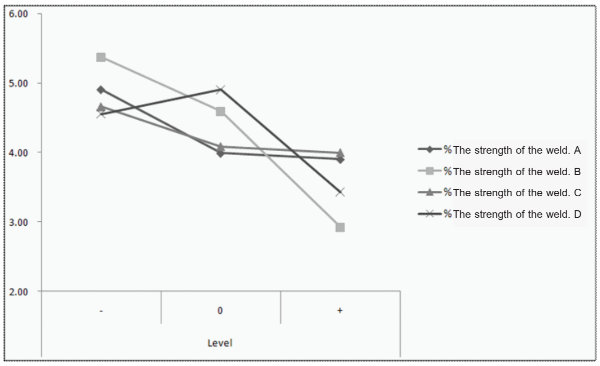

Figure 4 Graph of the response variable and the welding strength

Table 4 The welding-strength test

Level	Factor A	Factor B	Factor C	Factor D
1(-)	4.91	5.37	4.66	4.55
2(0)	3.99	4.59	4.09	4.91
3(+)	3.90	2.92	4.00	4.43

From the experiment data, it was shown that data variations were distributed evenly along the line indicating that data had normal data distribution.

The response variables of the welding-strength test i.e. power volume, spring pressure, overlapping area, size of wire welding affected welding strength as follows:

- The power volume at 45 amps was the suitable condition for the welding-strength test.
- The suitable condition for spring pressure was 60 daN.
- The suitable condition for overlapping area was 0.9 mm.
- The suitable size of wire welding was 2.08 mm.

These response variables had been tested (Figure 4 and Table 4 as a sample) and found the optimal conditions as follows: the power volume of electric current of 55 amp., spring pressure of 60 daN, over lapping area of 0.7 mm and wire size of 2.10 mm.

Finally, the evaluation criteria were used to calculate the highest value of the four test results (welding strength, welding interface, welding thickness, and welding elongation). The optimum condition for canned food packaging in test no. 26 was showed as follows:

1. Factor A (+) gave the electricity volume of 55 amps.
2. Factor B (0) gave the spring pressure of 60 daN.
3. Factor C (0) gave the overlapping area of 0.7 mm.
4. Factor D (+) gave the wire size of 2.10 mm.

The results from the welding thickness were shown as follows:
The score from welding-strength test was 10 points.

The score from welding line test was 9 points. The score from overlapping-area test was 10 points. The score from welding-elongation test was 9 points.

The comparison showed that the suitable conditions from properties experiment gave better welding condition. The strength of the weld was improved to 97 - 98 percent of the welding score which was better than the old condition at 89 - 90 percent score. The width of the weld increased from 0.48 MM. to 0.5 mm, and elongation of the welds increased from 110 MPa to 106 MPa.

Conclusion

The result from the experiment of the suitable factors for canned food showed that the welding strength and the welding line were affected by the electric volume and spring pressure. The welding thickness was affected by the overlapping area. And the welding line flexibility was affected by all testing factors.

The result from the analysis of the suitable conditions for tin coated steel canned welding of size “603 x 700” was found as follows: electric current of 55 amp, spring pressure of 60 daN., copper wire (and compressed) 2.10. mm., and the overlapping area of 0.7 mm.

Suggestion

The effect of electric current could be divided into 3 levels. It should be noted that some factors have high range of thickness. Therefore the factor adjustment should be employed in order to obtain narrow thickness.

The present study attempts to perform a research and development, thus more numbers of factors should be added in the experiment in order to gain the optimisation.

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