Application Of Statistical Quality Control Technique For Process Control In Welding

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Weld quality can be determined by different destructive and non-destructive tests. The tests are required to control the quality by variables as well as by attributes. In this paper, the specimens welded by submerged Arc Welding (SAW) are used for quality control and process control. The test data from charpy impact test have been used for quality controls by variables and radiography test results are utilised to control the quality by attributes. For each of the above cases statistical analysis have been made and control lines (using X -R Chart and P-Chart) are drawn to determine whether the SAW process is within control or not. The use of SQC technique for control of quality of welds in continous production saves money and time compared to other methods.

QUALITY CONTROL

The quality of a product or the desired service obtainable from the product is the degree to which characteristics of a product conforms to specification and fulfills the customer's need and requirements. Quality control refers to the systematic control of various factors that affect the quality of the product. In welding, the quality of the joints (products) depends on the material being welded, type of consumables used the equipments and machines used, skill of the worker and on the working condition. If quality is not satisfactory one has to search for the cause to take action.

Quality control by variables and by attributes

A special type of inspection is "Inspection by variables". The quality under consideration is measured on some continous scale and quantitatively expressed. This test, particularly in welding, is often destructive. Inspection by the method of variables results in an appreciable increase in efficiency as reflected by a smaller required sample. Economically, the destruction of good pieces in the sample may outweight the advantage of a smaller sample.

The simplest type of inspection consists of separating the good from the bad. A great deal of material is inspected in this manner for economic reasons since many quality characteristics are easily adapted to mechanical inspection of the go, no-go type. Many quality characteristics which are difficult to express in quantitative terms can be separated in this manner; for example, scams, cracks or porosity in welds. This type of inspection is called "Inspection by attributes".

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An object which is unacceptable is called "defective' and the number of defectives defected to the total number of pieces under consideration is the "fraction defective". Inspection by attributes is usually non-destructive and in this paper radiography test is conducted to find the defectives.

Process Control

As long as the output is satisfactory, we can conclude that the "process is in-control". If, however, the output is not satisfactory, the process is "out-of-control, and appropriate corrective action should be taken. The output from any process is subject to two kinds of variability. These include variability which can be attributed to both chance and assignable causes. When chance variations are the only source of variation, the process is said to be in-control. However, when variation is due to one of the assignable causes, the process is out-of-control. To know about the nature and extent of variations, we must set the upper and lower control limits. variations within these limits will be assumed to be from chance, and no remedial action will be taken. Variations outside of these limits will be attributed to assignable causes and remedial action will be initiated.

Test Procedure

RADIOGRAPHY TEST

The test materials used are low carbon steel plates welded with butt joint with the following characteristics and specifications.

Base metal	-	23 mm thick
Current : DC	-	Polarity : DCRP
Filler metal	-	4 mm.
Current	-	600 amp, volts - 26
Travel speed	-	8 mm/Sec.

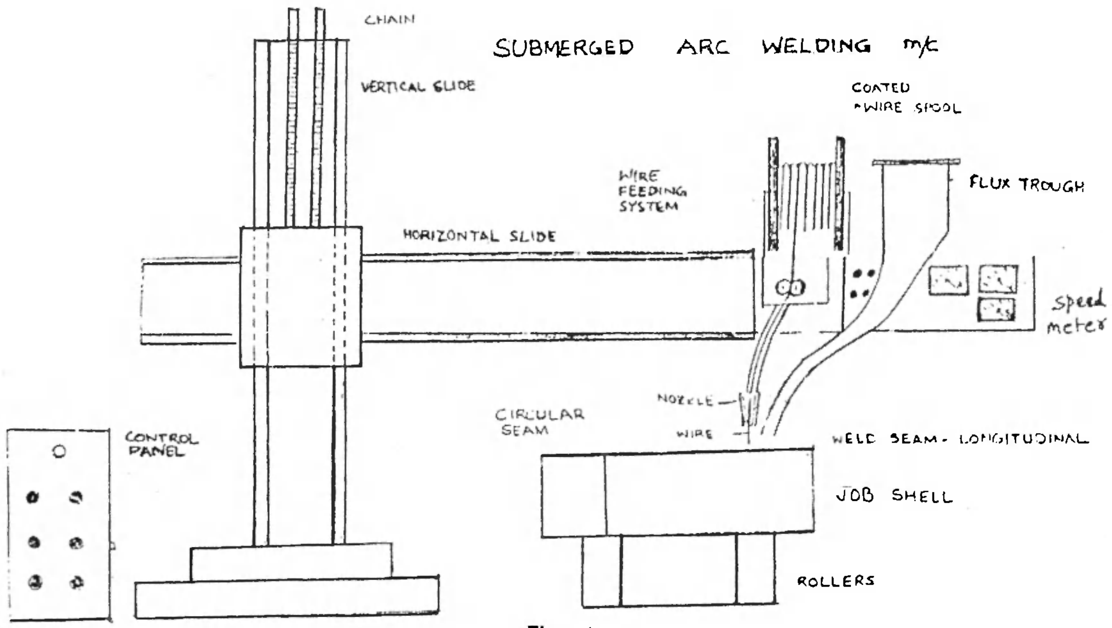


Fig : 1

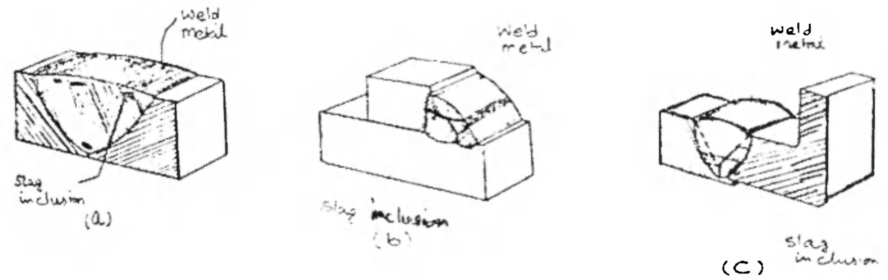
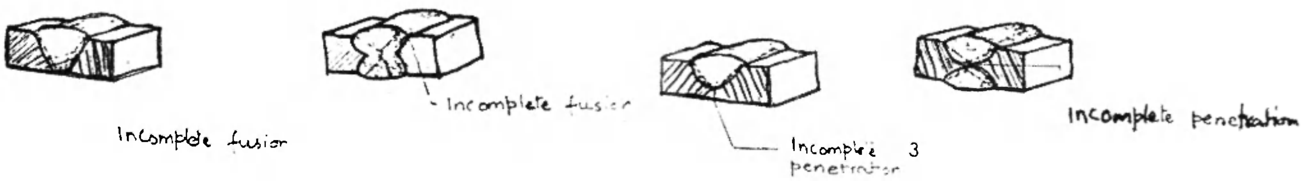


Fig : 2



Incomplete Fusion

Incomplete Penetration

Fig. 3

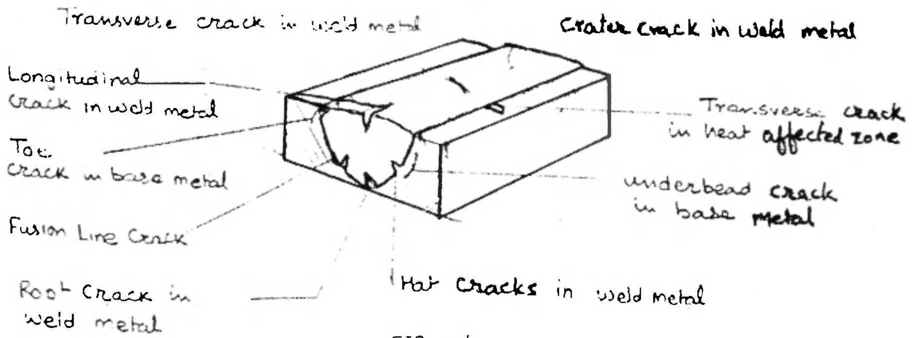


FIG : 4

WELD DEFECTS

Fig 4

After welding, the specimens are dressed and then radiographed to find out the defects, if any. The flaws can be basically of five categories viz. gas prorsity, slag entrapment, incomplete fusion, incomplete penetration and cracks. Fig. 1 indicates the SAW machine setup and Fig. 2-4 various types of defects in arc welding.

Table-1 shows the Radiography test data for 1st set of samples (L-seam) and Table-2 indicates those for 2nd set of samples (C- seam). The fraction defectives are calculated and analysis is made with the help of standard SQC procedure for P-chart. Finally the control lines are drawn to determine whether the process is within control or not.

FIRST SET OF DATA - FOR RADIOGRAPHY TEST

L-SEAMS

TABLE 1 TESTING OF 37 SAMPLES EACH 3 MM IN LENGTH

Sample No	Lenth of defective in mm	Fraction defective (Radiography)	Sample No.	Length of defective in mm	Fraction defective (Radiography)
1	.325	.11	21	610	.210
2	720	24	22	.160	.053
3	125	041	23	855	.283
4	270	09	24	090	030
5	750	25	25	180	06
6.	605	20	26	.250	083
7	350	12	27	120	040
8	620	21	28	.395	130
9	1 911	63	29	100	033
10	610	20	30	.430	14
11	.570	19	31	220	073
12	480	16	32	.960	.32
13	130	043	33	640	21
14	.420	14	34	445	.147
15	.530	175	35	.210	07
16	.160	053	36	.465	.160
17	225	.075	37	370	12
18	120	04			
19	460	152			
20	370	122			

CHARPY IMPACT TEST

Charpy impact test as per IS : 2825 is used to determine the behaviour of material under sudden loading which indicates the relative toughness of the material. Table-3 shows the test data and the control charts are done adopting standard procedure.

RADIOGRAPHIC INSPECTION

Radiography is a method used for non destructive inspection of component and assemblies that is based on differential absorption of penetrating

SECOND SET OF DATA - FOR RADIOGRAPHY TEST C-SEAM

TABLE 2 : TESTING OF 40 SAMPLES EACH 7 MM IN LENGTH

Sample	Length of defect in mm	Fraction defective	Sample No	Length of defect in mm	Fraction defective
1	445	.064	21	1 810	.260
2	200	.029	22	.580	.083
3	4.80	686	23	600	.086
4	5 20	.743	24	.530	.076
5	270	.040	25	190	.027
6	530	076	26	1 230	.176
7	226	03	27	.340	08
8	.406	.06	28	920	13
9	3.620	.51	29	1.390	20
10	1.290	18	30	0 560	08
11	920	13	31	1 295	.185
12	450	06	32	0 690	10
13	1 820	26	33	0 380	.054
14	6.300	9	34	0 610	087
15	.325	246	35	0.73	0 .11
16	1.655	236	36	0 770	13
17	1 130	161	37	0 21	0 .03
18	.290	.041	38	0 995	14
19	1.210	.18	39	0 315	045
20	.900	.12	40	0 395	180

radiation-either electromagnetic radiation of very short wave length or particulate radiation - by the part of test piece (object) being inspected. Because of differences in density and variations in thickness of the part, or differences in absorption characteristics caused by variations in composition, different portions of a test piece absorb different amount of penetrating radiation. Unabsorbed radiation passing through the part can be recorded on film photosensitive paper viewed on a fluorescent screen, or monitored by various types of electronic radiation detectors. The term radiography usually implies a radiographic process that produces a permanent image on film or paper.

When inspection involves viewing of a real line image on a fluorescent screen or image intensifier, the radiographic process in termed fluoroscopy. When electronic instruments are used to measure the intensity of radiation, the process is termed as radiation gaging.

CALCULATION FOR P-CHART

For percent defective

$\mu = .146 \quad \sigma = .11$

$$P = \frac{\text{fraction defective}}{\text{Total Length}} = \frac{5.4}{3 \times 37} = .049$$

U.C.L. = P $\pm$ 3 (1-P)) P

$$= .049 \pm 3 \; \frac{(1\text{-}.049)\ .049}{37}$$

$$= .049 \pm 3 \; \frac{.951 \ X \ .049}{37}$$

$$= .049 \pm .106$$

$= .155$ Upper Control Limit

L.C.L. $= 0$

Warning Limit

$$\text{U.C.L.} = .049 \pm 2 \; \frac{.951 \ x \ .049}{37}$$

$$= .049 \pm .07$$

$= .199$ (U.C.L.)

$= 0$ (U.C.L.)

Here the U.C.L. has been taken to control the quality of weld. The L.C.L. is Zero because it is preferable to have zero defect. When the fraction defective is more than 12% there is an indication of change in attributed as such needs corrective steps. If the % defective is more than 15.5% new process has to be developed or the various m/c. s. current, voltage, speed, etc. are to be watched and seen that there is no wide fluctuation. This chart gives a limit when the steps are to be taken to get weld of higher quality.

Analysis

% defective $n = 40$, $X = .168$, $\sigma = .196$. $\Sigma x = 6.741$

$$\bar{P} = \frac{6.741}{7.00 \ x \ 40} = .024$$

$$\text{C.L.} = \bar{P} \pm 3 \; \frac{.026\ (1\text{-}026\ )}{40}$$

$$= p \pm 3 \ x \ .025$$

$$= .024 \pm .075$$

U.C.L. $= .099$

$= .10$

L.C.L. $= 0$

Warning Limit :

$$P = .024 \pm 2 \; \frac{.026 \ X \ .974}{40}$$

$$= .024 \pm .05$$

U.C.L. Warning $= .074$

L.C.L. $= 0$

Thus when the % defective becomes more than 7.4% one should become careful & when the same exceeds 10% than some action is to be taken so that there is change in process or m/c & we should look out for trouble. Thus control of quality can be ensured and with limited cost.

TABLE 3 : WELD IMPACT VALUES,CHARPY-IMPACT TEST DATA

Sample	X1	X2	X3	X4	X5	X	S.D.	Range (Kgf.m)
1.	3.4	11.2	14.0	16.6	12.6	11.56	4.45	13.2
2.	16.2	10	9.8	5	11.6	10.48	3.53	11.2
3.	12.4	17.6	1.6	13.2	15.4	14.92	1.89	5.2
4.	12.2	12.4	12.0	11.6	14.8	12.6	1.13	3.2
5.	14.0	16	15.4	17.2	16.6	15.84	1.10	3.2
6.	12.0	14.6	8.6	7.4	13.4	11.2	2.76	7.2
7.	13.0	10	4.2	5.8	4.0	7.4	3.53	9.0
8.	4.2	10.8	7.6	1.8	6.4	6.16	3.05	9.0
9.	10.6	4.0	10.4	4	9.4	7.68	3.03	6.6
10.	5.2	11.0	10.6	1.8	11.2	7.96	3.80	9.4
11.	11.4	11.4	9.2	5.0	11.8	7.76	3.79	6.8
12.	2.8	15.0	13.4	10.2	10.6	10.4	4.19	12.2
13.	6.0	13.0	8.0	10.4	10.0	9.48	2.36	7.0
14.	3.0	12.6	11.0	1.8	15.2	8.72	5.25	13.4
15.	5.4	5.4	8.0	1.4	10.8	6.20	3.12	9.4
16.	8	9	5.8	12.0	13.6	9.68	2.80	5.6
17.	2.4	7.8	8.4	2.8	10.8	6.44	3.29	8.4
18.	8.0	4.4	7.6	1.8	12.6	6.88	3.65	8.2
19.	7.6	3.6	5.6	1.2	9.4	5.48	2.89	8.2
20.	13.6	2.0	3.0	3.8	6.6	5.84	4.16	11.6
21.	17.2	13.2	14.8	15.2	14.6	14.96	1.30	4.0
22.	11.0	8.2	10.6	10.2	10.6	10.12	.99	2.8
23.	1.6	7.0	8.6	2.4	11.6	6.24	3.77	10.0
24.	15.6	17.6	13.4	15.0	16.4	15.6	1.4	4.2
25.	6.4	7.6	4.0	3.0	7.8	5.76	1.93	4.8
26.	1.4	1.8	1.6	1.2	2.8	1.76	8.56	1.6
27.	11.6	13.4	14.6	4.2	12.0	11.16	3.64	10.4
29.	12.3	8.6	10.8	8.2	15.2	16.12	2.62	7.0
30.	11.6	11.4	2.6	16.6	1.8	8.8	5.70	14.8
31.	2.4	3.8	12.8	1.4	13.4	6.96	5.08	12.0
32.	5.4	5.4	1.2	1.0	14.4	5.48	4.86	13.4
33.	12.8	8.6	12.0	1.6	14.8	9.96	4.63	13.2
34.	3.0	3.8	5.0	1.6	7.4	4.16	1.96	5.8
35.	1.6	3.0	7.4	1.0	9.4	4.48	3.30	8.4
36.	5.4	2.6	6.6	1.2	13.2	5.80	4.17	12.0
37.	14.8	12.6	14.0	5.4	13	11.96	3.37	7.6
38.	8.0	3.8	11	12	13.0	9.56	3.33	9.2
39.	8.4	1.2	12.2	18.0	15.4	11.04	5.88	14.2
40.	3.2	1.4	14.2	15.8	11.0	9.12	5.80	9,6

IMPACT TESTING MACHINE

Standard Specimens (5 Nos for each run) for charpy impact test are prepared for every setup during the welding process in mass production system as shown in the fig. 5. The test results are indicated in Table 3.

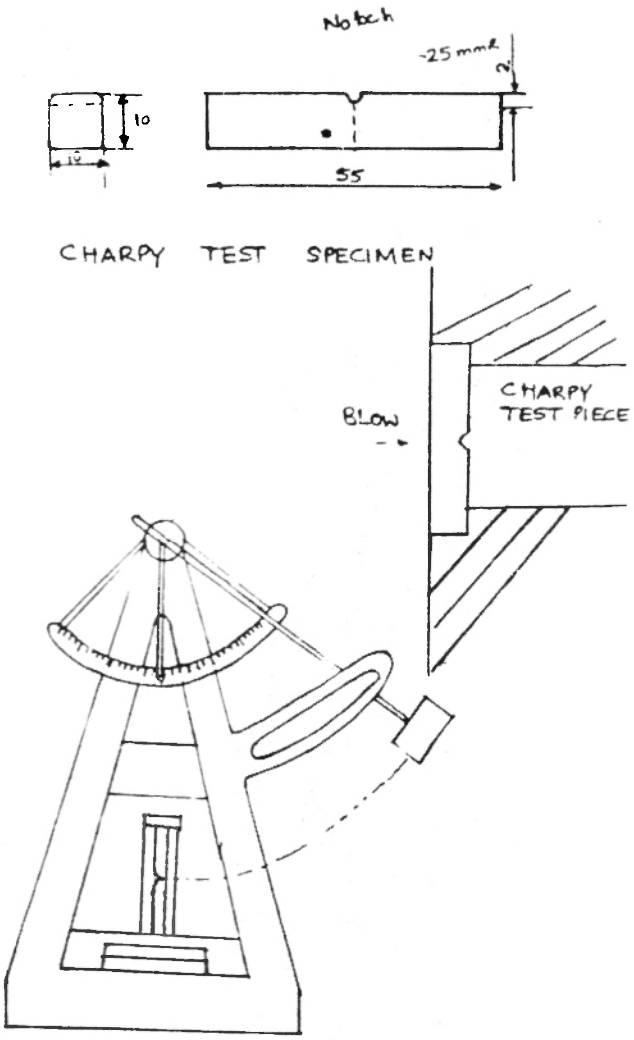


Fig. 5

Calculations

$X = 8.8, \quad \sigma = 3.29, \quad \bar{R} = 8.5$

$$\text{C.L. of } X = \frac{8.8 + 3 \times \sigma \times c}{n}$$

$$= \frac{8.8 + 3 \times 3.29 \times 1.1895}{5}$$

$$= 8.8 \pm 5.25$$

U.C.L. $= 14.05$

L.C.L. $= 3.55$

$$\sigma = \frac{\sigma \pm 3 \times 1.1895 \times 3.29}{2 \times n}$$

$$= 3.29 \pm 3.72$$

U.C.L. $= 7.01$

L.C.L. $= 0$

R $= 2.115 \times 8.5 = 18 =$ U.C.L.(R) Action

$= 1.81 \times 8.5 = 15.39 =$ Warning

L.C.L. $= .37 \times 8.5 = 3.145$ Warning

$= .16 \times 85 = 1.36$ action

Thus whenever the average impact values of the samples go beyond 14.05 or below 3.55 we can look for corrections. These values provide us indications. Also by finding the standard deviation, we can predict whether the process is in control or not. Similarly ranges have been found out and when range is above 18 corrective action is to be taken and it is preferable to have lower ranges.

Results

The control chart is a useful and effective technique for determining lack of statistical control by detecting variations in quality which are greater than can be attributed to chance effect. The p-chart for the 1st set of data (Radiography test) shows that out of 37 samples 25 data are within control. Only for sample No. 9 and for sample no. 32 the variations seem to be due to some assignable clauses for which action must be taken. Other variations may be due to chance effect and process is under control. The p-chart for the 2nd set of data (Radiography test) indicates that the process is not within control. For this the process-capability study has to be done before searching for any assignable causes.

From the analysis of charpy-impact test data, the control charts indicate the process is well within control and most of the data are within control limits. The operating charteristic curve also shows the standard pattern of probability of acceptance of the products.

The statistical quality control procedures adopted in this paper are quite useful and economical in process control and quality control in the field of welding. The analysis reveals that determining the cause of variation in quality and its removal is an engineering problem but as long as the data are rendomly dispersed about the mean and remain between control limits no remedial action has to be taken.

CONCLUSIONS

Inspection, testing and quality control of welded joints have become very essential because of the high stress levels used in different fabricated parts. A defective product apart from making loss of production and goodwill, may cause loss of life and property. Thus, by making inspections at various stages of production, the quality of welded joint may be maintained and control can be made. In mass production system or where a large number of identical components are fabricated by submerged arc welding (which is a fast process, automatic, and with high deposition rate) control of quality can be done by testing the samples drawn at different times and intervals of production run and by recording the data for variables or for the attributes. In this paper, out of various inspection methods, only two methods viz. radiography inspection and charpy impact test have been considered to illustrate their use for quality control. The control charts drawn helps us to know the process capability and also indicates whether corrective actions are to be taken or not. Without going for 100 percent inspection of all the welded components, which is much more costly, the procedures discussed above help us to take proper decisions for quality control. Statistical quality control technique can also be effectively utilised for jobs of complex and intricate geometry and for sophisticated electronic components fabricated in large numbers.

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