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Accuracy Control In Hull Construction of Ships- A Case Study

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Abstract

Accuracy control can be defined as the use of statistical techniques to monitor, control and continuously improve shipbuilding design details, planning, and work methods so as to maximize productivity. Accuracy Control essentially is based on the basic fact that there is no such thing as absolute accuracy. A study on the implementation of Accuracy Control System was carried out in a shipyard. To achieve this high degree of unit accuracy, the guidelines for systematically monitoring the production process was set. For implementation of accuracy control system, it is necessary to have an accuracy control data base. This gives the statistical history of the accuracy of the work processes employed. It is the quantitative measure of normal performance at every work stations. Each piece of data in accuracy control data base is associated with a particular work process.

Based on these findings, a proposal was recommended to the shipyard on how Accuracy control system (ACS) can be initiated. It is inferred that with these recommendations, the quality of ship produced can be improved along with reduction in production cost and thereby increased competitiveness. After implementation a pilot study was conducted to ascertain the benefits accrued in the sub assembly area of Hull fabrication from the introduction of accuracy control. The present work focuses on implementation of Accuracy control in plate preparation stage in hull fabrication of Ship building.

Keyword: Accuracy control, Control chart, hull fabrication, Ship building

Introduction
Accuracy control can be defined as the use of statistical techniques to monitor, control and continuously improve shipbuilding design details, planning, and work methods so

as to maximize productivity. Accuracy Control essentially is based on the basic fact that there is no such thing as absolute accuracy. Whatever be the method of production, variations from design dimensions are unavoidable. The reasons of which can be multifarious. However these variations are measurable and at the same time they are anticipated. Hence it is necessary to know the ranges of variations so that one can quantitatively target the end product accuracy.

The reasons for dimensional variations in any work process can be attributed to either some ***Common Cause*** or some ***Special Causes***. It is the result of the production system, including raw materials, incoming parts or interim products, worker training, work environment, tools and machinery etc. Variations caused by the so-called Common Causes reflect the status of accuracy level of the existing manufacturing process, which includes production process, machineries used, etc. It can only be changed when the production process or the machineries or both are changed.

Whereas the so-called Special Cause variation points directly to some fault in the production process. These dimensional variations are due to some fault that may have taken place in the machine or may be due to ignorance of the worker or even can be due to some kind of accident or any such reasons. Hence in such a situation these causes ought to be identified and removed as a regular part of monitoring a work process.

In a shipbuilding process, for example, spacing between longitudinal or the dimensions of plates cut in a Numerical Control (NC) machine or any other such work of repetitive nature will have dimensions varying from designed dimensions. For implementation of accuracy control system, it is necessary to have an accuracy control data base. This gives the statistical history of the accuracy of the work processes employed in the shipyard. It is the quantitative measure of normal performance at every work stations in a shipyard. Each piece of data in accuracy control data base is associated with a particular work process.

By introducing Accuracy Control, it is desired to totally eliminate the requirement of adjustment work, which accounts about half of the total fitting man-hours. Downstream production is adversely affected by inaccurate interim products. So it is necessary to monitor the construction of interim products to minimize delays and rework during erection of hull blocks to produce ships.

Literature Survey

Since 1924 when Dr. Shewhart presented the first control chart, various control chart (CC) techniques have been developed and widely applied as a primary tool in statistical process control. The major function of control chart is to detect the occurrence of assignable cause, so that the necessary corrective action can be taken before a large quantity of nonconforming product is manufactured. Many times, little attention is given to all dimensions of a process: cost, efficiency, productivity and quality. The improvement of effective quality can be an instrument for increasing productivity and reduction of costs. The installation of statistical process control and the consequent reduction of the variability results in a decrease of the manufacturing costs and an increase in productivity. This means an increase in production capacity, without any additional investment in equipment, workforce or overhead. In the control process, the data routinely collected are used and this information is employed in a practical way for the staff, engineers and managers to work on the process improvement. In this way the cost of implementing these improvements in quality and productivity is almost insignificant. One of the procedures applied, in this kind of confirmation is the control chart [Vaughn, 1990].

A fundamental assumption on which this procedure is based is that the process variable is an independent identically distributed (IID) random variable. In practice, over 80% of manufacturing and other process variables are not IID [Alwan and Roberts, 1988]. As a result, some process observations that fall above the UCL or below the LCL of the cc are due to systematic variations that are inherent in the process. That is, they are due to a common cause effect, not a special cause effect. A common cause is a systematically recurring cause. Examples include, but are not limited to, system inertia and worn components, controllers, and drift in monitoring instruments. The random process variability appears to be greater than or less than it really is. This in turn increases the probability of a type I error (producer risk) that an in control process is erroneously determined to be out of control, or increases the probability of a type II error (consumer risk) that an out of control process is erroneously determined to be in control, thereby reducing the reliability of Statistical Process Control(SPC). A complete discussion on false positives and negatives, and their probabilities of occurrence, may be found in Alwan [1992].

Methodology

Check Sheets

Plan sheets are used in preparing check sheets for recording measurements and for documentation of vital dimensions.

M/s ABC SHIPYARD

ACCURACY CONTROL

Machine No : Plasma II
Process : Plasma cutting
Instrument used : Steel Tape (837)

Sl No	Ship No.	Block	Nesting No	Plate thickness	Part No.	Type of measurement	Dimensions		Variation
							Required, R (mm)	Actual, A (mm)	X = A-R (mm)
Date	: 17/04/13								

Figure 1: Check sheet for plates from plasma cutting machine

Check sheets form the basis of the data collection system. These sheets provide the format for establishing existing performance levels and therefore are a critical check on tolerance limits determined initially by estimation. Additionally, check sheets for subassemblies and blocks will provide information necessary for establishing standards for excess and sequences for using these excesses. The check sheets are the medium on which all data are recorded.

Variation Merging

Ships are built by a lot of steps: first fabricate parts and then join these parts to create subassemblies. After that, subassemblies are put together for blocks and so on.

The basic steps can be described as:

Parts---> Subassemblies--->Assemblies--->Blocks--->Ship

If each work process is in statistical control, its normal distribution of variations can be determined. Then, with the data collected from each interim work process, the final variation of the structure can be predicted.

As we know, the output of each work process represents an independent normal distribution. Those distributions can be added to determine the expected normal performance at the following stages of construction**.** So for the completed hull, we can get the variation merging equation:

$$Z = \sum P_i + \sum S_i + \sum A_i + \sum E_i$$

Where,

Σ Pi= merged variations from all parts fabrication processes

Σ Si= merged variation from all subassembly processes

Σ Ai=merged variations from all block assembly processes

Σ Ei = merged variation from all erection processes.

The variation merging equation is based on the "theorem of addition of variance." For independent distributions, the theorem of addition of variance states:

$$S_F^2 = S_1^2 + S_2^2 + S_3^2 + \cdots = \sum S_i^2$$

Where Si is the standard deviations of earlier processes and F s is the standard deviation of a final process.

Considering variation merging, we will find that if the accuracy of interim products at each stage of construction can be reduced, the amount of rework at the erection stage will be decreased. Also, this equation is helpful to predict the probability of rework at erection, which will in turn be beneficial to production planning and scheduling.

Methodology of Data Analysis

Second stage in the implementation is the analysis of the collected data base. The analysis can be subdivided into two main areas: regular and urgent. Urgent analysis takes place when sampling indicates an interim product is not built within tolerance limits and therefore has the potential to disrupt ensuing work. This analysis is used to determine the best course of action, such as immediate rework and rescheduling of succeeding work packages, alteration of succeeding design details or any other method to correct the variations. Regular analysis is the foundation upon which the accuracy control system is built.

Most of the shipyards use simple statistics to monitor and analyse the production processes. Control chart is the most appropriate quality control tool can be used for statistical process control.

Historically, control charts are applied in manufacturing where a large number of identical parts are being produced. With the general trend toward product customization, batch sizes are significantly reduced, sometimes even to one. Consequently, the short run control chart was developed and is in common use for these situations.

Applying the principal of X-bar and R control charts to short run production, the measured quality characteristic is replaced by deviation from nominal. Already in the table of recorded data the variation of required and actual dimension of plate after cutting has been found. This can be expressed in the form of the following equation:

$$x_{i,w} = M_{i,w} - N_w$$

$M_{i,w}$ = the i th actual measurement of the quality characteristic of w,
N_w = deviation of actual measurement from nominal of the i th
Measurement of the quality characteristic w.
$X_{i,w}$ = the deviation of the actual measurement from nominal of the i th
Sample of the quality characteristic w.
Then, the principal of standard X - R control charts is utilized.

Calculation of Individual control limits and Moving Range

The average of the individual values (variations) is calculated using the equation

$$\overline{x} = \frac{\sum_{i=1}^{m} x_i}{m}.$$

Where,
X_i = sum of all variations
m$\sum$ = number of samples

The difference between variation data points in table x_i and its predecessor x_{i-1}, is calculated as

$$MR_i = |x_i - x_{i-1}|$$

For m individual values, there are m-1 ranges.

Next, the arithmetic mean of these values is calculated as

$$\overline{MR} = \frac{\sum_{i=2}^{m} MR_i}{m-1}$$

On a graph the calculated moving ranges are plotted. A line is added for the average value MR and lines are plotted for Upper Control limit (UCL) and Lower Control Limit (LCL).

Analysis of Cutting Accuracy of Cnc Plasma Cutting Machine

The X-R control charts are used by production workers who regularly plot the values obtained by process sampling. Here we used X-bar – MR charts because it involves plates with different dimensions and measurements are carried out at different times and the plate cutting is not a batch production. The purpose of the control chart is to act as a visual aid to tell workers whether the process is in control or out of control. If values fall outside the control limits, the cause must be determined, a decision on rework must be taken, and a correction made to eliminate the problem causing the variation. Depending on the nature of the problem, this may involve the workers themselves, supervisors, management or the entire shipyard.

One major advantage to using control charts is that the production workers becomes directly involved in managing their own work. This can be a source of pride and motivation for the workers. It may also stimulate them to suggest creative ideas and workable process improvements. This can eventually promote greater job satisfaction and produce tangible rewards for the organization

The accuracy control check sheets are the medium on which all data are recorded. The A blank check sheet is shown in Fig.1. In this check sheet the different dimensions of the plate after cutting were noted, and it is compared with the required dimensions of the plate from design nesting diagram. The variation from required dimension are also noted in the check sheet. From the random sample of plate dimension control charts are prepared. Measurements were carried out on plates cut at machine No. II using the process of plasma cutting. Measurements were taken manually using a steel tape (No 837). The design and the measured dimensions were noted for the plasma cut components.

Table 1: Recorded dimensional data of CNC Plasma II (sample)

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M/s ABC SHIPYARD ACCURACY CONTROL									
Machine No : Plasma II									
Process : Plasma cutting									
Instrument used : Steel Tape (837)									
Sl No	Ship No.	Block	Nesting No	Plate thickness	Part No.	Type of measurement	Dimensions		Variation
							Required , R (mm)	Actual, A (mm)	X = A-R (mm)
Date : 17/04/13									
1	XXX	YY	ZZ	10	P0A-SS3-B-P	Length	2110	2112	2
2	XXX	YY	ZZ	10	P0A-SS3-B-P	Width	2211	2214	3
3	XXX	YY	ZZ	10	P0A-SS3-B-S	Length	2110	2108	-2
4	XXX	YY	ZZ	10	P0A-SS3-B-S	Width	2211	2212	1
5	XXX	YY	ZZ	10	P0A-SS4-A-S	Length	1053	1050	-3
6	XXX	YY	ZZ	10	P0A-SS4-A-S	Width	2211	2206	-5
7	XXX	YY	ZZ	10	P0A-SS4-B-P	Length	2110	2114	4
8	XXX	YY	ZZ	10	P0A-SS4-B-P	Width	2211	2217	6
9	XXX	YY	ZZ	10	P0A-SS5-A-P	Length	1053	1051	-2
10	XXX	YY	ZZ	10	P0A-SS5-A-P	Width	2211	2209	-2
11	XXX	YY	ZZ	10	P0A-SS5-A-S	Width	2211	2208	-3
12	XXX	YY	ZZ	10	P0A-SS5-A-S	Length	1053	1051	-2
13	XXX	YY	ZZ	10	P0A-SS4-B-S	Length	2110	2108	-2
14	XXX	YY	ZZ	10	P0A-SS4-B-S	Width	2211	2210	-1
15	XXX	YY	ZZ	10	P0A-SS5-B-P	Length	2110	2113	3
16	XXX	YY	ZZ	10	P0A-SS5-B-P	Width	2211	2216	5
17	XXX	YY	ZZ	10	P0A-SS6-A-P	Length	1053	1054	1
18	XXX	YY	ZZ	10	P0A-SS6-A-P	Width	2251	2250	-1
19	XXX	YY	ZZ	10	P0A-SS5-B-S	Length	2110	2110	0
20	XXX	YY	ZZ	10	P0A-SS5-B-S	Width	2211	2210	-1
21	XXX	YY	ZZ	10	P0A-SS6-A-S	Length	1053	1052	-1
22	XXX	YY	ZZ	10	P0A-SS6-A-S	Width	2251	2248	-3
23	XXX	YY	ZZ	10	P0A-SS6-B-P	Length	2110	2111	1
24	XXX	YY	ZZ	10	P0A-SS6-B-P	Width	2251	2250	-1
25	XXX	YY	ZZ	10	P0A-SS6-E-P	Length	1777	1778	1
26	XXX	YY	ZZ	10	P0A-SS6-E-P	Width	2251	2250	-1
27	XXX	YY	ZZ	10	P0A-SS6-B-S	Length	2110	2108	-2
28	XXX	YY	ZZ	10	P0A-SS6-B-S	Width	2251	2249	-2
29	XXX	YY	ZZ	10	P0A-SS6-E-S	Length	1777	1773	-4
30	XXX	YY	ZZ	10	P0A-SS6-E-S	Width	2251	2250	-1
31	XXX	YY	ZZ	10	P0F-SS2-B-P	Length	2110	2110	0
32	XXX	YY	ZZ	10	P0F-SS2-B-P	Width	2211	2212	1
33	XXX	YY	ZZ	10	POF-SS6-A-P	Length	1053	1052	-1
34	XXX	YY	ZZ	10	P0F-SS6-A-P	Width	1701	1705	4
35	XXX	YY	ZZ	10	P0F-SS2-B-S	Length	2110	2110	0
36	XXX	YY	ZZ	10	P0F-SS2-B-S	Width	2211	2214	3
37	XXX	YY	ZZ	10	P0F-SS6-A-S	Length	1053	1050	-3
38	XXX	YY	ZZ	10	P0F-SS6-A-S	Width	1701	1700	-1
39	XXX	YY	ZZ	10	P0F-SS2-D-P	Length	2110	2106	-4
40	XXX	YY	ZZ	10	P0F-SS2-D-P	Width	2211	2214	3
41	XXX	YY	ZZ	10	P0F-SS3-B-P	Length	2110	2109	-1
42	XXX	YY	ZZ	10	P0F-SS3-B-P	Width	2211	2215	4
43	XXX	YY	ZZ	10	P0F-SS2-D-S	Length	2110	2112	2
44	XXX	YY	ZZ	10	P0F-SS2-D-S	Width	2211	2211	0
45	XXX	YY	ZZ	10	P0F-SS3-B-S	Length	2110	2109	-1
46	XXX	YY	ZZ	10	P0F-SS3-B-S	Width	2211	2210	-1

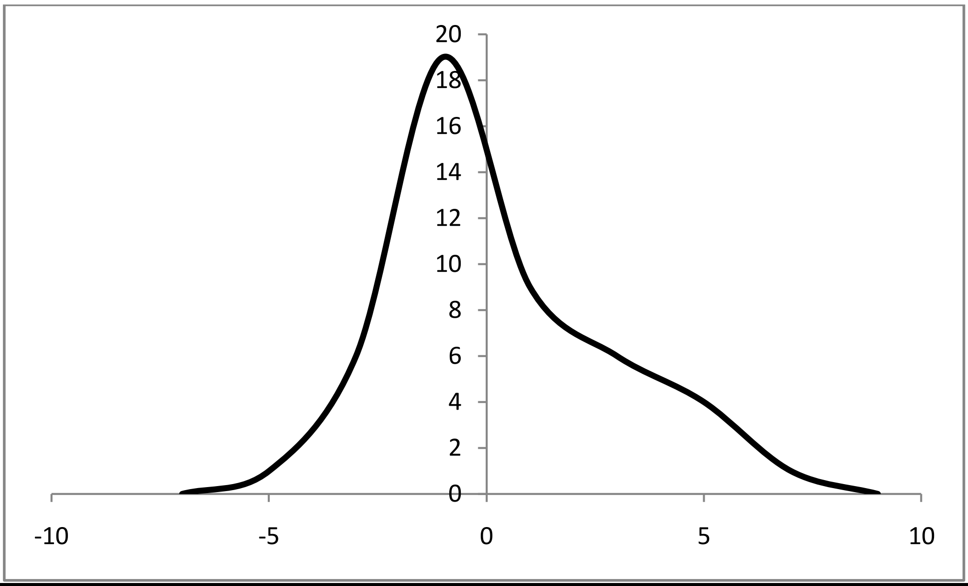

Figure 2: Normal Distribution curve of variations

Analysis of Data

The goals of an accuracy control system will be obtained by analysis of the data collected and recorded. The analysis can be subdivided into two main areas: regular and urgent. Urgent analysis takes place when sampling indicates an interim product is not built within tolerance limits and therefore has the potential to disrupt ensuing work. This analysis is used to determine the best course of action, such as immediate rework and rescheduling of succeeding work packages, alteration of succeeding design details or any other method to correct the variations. Regular analysis is the foundation upon which the accuracy control system is built.

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N_w = deviation of actual measurement from nominal of the i th

Measurement of the quality characteristic w.
$X_{i, w}$ = the deviation of the actual measurement from nominal of the i th
Sample of the quality characteristic w.

Then, the principal of standard X - R control charts is utilized. Furthermore, in the case where the measurement sample size is one, the ideas of short run process control can be combined with the principal of X - MR control charts, resulting in the short run X - MR control chart. This was used to sample and analyze data from CNC plasma cutting machine. Figure 3 and 4 shows the short run X - MR control chart to the Plate cutting process plasma II.

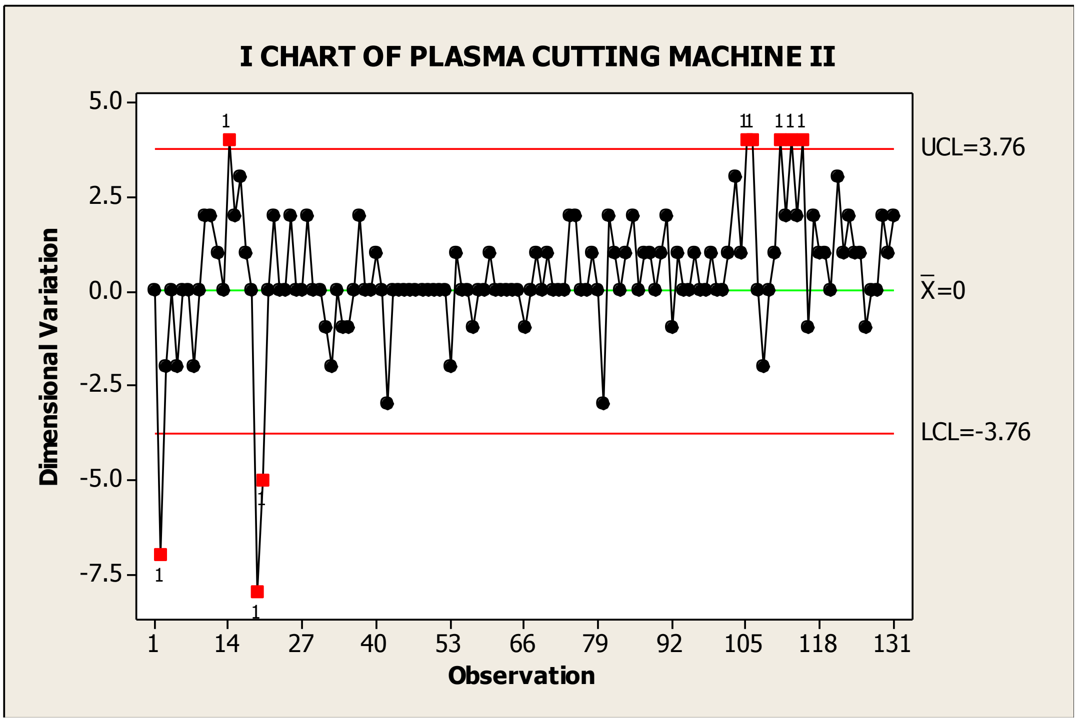

Figure 3: I Chart for Plasma Cutting Machine II

The control rules are violated and show assignable causes of variations at various regions of production process. The control rules violated are tabulated in table as given below.

Rules Violations for moving range of Plasma II	
Case Number	Violations for points
2	Greater than +3 sigma
3	Greater than +3 sigma
18	Greater than +3 sigma
20	Greater than +3 sigma
106	Greater than +3 sigma
115	Greater than +3 sigma

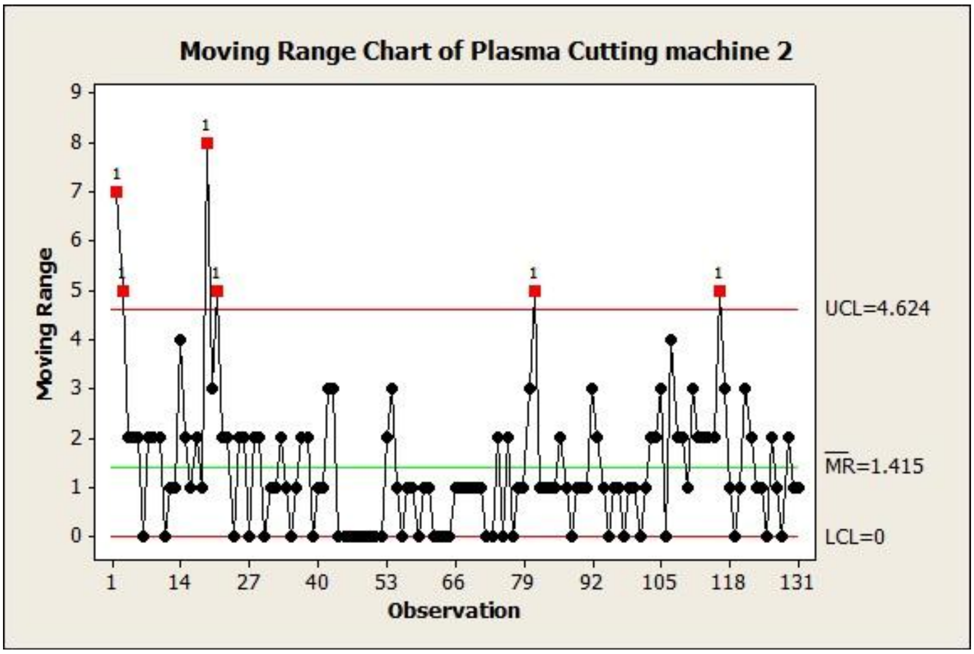

Figure 4: Moving Range Chart for Plasma Cutting Machine II

Rules Violations for X-bar of Plasma II	
Case Number	Violations for points
2	Less than -3 Sigma
14	Greater than +3 sigma
19	Less than -3 Sigma
20	Less than -3 Sigma
105	Greater than +3 sigma
106	Greater than +3 sigma
111	Greater than +3 sigma
113	Greater than +3 sigma
115	Greater than +3 sigma

Recomendations and Conclusion

It is observed that the

- Process in plasma cutting machine II is out of control. Nine points of X-bar chart of Plasma II are out of control.
- Six points of MR chart of Plasma II is out of control.

The above two observations from the study shows assignable causes of variations. These assignable causes are of larger in magnitude and are controllable in the production process of the plates. The assignable causes are to be eliminated from the production process to make the process efficient. The different causes which have the possibility on the effect of variation in accuracy of plasma cutting process have been analysed. The major causes are collected by detailed survey from operators, supervisors and managers those who are directly involved in this process on a day to day basis and the same along with remedial measures are furnished below.

- The conversion of design drawing of a plate to text file for CNC is done without considering the capability of the machine. The speed of cutting of the plate in programme text file sometimes exceed the maximum speed that can be cut with the nozzle available for the machine. This aspect need to be considered while making programme.
- Current load variation is the other factor which effect on accuracy. It was noted that the voltage has a variation from 380 to 420V. For accurate cutting CNC need constant voltage source. It was recommended to use a new electronic Automatic Voltage regulator (AVR) to overcome the issue.
- Regular check of consumables of plasma nozzle is not carried out. Because of that the orifice of the nozzle becomes oval shape. This will decrease the cutting quality as well as kerf width. It was recommended to have regular check of nozzles on a daily basis
- Pressure variation of gases will affect the cutting quality. So the pressure of gases is to be ensured that the same is in the recommended range.
- The slip occurring in the drive belts which are used for power transmission will affect the accuracy of process. So the belts are to be regularly checked for tightness.
- Failure to maintain constant arc height is another problem which affects accuracy Even though there is a sensor to adjust the arc height according to level variation of plate, but due to poor response rate at higher speed it fails to adjust. So a proper sensor with adequate response time will improve the accuracy of the process.

Factors affecting the accuracy in cutting have thus been identified and recommendations to overcome the same have been made.

The recommendations have been implemented and a pilot study was conducted in a selected subassembly section of hull fabrication which is downstream to the plate preparation stage to ascertain the effect. The findings are summarised below.

The productivity of the area has been significantly improved after the implementation of the corrective actions. There is an increase of about 10% in the tonnes of steel fabricated upon the man-days employed. This is due to the elimination of adjustment works due to better accurate input material for fitting, thereby reducing the total fitting man hours. Thus substantial man-hour and resources can be saved by accurate input material and thereby delays can also be eliminated. It is concluded that regulation of accuracy as a management technique can be employed for improving the productivity of the entire shipbuilding system by focusing attention on individual areas.

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