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Statistical Process Control Tools: A Practical guide for Jordanian Industrial Organizations

Rami Hikmat Fouad*, Adnan Mukattash

Department of Industrial Engineering, Hashemite University, Jordan.

Abstract

The general aim of this paper is to identify the key ingredients for successful quality management in any industrial organization. Moreover, to illustrate how is it important to realize the intergradations between Statistical Process Control (SPC) is seven tools (Pareto Diagram, Cause and Effect Diagram, Check Sheets, Process Flow Diagram, Scatter Diagram, Histogram and Control Charts), and how to effectively implement and to earn the full strength of these tools. A case study has been carried out to monitor real life data in a Jordanian manufacturing company that specialized in producing steel. Flow process chart was constructed, Check Sheets were designed, Pareto Diagram, scatter diagrams, Histograms was used. The vital few problems were identified; it was found that the steel tensile strength is the vital few problem and account for 72% of the total results of the problems. The principal aim of the project is to train quality team on how to held an effective Brainstorming session and exploit these data in cause and effect diagram construction. The major causes of nonconformities and root causes of the quality problems were specified, and possible remedies were proposed.

Keywords: Statistical Process Control, Check sheets, Process Flow Diagram, Pareto Diagram, Histogram, Scatter Diagram, Control Charts, Brainstorming, and Cause and Effect Diagram..

1. Introduction

Quality is a concept whose definition has changed overtime. In the past, *quality* meant “conformance to valid customer requirements”. That is, as long as an output fell within acceptable limits, called specification limits, around a desired value, called the nominal value (denoted by *m*), or target value, it was deemed conforming, good, or acceptable. We refer to this as the “goalpost” definition of Quality Gitlow and Levin [5].

The definition of statistics according to Deming, is to study and understand variation in processes and populations, interactions among variables in processes and populations, operational definitions (definitions of processes and populations variables that promote effective communication between people), and ultimately, to take action to reduce variation in a process or population. Hence, statistics can be broadly defined as the study of data to provide a basis for action on a population or process Deming [1].

Total Quality Management tools and techniques divided into the categories of quantitative and non-quantitative. The basic quantitative ones are statistical process control (SPC). SPC often called “The Magnifecent Seven” is comprised of seven tools, Pareto Chart, Histogram, Process Flow Diagram, Control Charts, Scatter Diagram, Check Sheets and Cause and Effect Diagram Besterfield [2]. The main objective of this paper is to apply basic statistical tools of quality control. SPC seeks to maximize profit by the following ways: Improving product quality, improving productivity, reducing waste, reducing defects and improving customer value. A Jordanian manufacturing company was chosen to implement SPC tools and concepts in order to improve the product quality and reduce process variability.

2. Company Background

Jordan Steel (JS) is a Public Limited Shareholding Company (P.L.C.) established in 1993 with a production capacity of 300,000 MT tons per year. It is the largest steel manufacturing company in Jordan. JS produces construction steel (Re bars) (diameters 8 - 32 mm) utilizing a fully automated production line. The manufacturing process at JS controlled, tracked and recorded by computer. Computer’s software at JS enables on line quality test and inspection. JS got ISO 9002 certification in 1998. Quality control procedure at JS works along the value chain starting from the supplier’s evaluation and selection, receiving raw material (Billets) all the way to after sales services. Billets are initially classified according to their chemical composition and stored in predetermined locations. Final products are tested for mechanical properties and results are handed to customers upon request. Production tractability is ensured through a label that shows the date of production and other information such as diameter, length, weight of bundle and grade. In order to develop process definition,

* Corresponding author. rhfouad@hu.edu.jo

understanding, and workflow a process flow chart of JS is shown in Figure 1.

3. SQC TOOLS

QC department at JS is currently implements only one SPC tool that is the Control Charts. QC department analyze and review quality data once a week. The general purpose of this paper is to promote and implement other statistical tools as follows:

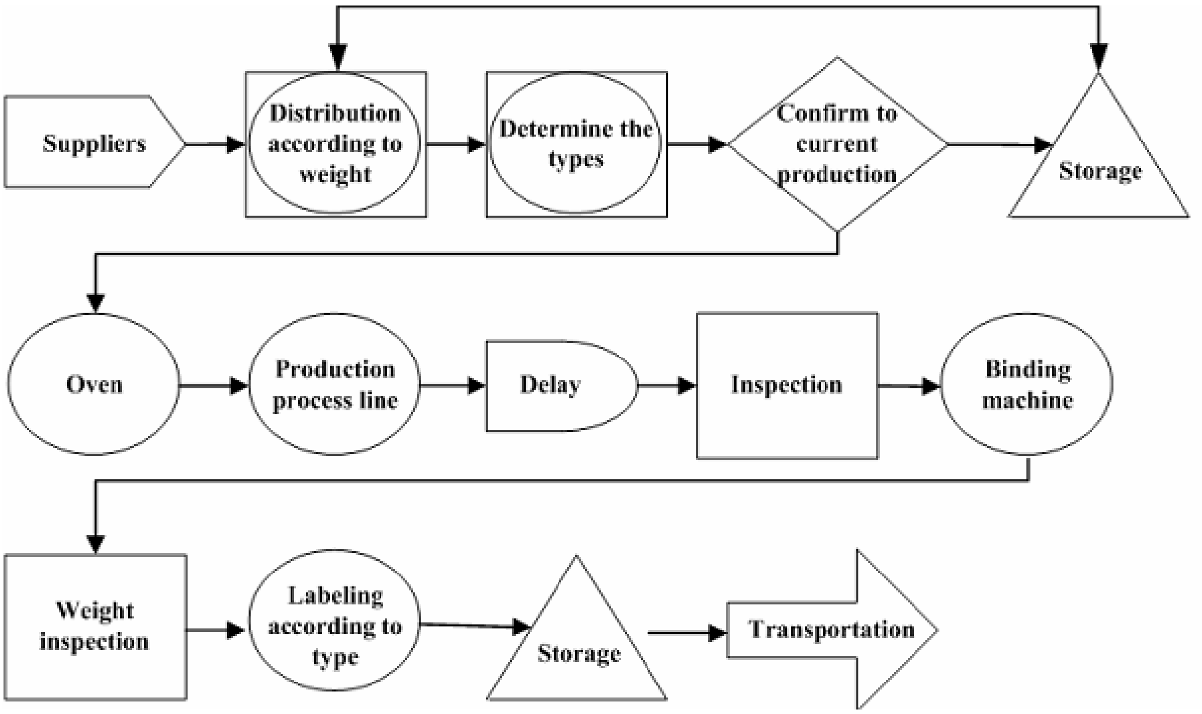

Figure 1: The Process Flow Chart of JS factory.

4. CHECK SHEET

The main purpose of Check Sheets is to insure that the date collected is carefully and accurately by operating personnel. Data should be collected in such manner that it can be quickly and easily used and analyzed. The form of the check sheet is individualized for each situation and is designed by the project team Besterfield [3]. The check sheet shown in Table 1 was created by tallying each type of call defect during a specified time. It shows the types of defects and how many of each type occurred during that period. Keeping track of these data provides management with information on which to base improvement actions.

5. Pareto Chart

The Pareto (pah-ray-toe) chart is a very useful tool whenever one needs to separate the important from trivial Goetsch [3]. A Pareto Chart is simply a frequency distribution (or Histogram) of attribute data arranged by category Montgomery [7]. It is a special type of bar charts in which the categories of responses are listed on the X-axis, the frequencies of responses (listed from largest to smallest frequency) are shown on the left side Y-axis, and the cumulative percentages of responses are shown on the right side of Y-axis. This diagram named after the Italian economist Alfredo Pareto. Dr. Joseph Juran recognized this concept as a universal that could be applied to many fields. He coined the phrases Vital Few and Useful Many in quality problems Besterfield [1].

Pareto chart was constructed based upon data collected by check sheet for the main tests performed on steel and shown in the following Table 1 and Figure 2. The figure reveals that the tensile strength is the vital few quality problems and represents around 72% of the total cumulative percentage of non-conformities so that the main reason of most rework is the tensile strength. The rest of tests are considered as Useful Many and represents around 28% of the total cumulative percentage

Table 1: Check Sheet for various steel tests with their respective frequancy and percentage

Category	***Repetition***	***Frequency***	Cumulative Frequency	Percentage	Cumulative percent
Tensile strength	卌 卌 卌 卌 卌 III	28	28	72%	72%
Yield Strength	卌	5	33	85%	85%
Elongation Percent	III	3	36	92%	92%
Effective diameter	II	2	38	97%	97%
Effective Weight	I	1	39	100%	100%

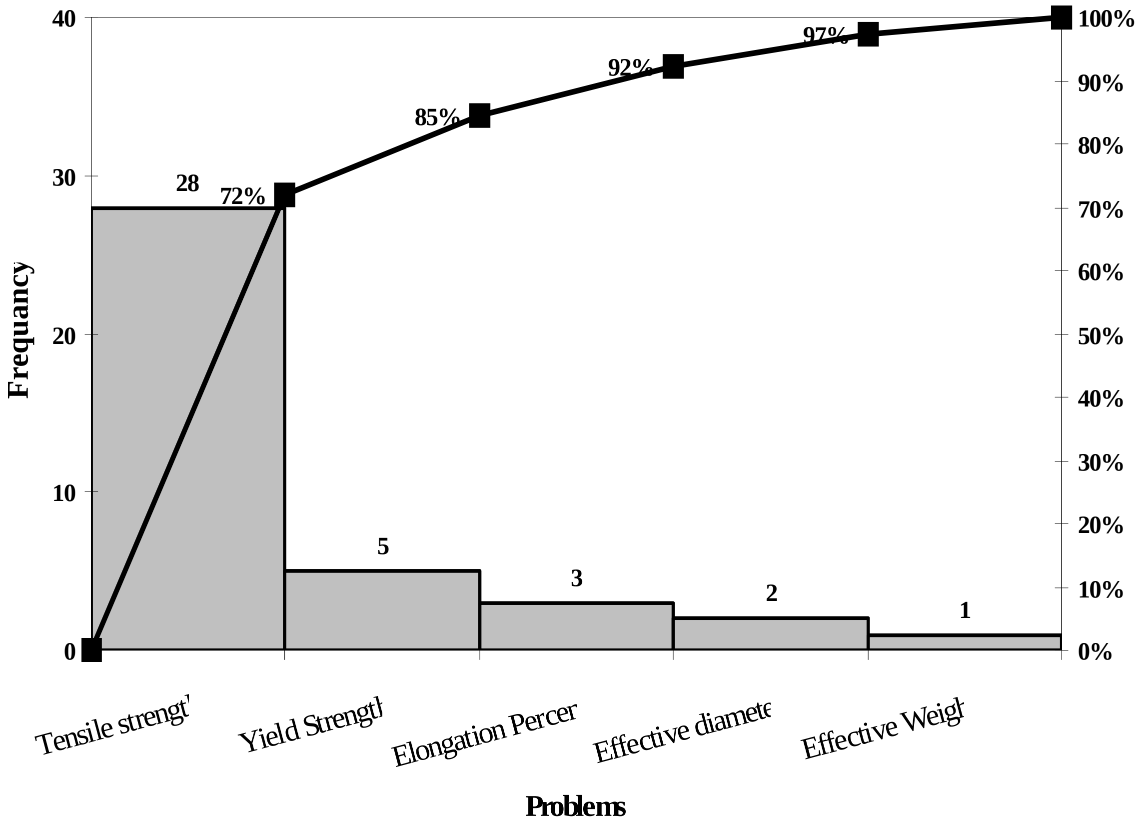

Figure 2: Pareto Chart for tensile strenghth test

6. Histogram

Histogram is a special bar chart for measurement dat. Histograms is used to chart frequency of occurrences Goetsch [3]. In the histogram, the data is grouped into adjacent numerical categories. Minitab can organize the data into groups, and plot the histogram. The difference between bar chart and histogram is that the X-axis on a bar chart is a listing of categories; where as the x-axis on a histogram is a measurement scale. In addition, there are no gaps between adjacent bars.

Data concerning the tensile strength test is shown in Table 2 and used to illustrate the histogram in Figure 3.

Table 2: Cell boundaries of tensile strength data

Class	Cell Boundaries		Freq		Class	Cell Boundaries		Freq
1	520.0	538.6	3.0		9	668.8	687.4	14
2	538.6	557.2	3.0		10	687.4	706.0	13
3	557.2	575.8	4.0		11	706.0	724.6	6
4	575.8	594.4	2.0		12	724.6	743.2	11
5	594.4	613.0	10.0		13	743.2	761.8	14
6	613.0	631.6	14.0		14	761.8	780.4	5
7	631.6	650.2	25.0		15	780.4	799.0	6
8	650.2	668.8	10.0					

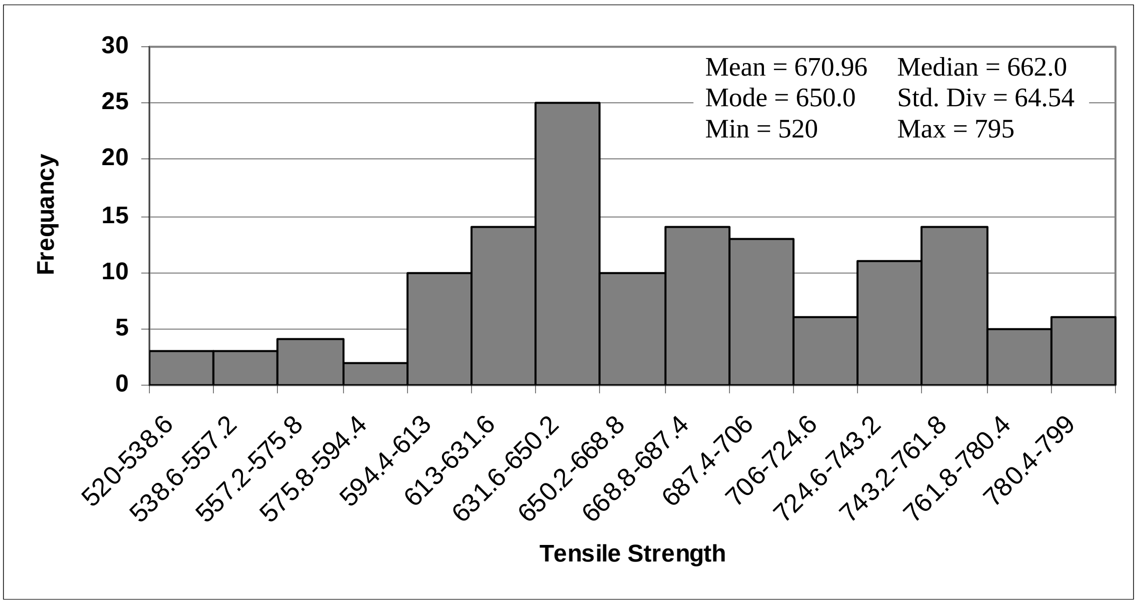

Figure 3: Histogram for tensile strength data.

7. Scatter Diagram

The scatter diagram is the simplest of the seven tools and one of the most useful. The scatter diagram is used to determine the correlation (relationship0 between two characteristics (variables) Goetsch [3].

The shape of the scatter digram often indicates what type of relationship may exist between the two variables. A scatter diagram, shown in **Error! Reference source not found.**, was constructed to find the relationship between water flow used to cool down the steel during various production stages and steel tensile strength using collected data that represent the average for the sample readings per hour for the water flow and tensile strength. The scatter diagrams clarifys that there is no direct relationship exists between tensile strength and water flow.

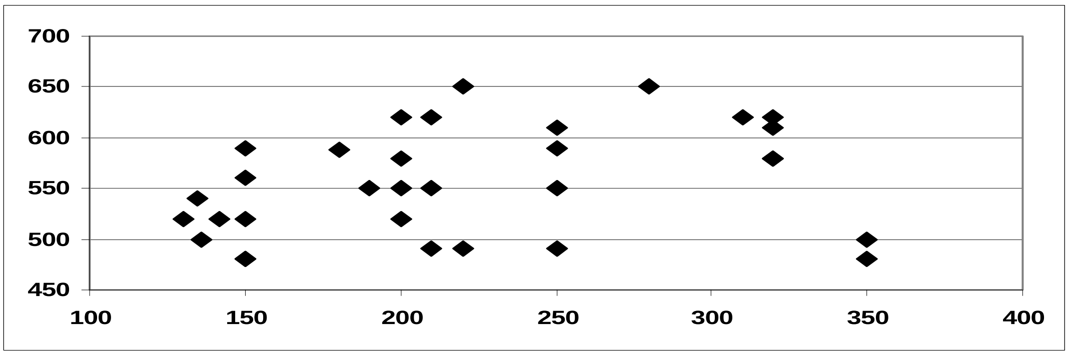

Figure 4: Scatter Diagram between Tensile Strength and Water flow

8. Control Charts

Variable control charts are used to study a process when characteristics is a measurement, for example, cycle time, processing time, waiting time, highest, area, temperature, cost or revenue. Measurement data provides more information than attribute data: consequently, variables charts are more sensitive in detecting special cause variation than are attribute charts. Variable charts are typically used in pairs. One chart studies the variation in a process, and the other studies the process average. The chart that studies variability must be examined before the chart that studies the process average. This is so because the chart that studies the process average assumes that the process variability is stable over time. One of the most commonly employed pair of charts is the Xbar-chart and the R-chart. Through the use of control charts, similar gains can be realized in the manufacturing sector. Users of control charts report savings in scrap, including material and labor, lower rework costs, reduced inspections, higher product quality, more consistent part characteristics, greater operator confidence, lower trouble shooting, reduced completion time, faster deliveries and others Summers [8].

Figure 5 illustrates the XmR range chart obtained from Minitab for historical data and Figure 5 presenting new real life data.

Comparison between factory historical data and new real life data shows that the historical data is not accurate the reason for that is lack of precision in sampling process, inaccuracy in sampling size and sampling intervals. This contradict with a major objective of SPC is to quickly detect the occurrence of assignable causes of process shifts so that investigations of the process and corrective action may be undertaken before many nonconforming units are manufactured.

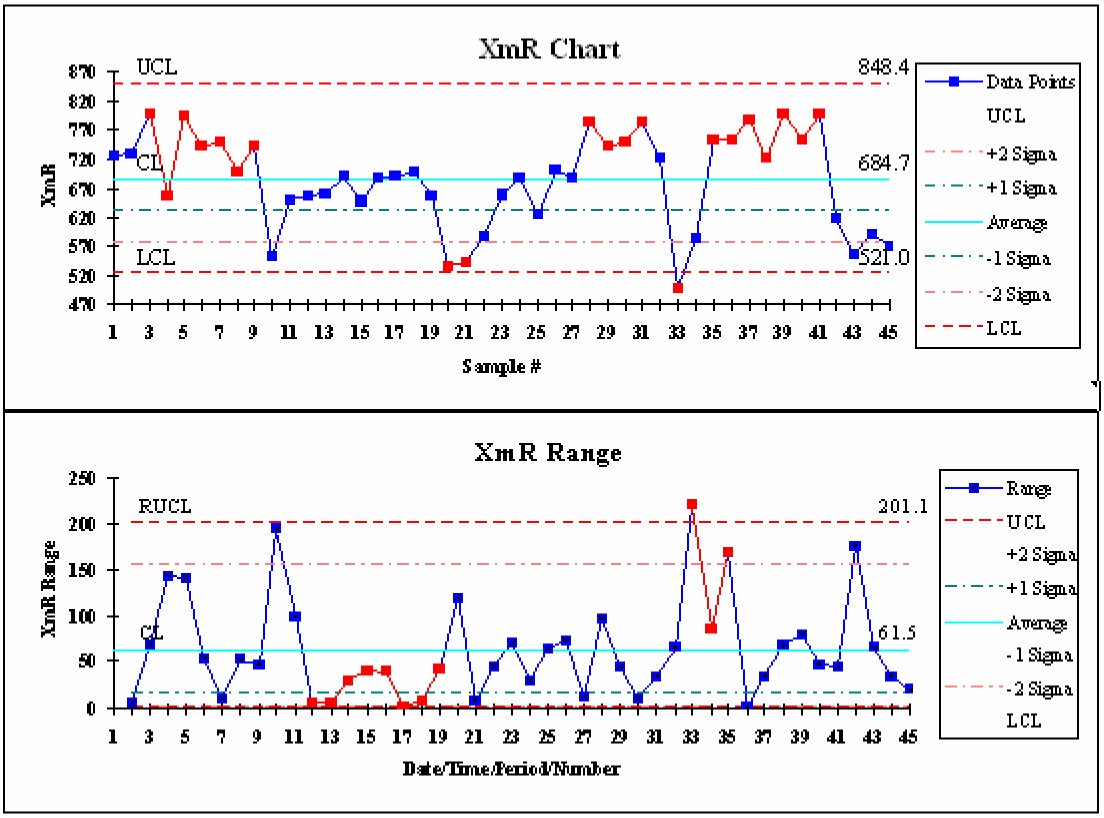

Figure 4: XmR Range and XmR Control Chart for historical data

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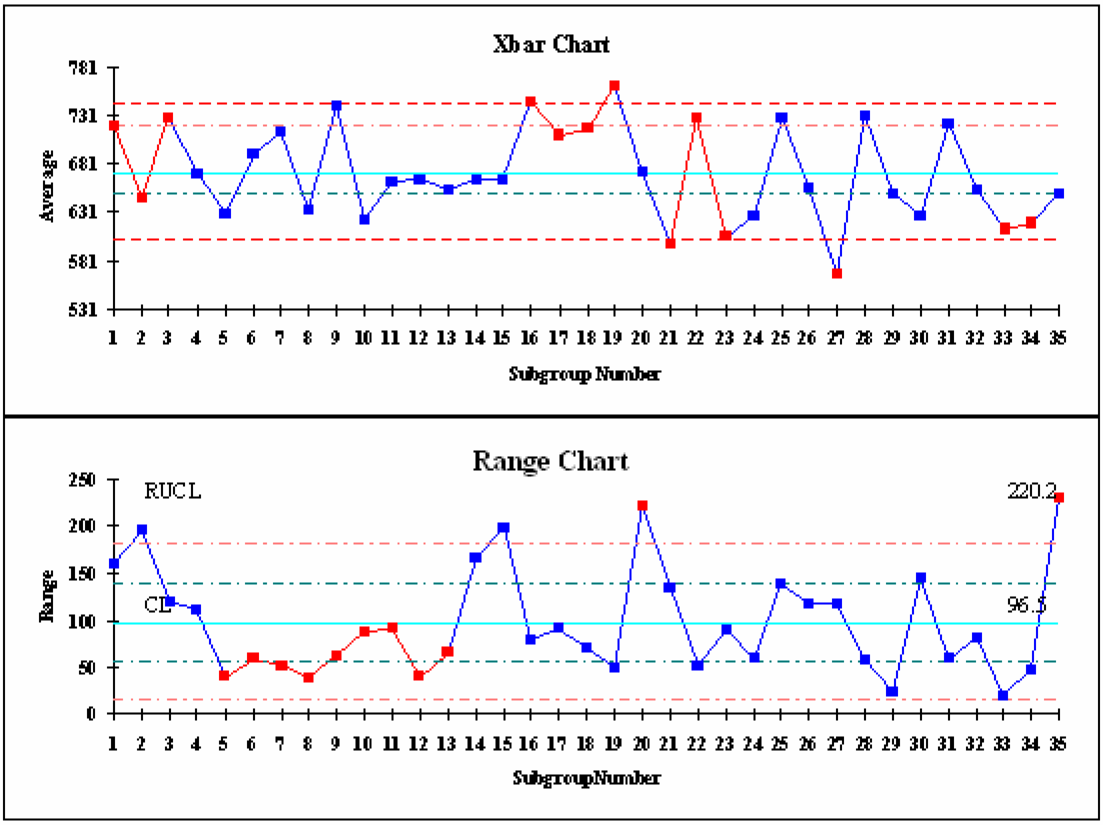

Figure 5: New XmR Range and XmR Control Chart for real life data

9. Brainstorming and Cause and Effect Diagram

Brainstorming is a technique used to elicit a large number of ideas from a team using its collective power. It normally takes place in a structured session involving between 3 to 12 people, with 5 to 6 people being the optimal group size. The team leader keeps the team member focused, prevents distractions, keeps ideas flowing, and records the outputs (or make sure that team members record their own outputs). The brainstorming session should be a closed-door meeting to prevent distractions. Seating should be arranged in a U-shape or circle to promote the flow of ideas among group members Gitlow and Levin [5].

There are specific steps are recommended prior to a brainstorming session as to clarify the subject of brainstorming session. Moreover, many rules should be observed by the participants to ensure that participation is not inhibited. These rules are as follows:

- Do not criticize anyone's ideas, by word of gesture.
- Do not discuss any ideas during the session, except for clarification.
- Do not hesitate to suggest an idea because it sounds "silly". Many times, such as an idea can lead to the problem solution.
- Do not allow any group member to present more than one idea at a time.
- Do not allow any group to be dominated by one or two people.
- Do not let brainstorming because a gripe session.

The above mentioned procedures and rules were taught to the quality team members at JS as to establish the Cause-and-Effect (C&E) diagram.

The Cause-and-Effect (C&E) diagram is a tool used to organize the possible factors that could be negatively impact the stability, centre, spread, and shape of a critical to quality (CTQ) characteristics measure.

A team typically used a Cause-and-Effect (C&E) diagrams to identify and isolate causes of a problem. The late Dr. Kauro Ishikawa, a noted Japanese quality expert, developed the technique, so some times the diagram is called an *Ishikawa diagram*. It is also called a *Fishbone Diagram* because that is what it looks like Goetsch [6]. If it is the Pareto diagram that helps us to prioritize our efforts and focus attention on the most pressing problem or symptom, it is the Cause-and-Effect (C&E) diagram that helps to lead us to the root cause of the problem Devor [4]. The data analyzed by The Cause-and-Effect (C&E) diagram usually comes from a brainstorming session.

The C&E diagrams shown in Figure 6 and Figure 7 were constructed by quality improvement team and through brainstorming sessions involving all employees taking part in the related production and test activities.

10. Conclusions

- Pareto diagram identifies that the tensile etrength is the vital view steel characteristic that need attention.
- Scatter diagram proves that there is no direct relashinship between tensilt strength and flow of water used to cool down steel during different production stages.

- The interpretation of control charts indicates sources of assignable causes were sampling process and specifying the correct sample size and sampling intervals. Sources of chance causes were defined as mistakes such as errors in calculations, poor maintenance plans, having different workers taking samples and using the same chart and poor storage conditions.
- There is a necessity in Jordan Steel to introduce ongoing education and training programs of management and line staff on interrelation between SPC tools and its implementation steps.
- Jordan Steel lacks the ability to properly forming quality teams and hold brainstorming sessions according to standard rules and precedures.

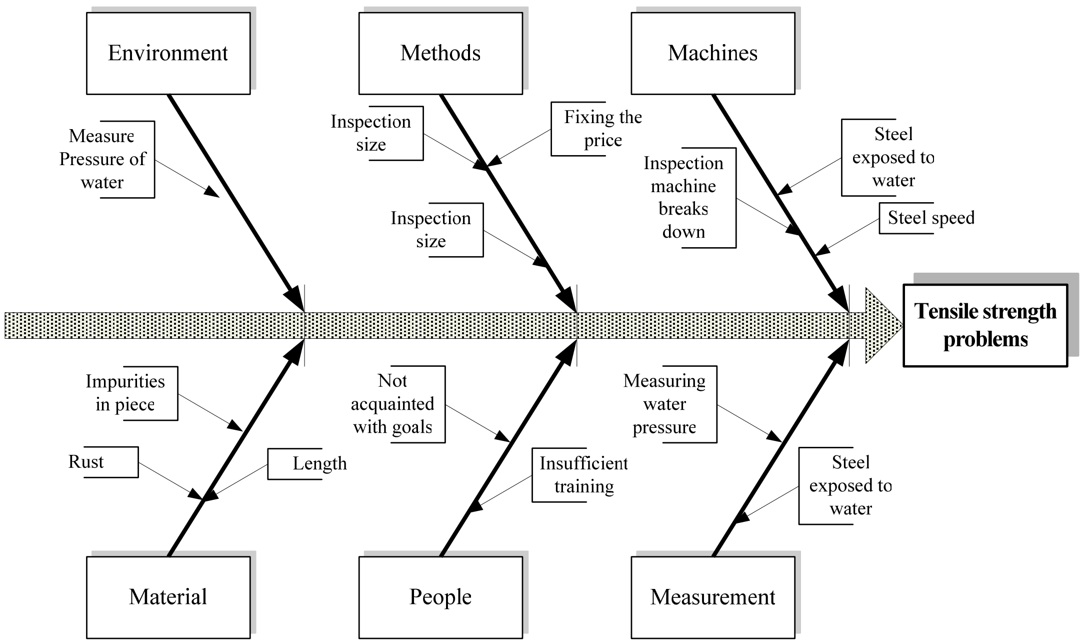

Figure 6: Cause &Effect Diagram for Tensile strength Problems

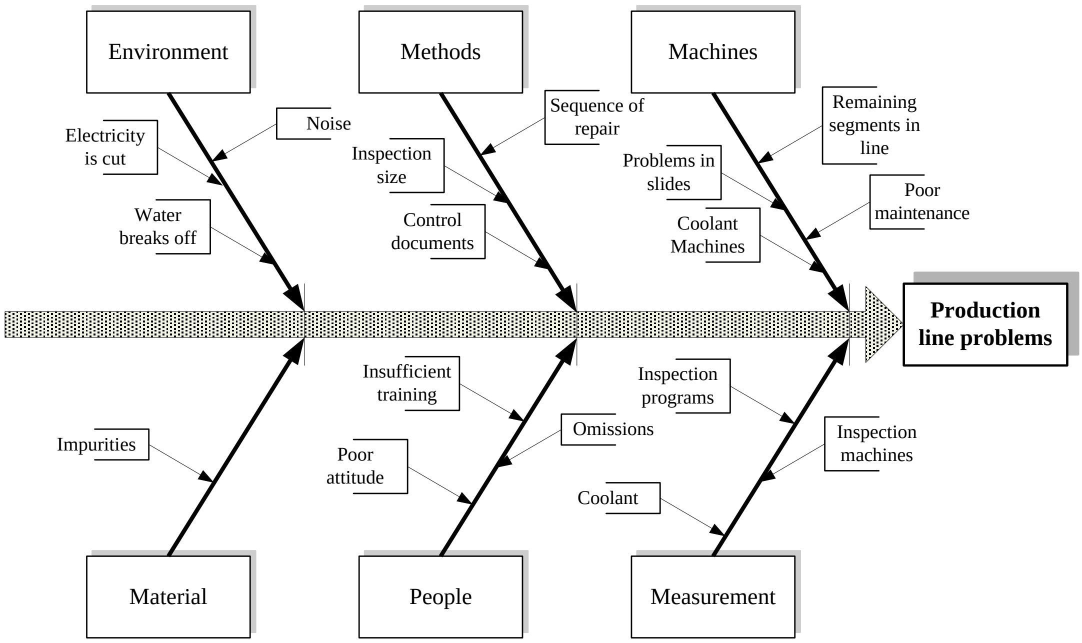

Figure 7: Cause &Effect Diagram for Production Line Problems

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