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REWORK REDUCTION IN HEAT TREATMENT PLANT BY PROCESS IMPROVEMENT

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ABSTRACT

Acquiring the required hardness and surface quality is the foremost goal of any heat treatment process. Detailed study of the process undergone by any industry, analyzing and locating the area where the surface quality and required hardness can be improved and finding out the root cause of not attaining the required hardness value. A major tool in this area is root cause analysis and pareto chart. In this paper the drop in required hardness in the heat treatment plant of a Machine Tools industry, has been analyzed by Individual control charts, root cause analysis and pareto analysis methods. The major factors contributing to the efficiency drop have been identified and suggestions were given to overcome these problems. By implementing the suggestions, the hardness value very near to the required value can be acquired without reworks.

KEYWORDS: Reworks in Heat Treatment Plant, Hardness Testing, Pareto Analysis, Control Chart

INTRODUCTION

Heat treating is the controlled heating and cooling of a material to achieve certain mechanical properties, such as hardness, strength, flexibility, and the reduction of residual stresses. Many heat treating processes require the precise control of temperature over the heating cycle. Heat treating is used extensively in production of metallic parts. Typically, the energy used for process heating accounts for 2% to 15% of the total production cost. The hardness value is the most required factor in heat treatment. Different heat treatment processes such as hardening, case hardening, toughening, carburizing, etc. requires furnace heat treatment and thereafter quenching treatment in order to attain the required hardness value. Due to different factors such as non uniform temperature in salt bath, required temperature not attained in quenching bath, thermocouple being not able to indicate the temperature correctly, socking time variation, heat loss before quenching, visual inspection and variation in composition of material may lead to not achieving the required hardness value.

If the required hardness value is not attained by the existing heat treatment process, it is very much important to upgrade the existing heat treatment process in order to avoid the reworks occurring in different heat treatment processes. In this paper a set of hardness values obtained and number of reworks were obtained by different heat treatment processes. Two methods were suggested in order to reduce the reworks in heat treatment process.

PROBLEM DEFINITION

The primary aim of this case study is to explore the possibility of a suitable method to improve the heat treatment process for achieving the required hardness value which was not achieved during different heat treatment operations in the industry and suggest suitable alternative to achieve required hardness of the end product.

DATA COLLECTION AND ANALYSIS

Sixty sets of different items have undergone different heat treatment operations such as hardening, case hardening, carburising and toughening. Statistical studies can evaluate how well a machine or process is capable of producing components within the given tolerance limits. An effective quality management system should assure the quality of the components based on taking appropriate corrective actions and measurement results. The tools used primarily are to determine whether the process is suitable for attaining the required hardness within the intended tolerance limits.

Materials that usually undergo heat treatment operations are low carbon steel and medium carbon steel. Mostly the hardness value required for carbon steel is 60 HRC, 40 HRC and 32 HRC. It is normally obtained by case hardening, toughening and carburizing. Rework is required if the required hardness value is not attained. If the obtained hardness value is less the work cannot be finished, but if it is high the work cannot be machined due failure of tool tip.

Two methods are mainly used to check the hardness of a work piece undergoing different heat treatment operations

- Brinell hardness Testing
- Rockwell Hardness Testing

For the analysis of heat treatment quality, the hardness of different parts were checked after different heat treatment processes, and then compared with required value of hardness. The results were tabulated in three tables according to the value of hardness required. Statistical process control charts are used for the analysis of the tabulated data. Different hardness readings of different parts were taken in different time. So individual control charts, moving range chart, cause and effect diagram and pareto chart were adopted for the analysis.

The graphs for different hardness values are plotted in Figure 1, Figure 2 and Figure 3.

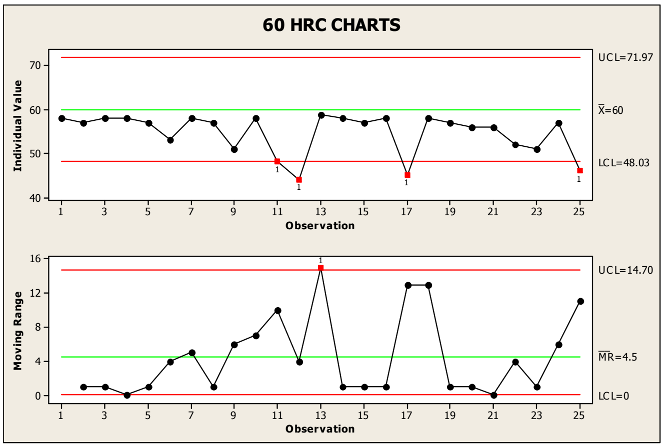

Figure 1: Control Chart for Hardness Test Result of 60 HRC Hardened Parts

Table 1: Hardness Test Result for 60 HRC Hardened Parts

Sl. No.	Component	Material	Operation	Qty	Qty Ok	H/T REQUIRED (HRC)	H/T OBTAINED (HRC)	H/T OBTAINED AFTER REWORK
1	SHAFT 2	L C STEEL	HARDENING	3	3	60	58	
2	SHAFT 3	L C STEEL	HARDENING	3	3	60	57	
3	HARD WASHER	L C STEEL	CASE HARDENING	20	20	60	58	
4	PISTON	L C STEEL	CASE HARDENING	6	6	60	58	
5	COOLANT LOCATING PIN	L C STEEL	HARDENING	62	62	60	57	
6	TURNING TOOL HOLDER	L C STEEL	HARDENING	9	0	60	53	58 HRC
7	CLAMP PIECE	L C STEEL	HARDENING	100	100	60	58	
8	CLAMP PIECE	L C STEEL	HARDENING	150	150	60	57	
9	TURNING TOOL HOLDER	L C STEEL	HARDENING	38	0	60	51	57 HRC
10	SPUR GEAR	L C STEEL	HARDENING	11	11	60	58	
11	SPUR GEAR	L C STEEL	HARDENING	47	0	60	48	58 HRC
12	SPUR GEAR	L C STEEL	HARDENING	62	0	60	44	
13	SPUR GEAR	L C STEEL	HARDENING	14	14	60	59	
14	PISTON	L C STEEL	CASE HARDENING	42	42	60	58	
15	JAW	L C STEEL	CASE HARDENING	80	80	60	57	
16	JAW	L C STEEL	CASE HARDENING	124	124	60	58	
17	COLLET HOLDER	L C STEEL	HARDENING	6	0	60	45	57 HRC
18	PISTON	L C STEEL	HARDENING	6	6	60	58	
19	PISTON	L C STEEL	HARDENING	3	3	60	57	
20	CHUCKING JAW	L C STEEL	HARDENING	55	55	60	56	
21	CHUCKING JAW	L C STEEL	HARDENING	63	63	60	56	
22	SHAFT	L C STEEL	HARDENING	3	0	60	52	58 HRC
23	SHAFT	L C STEEL	HARDENING	2	0	60	51	57 HRC
24	SPINDLE	L C STEEL	HARDENING	2	2	60	57	
25	STUD	L C STEEL	HARDENING	5	0	60	46	47 HRC

By analysing the chart for 60 HRC heat treated parts, it is found that some observations are out of control. So the existing process is not capable to produce heat treated parts of required hardness (60 HRC)

Table 2: Hardness Test Result for 40 HRC Hardened Parts

Sl. No.	Component	Material	Operation	Qty	Qty Ok	H/T REQUIRED (HRC)	H/T OBTAINED (HRC)	H/T OBTAINED AFTER REWORK
1	SHAFT 6	M C STEEL	TOUGHENING	63	0	40	28	37 HRC
2	SLEEVE	M C STEEL	TOUGHENING	63	63	40	38	
3	SHAFT 7	M C STEEL	TOUGHENING	63	0	40	29	38 HRC
4	PISTON	M C STEEL	TOUGHENING	6	6	40	37	
5	TOOL CLAMP BOLT	M C STEEL	TOUGHENING	38	38	40	39	
6	BALL NUT HOUSING	M C STEEL	TOUGHENING	26	0	40	21	37 HRC
7	BALL NUT HOUSING	M C STEEL	TOUGHENING	2	2	40	37	
8	PISTON	M C STEEL	TOUGHENING	6	6	40	38	
9	SPECIAL WASHER	M C STEEL	TOUGHENING	50	50	40	39	
10	LOCK NUT	M C STEEL	TOUGHENING	32	32	40	38	
11	SPECIAL NUT	M C STEEL	TOUGHENING	13	13	40	39	
12	SPECIAL LOCK NUT	M C STEEL	TOUGHENING	13	13	40	39	
13	ALIGNING BLOCK	M C STEEL	TOUGHENING	3	3	40	39	
14	MOTOR PULLEY	M C STEEL	TOUGHENING	5	0	40	30	38 HRC
15	PULLEY FLANGE	M C STEEL	TOUGHENING	63	0	40	31	37 HRC
16	WORM WHEEL SHAFT	M C STEEL	TOUGHENING	155	0	40	30	38 HRC
17	DOUBLE GEAR	M C STEEL	TOUGHENING	62	0	40	45	38 HRC
18	SPUR GEAR	M C STEEL	TOUGHENING	63	63	40	37	
19	TAPER LOCK BUSH	M C STEEL	TOUGHENING	6	6	40	38	
20	SPACER	M C STEEL	TOUGHENING	5	5	40	34	
21	SPUR GEAR	M C STEEL	TOUGHENING	63	0	40	21	36 HRC
22	SPUR GEAR	M C STEEL	TOUGHENING	63	63	40	37	
23	TAPER LOCK BUSH	M C STEEL	TOUGHENING	6	6	40	36	
24	PICK OFF GEAR	M C STEEL	TOUGHENING	63	0	40	21	36 HRC
25	PICK OFF GEAR	M C STEEL	TOUGHENING	63	63	40	35	

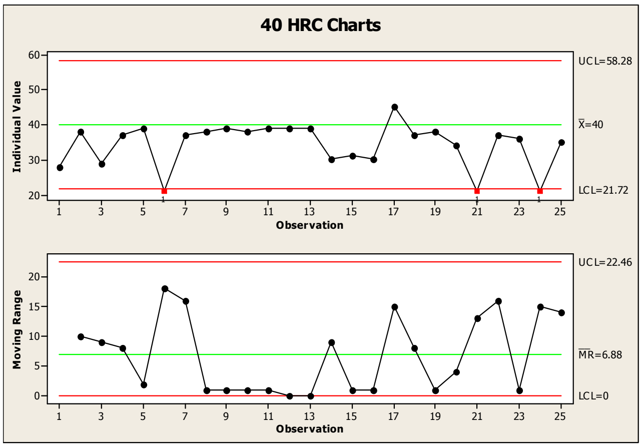

Figure 2: Control Chart for Hardness Test Result of 60 HRC Hardened Parts

By analysing the chart for 40 HRC heat treated parts, it is found that some observations are out of control. So the existing process is not capable to produce heat treated parts of required hardness (40 HRC)

Table 3: Hardness Test Result of 32 HRC Hardened Parts

Sl. No.	Component	Material	Operation	Qty	Qty Ok	H/T REQUIRED (HRC)	H/T OBTAINED (HRC)	H/T OBTAINED AFTER REWORK
1	PISTON	LOW C STEEL	CARBURISING	3	3	32	33	
2	CHUCKING JAW	LOW C STEEL	CARBURISING	63	63	32	31	
3	CHUCKING JAW	LOW C STEEL	CARBURISING	55	55	32	30	
4	PISTON	LOW C STEEL	CARBURISING	6	6	32	30	
5	SPUR GEAR	LOW C STEEL	CARBURISING	16	16	32	29	
6	ECCENTRIC SHAFT	LOW C STEEL	CABURISING	126	0	32	35	32 HRC
7	CLAMP PIECE	LOW C STEEL	CABURISING	74	0	32	19	30 HRC
8	NUT	LOW C STEEL	CARBURISING	2	2	32	29	
9	DISTRIBUTOR	LOW C STEEL	CARBURISING	37	37	32	30	
10	SPUR GEAR	LOW C STEEL	CARBURISING	3	3	32	33	

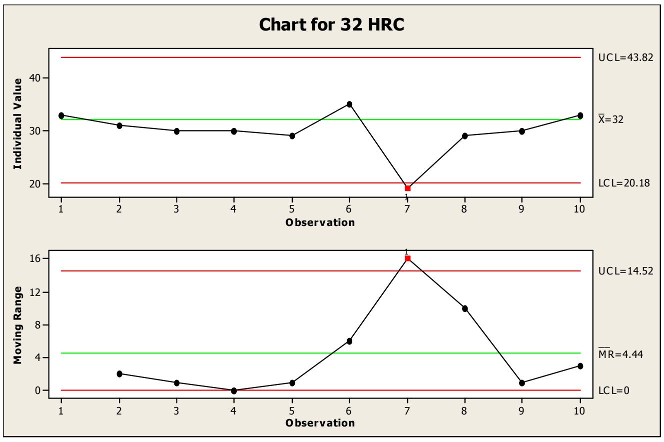

Figure 3: Control Chart for Hardness Test Result of 60 HRC Hardened Parts

By analysing the chart for 32 HRC heat treated parts, it is found that some observations are out of control. So the existing process is not capable to produce heat treated parts of required hardness (32 HRC)

Statistical process control study shows the assignable cause of variation in heat treatment processes. These assignable causes are larger in magnitude and are controllable in the heat treatment process. The assignable causes are to be eliminated from the production process to make the process efficient. The major causes are collected by detailed survey from operators, supervisors and managers who are directly involved in this process.

To identify the root causes, cause and effect diagrams are constructed with possible causes which affect the hardness of the heat treated parts.

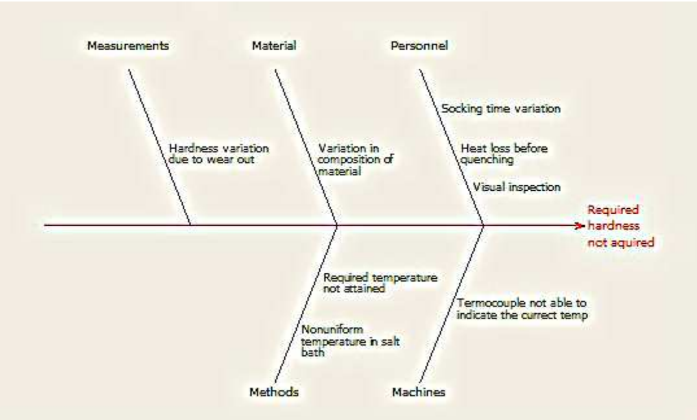

Figure 4: Cause and Effect Diagram

Some common reasons for not attaining the required hardness are non uniform temperature in salt bath, required temperature not attained in quenching bath, thermocouple being not able to indicate the temperature correctly, socking time variation, heat loss before quenching, visual inspection and variation in composition of material.

PARETO ANALYSIS

Table 4: Rework Analysis

Sl. No.	Reasons	No. of Rework	Cum No.	%
1	Quenching temp not attained	479	479	55.18
2	Furnace Temp variations	314	793	91.36
3	Heat Loss before quenching	44	837	96.43
4	Socking time variation	26	863	99.42
5	Composition of material	5	868	100.00
	Total	**868**		

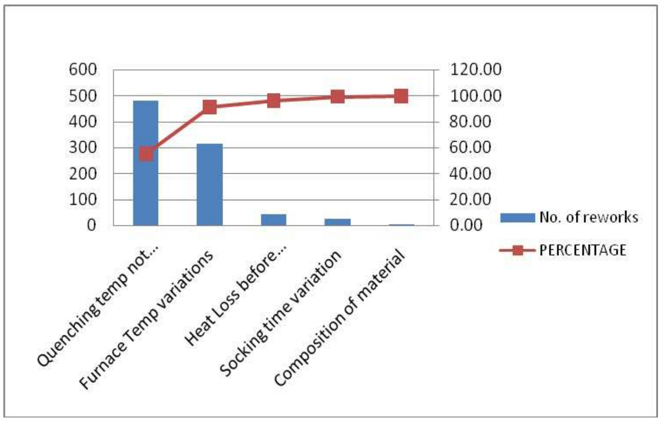

Figure 5: Pareto Chart: Rework Analysis

From the pare to chart analysis, it is clear that the total number of reworks required are due to the quenching treatment problems. Above 80 % of the rework is due to the inefficiency of the existing oil quenching process. So the root cause for not attaining the required hardness in heat treatment plant is due to the use of oil quenching process. It is also found that, the non uniform temperature in salt bath furnace also effect the required hardness value. It also plays a key role in the heat treatment process.

A suitable suggestion is to replace the oil quenching process with the intensive quenching (IQ) method, which is an innovative thermal process for hardening steel parts. The IQ process is an environmentally friendly process conducted in highly agitated plain water. One of the major benefits of the IQ technique is the development of high, beneficial residual compressive stresses in the part surface layer during quenching. The IQ process is interrupted at the computer calculated time when residual surface compressive stresses reach their maximum value. Chilled cooling system can also be used to improve the process efficiency of the quenching treatment.

Use of gas carburizing instead of salt bath furnace will help to avoid the reworks due to the uneven temperature variations in the furnace. Problem of salt bath furnace is not only the uneven distribution of temperature in furnace but also makes the environment very much polluted by different hazardous gases & used salts.

CONCLUSIONS

Attaining the required amount of hardness is the most important role of all heat treatment processes. The hardness value can be deviated from the required value due to different reasons. We can use statistical tools for the analysis of different heat treatment processes for different required values of hardness. Process improvement is the only effective method that can be adopted to reduce the number of reworks in heat treatment plant. Lot of new technologies available for this process improvement. It includes different quenching methods such as intensive quenching, using chilled cooling system in quenching operations and using gas carburizing instead of conventional salt bath furnace for different heat treatment processes in heat treatment plants. By using these technologies we can improve the different heat treatment processes and thereby attain the required hardness value with minimum number of reworks.

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