APPLICATION OF ROBUST TAGUCHI DESIGN AND ANALYSES FOR "CONDOM PACKING OPERATION OPTIMIZATION" AT HLL LIFECARE LIMITED, INDIA

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Abstract:

The problem faced by the Kanagala Unit of HLL Life Care Limited Company was 0.5% rejection at condom packing operation due to failure in Sealing-Integrity-Test which contributed a revenue loss around 800 000 per year.

The authors along with dedicated team of cross functional executives of Kanagala Unit, HLL Life Care Limited had used the Robust Parameter Design through Taguchi Approach for Condom Packing Operation Optimization and ensured breakthrough Improvement in Condom Packet Sealing (Sealing Integrity) which in-turn ensured Zero Sealing Integrity rejection and a net saving of Rs. 750 000 (Total Saving Rs. 800 000 – Rs. 50 000 Project Cost).

After arriving optimal input parameter setting i.e. Machine Speed MS is 83 Strips per minutes, Press Roller Temperature PRT is 200 ^{0}C, Pressure Between Rollers PBR is Medium, Press Roller Type PRT - 1, 15 batches i.e around 7.0 Million condom have been packed with the above optimal setting with slight machine to machine variation as validations trails with the mentioned optimal parameter setting and proved that all the batches had been passed in Sealing Integrity test as well as in visual inspection.

Key Words: Factors, Factor Levels, Main-Effect-plots-for-Means, Main-Effect-Plots-for-SN Ratio, Robust Design.

1. Introduction

1.1 Brief Profile of HLL Lifecare Limited

HLL Life-care Limited Kanagala Facility, Belgaum, India: The Kanagala plant in Belgaum, Karnataka, India commenced its operation with production of condoms in 1985 using Japanese technology. This unit underwent diversification in 1992 with the tabletting manufacturing facility for birth control pills - Mala-D/N and the formulation and tabletting of Saheli (Centchroman) the indigenous, non-steroidal once-a-week pill. The tabletting of Emergency Contraceptive pills was started in 2003 (7)

1.2 Literature Review

The Taguchi's Approach: Genichi Taguchi believed that quality should be designed into the products and not inspected into it. Inspection does not produce good products but only segregates them from bad products. He also propagated that quality is best achieved by minimizing the deviation from a target and the cost of quality should be measured as a function of the deviation from the standard (5)

R.A Fisher in England developed the classical methods for design of experiments, in the early part of the 20th century. They include a full variety of statistical design techniques based on Latin squares (balanced square arrangements required for unbiased statistical experimentation) and developed for agricultural industry. While rigorous, a major problem with applying Fisher's method in manufacturing industry is the time and cost required to learn and use it. Further, Fisher's methods are often cumbersome to implement in manufacturing industrial experimentation because of certain assumptions and procedural emphasis.

Taguchi's approach to the design of experiments utilizes the concept of robust design. Robust design refers to designing a product or a process in a way that it has minimal sensitivity to the external noise factors. Robust design adds a new dimension to Fisher's statistical experimental design by explicitly addressing the concerns faced by all process and product designers, namely (5)

- How to reduce economically the variation of a product's function in the customer's environment, and
- How to ensure that the decisions found to be optimum during laboratory experiments will

prove to be so in manufacturing and in customer environments.

In contrast to Statistical Process Control (SPC), which attempts to control the factors that adversely affect the production, Taguchi methods focus on *design*-the development of *superior performance designs* (for both products and manufacturing processes) to deliver quality.

Taguchi methods lead to excellence in the selection and setting of product/process design parameters and their tolerances. In the past decade, engineers have applied these methods in over 500 automotive, electronics, information technology and process-industries worldwide. These applications have reduced cracks in castings, increased the life of drill bits, produced VLSI with fewer defects, speeded up the response time of UNIX V, and even guided human resource management systems design.

I.E. Klein applied the Taguchi methods to the production of thin RF integrated circuits on alumina [1]. The substrates had 20 via holes of 1 mm in diameter, which led to a perturbation to the homogeneous spread of photo resist (by spinning) adjacent to the holes. Consequently, the overall process yield was 30%. Implementation of Taguchi methods resulted in a substantial increase in production yield — to a value of 90%, which was obtained repeatedly. Thus, a robust cost-effective process was achieved. The Taguchi's signal-to-noise ratio (SNR) analysis has also been adopted to develop a robust design for the Rayleigh surface acoustic wave (SAW) gas sensing device operated in a conventional delay-line configuration [2].

K. Palanikumar et al had made use of Taguchi's method and ANOVA analysis for optimizing the cutting parameters in turning glass fiber reinforced plastic (GFRP) composites using a poly crystalline diamond (PCD) tool for minimizing surface roughness [3]. Der Ho Wu and Mao Sheng Chang had conducted a study which applies the Taguchi method to optimize the process parameters for the die casting of thin-walled magnesium alloy parts in computer, communications, and consumer electronics (3C) industries [4].

Taguchi methods systematically reveal the complex cause-effect relationships between design parameters and performance. These in turn lead to building quality performance into processes and products before actual production begins.

The Taguchi's technique of Robust Design is one of the methods for reducing the variation among the products. The Taguchi's method of statistical design of experiments by using Orthogonal Arrays and analyzing the experimental outcome by Main effect plots of means, Main effect plots for S/N ratios for various quality characteristics of output (Tablets) are considered and optimization has been used for reducing the rejections of Lots of Tablet that are produced by Tablet Compression Machines of HLL Lifecare Limited.

1.3 The Problem Statement

The problem faced by the Kanagala Unit of HLL Life Care Limited Company was 0.5% rejection at condom packing operation due to failure in Sealing-Integrity-Test which contributed a revenue loss around 8 Lakhs per year.

Sealing-Integrity-Test: As per Schedule 'R' 32 strips are randomly sampled from a lot and kept in glass vassal of sealing-tester and subjected with the Negative Pressure i.e 375 +/- 50 mm Hg, the strip with quality sealing will inflate as the air pressure inside strip is more than outside strip. The defective strip with minute holes cannot inflate as the excess pressure/air in inside strip will pass outside through minute holes and maintains the same pressure inside and outside of the strip.

As per the schedule 'R' maximum of 2 failure are allowed in 32 strips as per above sealing integrity test to accept the whole lot of the product provided the visible defects such as edge cutting, improper stamping, improper feeding (two condoms in a strip), body under press, improper foil alignment, improper sealing etc., are absent.

The author (1) of the paper was working as Senior Assistant Manager (Quality), HLL Lifecare Limited, Kanagala Unit, Belgaum, interested to deploy the Taguchi Robust Design for solving the above problem .

2. Methodology Selected for Solving Above Problem

Methodology for deploying Robust Taguchi approach for process optimization (10 step methodology for problem solving) (6)

1. Defining the Statement of problem
2. Determination of the objectives
3. Ensuring correctness of Measurement System
4. Identification of Primary Packing Quality Characteristics that are to be optimized
5. Identification of the controllable and noise factors that are influencing the above identified performance characteristics and determination of the levels and values for all identified controllable and noise factors
6. Developing Design for Experimentation with

the help of Minitab Software

7. Conducting the experiments as per Designs, analyzing the strips for selected quality characteristics and posting the values in Minitab worksheet as needed
8. Analysis of data of strips' for selected Quality Characteristics by Taguchi approach with the help of Minitab Software and Interpretation of Analyses and selection of the optimum levels of the significant factors
9. Prediction of the expected results for optimal setting with the help of Minitab
10. Validation of optimal setting by a confirmation Trails.

2.1 Step 1: Statement of the Problem

The problem faced by the Kanagala Unit of HLL Life Care Limited Company was 0.5% rejection at condom packing operation due to failure in Sealing-Integrity-Test which contributed a revenue loss around 8 Lakhs per year.

The author (1) of the paper was working as Senior Assistant Manager (Quality), HLL Lifecare Limited, Kanagala Unit, Belgaum, interested to deploy the Taguchi Robust Design for solving the above problem.

***2.2** Step 2: Objectives of Study*

- Acquiring knowledge of deployment of Robust Taguchi Approach for solving Problem
- Deploying the Robust Taguchi Approach at Problem area systematically in 10 steps as above
- Ensuring elimination of 0.5% rejection completely by optimum setting of input parameters

2.3 Step 3: Measurement System Analyses

Gauge R&R calculated for all applicable measurement-systems of packing operation and Sealing Integrity Tester and found it is well within limits.

2.4 Step 4: Identification of tablets Quality Characteristics 'Y' that is to be optimized

The Brainstorming Technique was used by involving all the concerned employees and executives and decided to optimize 'Sealing Quality' of Strips which should lead to zero defect. (Y = Strip Sealing Quality)

2.5 Step 5: Identification of the Controllable and Noise factors and factor levels that are influencing Packing Quality of Strips.

After application of Brainstorming technique with all the concerned employees and executives and after establishing cause and effect relations between input- parameters and output-parameters of condom packing process the most significant four process parameters are identified as control parameters along with levels as shown in table1 inner array and one noise factor i.e room temperature with three levels as shown in table1 outer array.

Step 6: Development of Experimentation Design with the help of Minitab Software

The above Factors and levels have been used and developed the L9 Robust Taguchi Design for experimentation with the help of Minitab Software is shown in table 2

2.6 Step 7: Conducting Experimentation

As per above design each of nine treatments three experiments one at each noise level are conducted (9*3*1 = 27) and produced 27000 condom-packed-strips i.e 1000 strips per each combination of 'treatment and noise level' and subjected each of 1000 strips for sealing integrity separately and found good strips per 1000 and posted in Minitab worksheet shown in table 3:

Sealing-Integrity-Test: 1000 strips are kept in glass vassal of sealing-tester and subjected with the Negative Pressure i.e 375 +/- 50 mm Hg, the strip with quality sealing will inflate as the air pressure inside strip is more than outside strip. The defective strip with minute holes cannot inflate as the excess pressure/air in inside strip will pass outside through minute holes and maintains the same pressure inside and outside of the strip.

2.7 Step 8: Analyses of data of good/passed strips' for sealing quality optimization by ANOVA and Robust Taguchi Approach with the help of Minitab Software, Interpretation of Analyses and selection of the optimum levels:

Based on the 'General Liner Model ANOVA' developed by Minitab software, shown below yield (PQP1000) good quantity strips per 1000 as response variable for investigating significance effect of four input variables PRT, PBR, RT and MS on PQP1000 concluded that all the four input variable PRT, PBR, RT and MS except PRT (all the p-values are 0.00 i.e less than 0.05 and linear model R-square value is more than 99%) are significantly effecting the the response PQP1000.

The optimal setting as shown in table 4 has been arrived after developing and observing Main Effect plots for means shown in Graph.1, Main Effect plots for SN Ratios in Graph 2, Main Effect plots for Standard Deviation in Graph 3, and by considering all the delta values for Means, SN Ratios and standard deviations (5) .

Optimal input parameter setting i.e. Machine Speed MS is 83 Strips per minutes, Press Roller Temperature PRT is 200 0C, Pressure Between Rollers PBR is Medium, Press Roller Type PRT - 1, (The Minitab generated ANOVA, three main effect plots and delta value for three different scenarios are shown below)

General Linear Model: PQP1000 **versus PRT, PBR, RT, MS**

Factor	Type	Levels	Values
PRT	fixed	3	1, 2, 3
PBR	fixed	3	L, M, H
RT	fixed	3	140, 170, 200
MS	fixed	3	80, 83, 86

Analysis of Variance for PQP1000, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PRT	2	0.89	0.89	0.44	0.52	0.602
PBR	2	193.56	193.56	96.78	113.61	0.000
RT	2	800.67	800.67	400.33	469.96	0.000
MS	2	214.22	214.22	107.11	125.74	0.000
Error	18	15.33	15.33	0.85		
Total	26	1224.67				

S = 0.922958 R-Sq = 98.75% R-Sq(adj) = 98.19%

2.8 Step 9: The predicted value for optimal setting has been arrived by Minitab Software for both the parameters Friability and Hardness are as follows:

Factor levels for predictions

PRT	PBR	RT	MS
1	Medium	200	83

Predicted values

S/N Ratio	Mean	StDev	Ln(StDev)
60.0005	1000	0.577350	-0.549306

The predicted mean for above optimal setting is 1000 per 1000 i.e no sealing integrity failure of strip packs.

2.9 Step 10: Validation of Optimal Setting

15 batches i.e around 7.0 Million condom have been packed with the above optimal setting with slight machine to machine variation as validations trails with the mentioned optimal parameter setting and proved that all the batches had been passed in Sealing Integrity test as well as in visual inspection.

Sealing Integrity test: Here the test has been conducted as per the schedule R:

As per Schedule 'R' 32 strips are randomly sampled from a lot and kept in glass vassal of sealing-tester and subjected with the Negative Pressure i.e 375 +/- 50 mm Hg, the strip with quality sealing will inflate as the air pressure inside strip is more than outside strip. The defective strip with minute holes cannot inflate as the excess pressure/air in inside strip will pass outside through minute holes and maintains the same pressure inside and outside of the strip.

As per the schedule 'R' maximum of 2 failure are allowed in 32 strips as per above sealing integrity test to accept the whole lot of the product provided the visible defects such as edge cutting, improper stamping, improper feeding (two condoms in a strip), body under press, improper foil alignment, improper sealing etc., are absent.

3. Conclusions

The Robust Parameter Design through Taguchi Approach is shown a breakthrough Improvement in Condom Strips Sealing Quality (Sealing Integrity) at Kanagala Unit, HLL Life Care Limited, by reducing the 0.5% rejection to Zero Percent rejection in sealing integrity test which in-turn ensured a net saving of Rs. 7,50,000/- (Total Saving Rs. 800000 – Rs. 50000 Project Cost)

4. References

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List of Tables and Graphs

Table 1: Controllable and Noise factors and factor levels:

Inner Array					Outer Array		
Sl.No	Controllable Factors	Levels			Noise Factor (Room Temperature) Ni		
					N1: 12 ^{0}C R1	N2 = 24 ^{0}C R2	N3=36 ^{0}C R3
1	*PRT*	1	2	3			
2	RT	140	170	200			
3	*PBR*	Low	Medium	High			
4	MS	80	83	86			

Description of Factors, Notation and Unit of Measures

Sl. No.	Name of the Factor	Notation	Unit of Measure
1	*Press Roller Type*	PRT	Type: 1, 2, & 3
2	*Roller Temperature*	*RT*	^{0}C
3	*Pressure Between Rollers*	*PBR*	Levels: Low, Medium & High
4	*Machine Speed*	*MS*	Strips per Minutes
5	Noise Factor (Room Temperature)	Ni	^{0}C

Table. 2: L9 Robust Taguchi Design for Experimentation is developed by Minitab software

Inner Array					Outer Array: three readings are taken at three different noise level 12^{0}C, 24^{0}C & 36^{0}C			
					Noise	12^{0}C,	24^{0}C	36^{0}C
Sl. No.	PRT	PBR	RT	MS		R1	R2	R3
1	1	L	140	80				
2	1	M	170	83				
3	1	H	200	86				
4	2	L	170	86				
5	2	M	200	80				
6	2	H	140	83				
7	3	L	200	83				
8	3	M	140	86				
9	3	H	170	80				

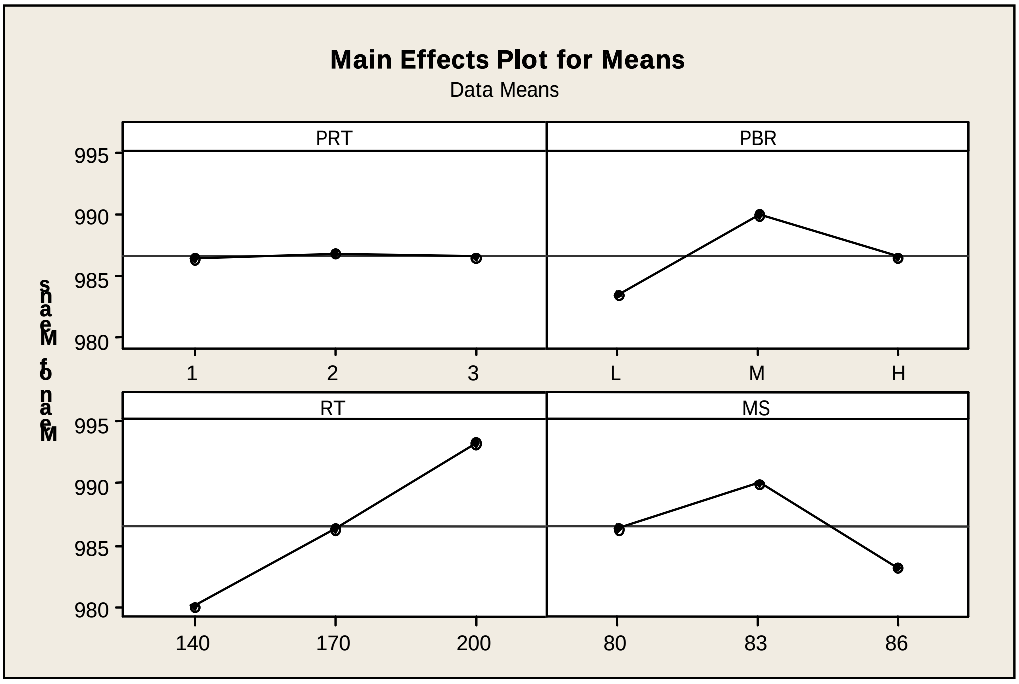
Table 3: Experimental Output

Inner Array					Outer Array: three readings are taken at three different noise level 12^0C, 24^0C & 36^0C			
					Noise	12^0C,	24^0C	36^0C
Sl. No.	PRT	PBR	RT	MS		R1 PQP1000	R2 PQP1000	R3 PQP1000
1	1	L	140	80		976	977	976
2	1	M	170	83		992	993	994
3	1	H	200	86		989	990	990
4	2	L	170	86		980	979	981
5	2	M	200	80		996	997	997
6	2	H	140	83		982	984	985
7	3	L	200	83		994	993	994
8	3	M	140	86		980	979	981
9	3	H	170	80		987	986	985
PQP1000 = Passed/Good Quantity per 1000 strips								

Table 4: Optimal setting is arrived after considering main effect plots and delta values

Sl. No.	**Name of the Factor**	**Notation**	**Optimal Level**
Sl. No.	Name of the Factor	Notation	Unit of Measure
1	Press Roller Type	PRT	Type: 1,
2	Roller Temperature	*RT*	*200 ^{0}C*
3	Pressure Between Rollers	*PBR*	Levels: Medium
4	Machine Speed	*MS*	83 Strips per Minutes

Graph 1: Main Effect Plot for Means (Minitab16 Software Output)



Graph 2: Main Effect Plot for SN Ratios (Minitab16 Software Output)

Graph 3: Main Effect Plot for StDevs (Minitab16 Software Output)