AC 2009-755: IMPLEMENTING THE USE OF STATISTICAL ANALYSIS TOOLS IN THE MANUFACTURING PROCESSES OF THE AUTOMOTIVE INDUSTRY

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Implementing the use of Statistical Analysis Tools for the Optimization of Manufacturing Processes in the automotive industry

Abstract

Senior design project in the Engineering and Technology curriculum provide an excellent opportunity for the students to experience for the first time the real world application of engineering and mathematical tools. Project based learning such as the senior design project bring the students close to the teacher and shop floor engineers and teaches them the art of confidently approaching the intricate shop floor problems and propose optimum solutions. This article looks at the successful trouble shooting and problem solving approach to a complex manufacturing problem attempted through the application of Statistical Analysis Tools.

Introduction

Project-Based learning (PBL) is an innovative teaching methodology available to teachers in the form of senior design projects. PBL is designed to make learning relevant and useful to students through the establishment of connections outside of the classroom[1]. The main objective of the senior design project is to provide an opportunity to the student to attempt a real life engineering problem and solve it with the flexible use of engineering, mathematical and scientific concepts learnt in the program. In this aspect, university and industry cooperation plays a vital role in providing and trusting the student with a complex practical industrial problem. The senior design study presented in this article explores the trouble shooting and successful implementation of statistical analysis tools for the optimization of manufacturing process in an automotive industry.

The industry sponsor for this project is a leading global supplier of mobile electronics and transportation systems for automobile industries including safety and security systems. Products and systems from this industry are engineered to meet and exceed the rigorous standards of the automotive industry. The automotive industry is the industry involved in the design, development, manufacture, marketing, and sale of motor vehicles. In 2008, more than 73 million motor vehicles, including cars and commercial vehicles were produced worldwide[2]. However, the quality of the products is an important issue that needs to be addressed consistently. All the products from the sponsor industry including the airbag deployment system, which is the product chosen for the study, are designed and produced to meet or exceed customer requirements.

The airbag deployment system offers self-contained assessment of occupant size and proximity during airbag deployment and adjusts its output to provide an appropriate level of restraint. The airbag lowers its deployment energy for near-proximity occupants, helping to reduce the need for seat-based suppression systems. This is achieved through the control of a parameter known as 'High Slope.' The high slope is the mathematical calculation of the output pressure in KPa in relation to the time in ms, and it is measured in KPa/ms. The slope is the rate of output pressure (KPa/ms) measured in the time between the 10 % and the 50 % of the peak pressure, which means how fast the output pressure passes through the gates. The airbag deployment systems that have failed the inspection have high slope conditions. This was severely affecting the sponsor industry in meeting their daily production schedule. One of the major problems with the system was the 'High Slope' measured at 5 ms was consistently out of range from the target value of less than or equal to 5 KPa/ms. This paper discusses the experiences gained in the successful use of statistical analysis tools in isolating the problematic factors and optimization of the manufacturing processes.

Problem Identification

Automobiles are the main form of transportation around the world and passenger safety is of paramount importance. This is the reason for which an automobile must meet certain criteria and specifications related to the security of the passengers. According to the World Health Organization (WHO) - 800,000 people die each year worldwide due to road accidents and nearly 20 million others are injured. [3]

One of the most important ways to prevent a death is the use of airbags in automobiles. A bag of gas that inflates in front of the driver or occupant of the vehicle in the event of a collision is the simplest definition for an airbag. The airbag was created to reduce injuries that occur in frontal collisions, and currently there are airbags for all other needs as well. This device is the result of investigations that began when the statistics showed that the leading cause of death in frontal collisions was the impact of the driver against the steering column.

Main functions of an airbag:

- Avoid impact of the driver or passenger against harsh elements of the vehicle (steering wheel, dashboard, windshield, etc.).
- Absorb part of the kinetic energy of the body.
- To protect occupants from impact of crystals from the windshield.
- Decrease the head movement and the risk of cervical lesions.

However, airbags are installed in other areas of the modern cars as well.

An airbag needs a sophisticated deployment system for its successful operation.

According to the laboratory reports of the sponsor company, the airbag deployment system has problem with high slope conditions and hence the systems are rejected for nonconformity to standards. The objective of this project is to find the cause of the high slope conditions and propose a prevention strategy by process optimization.

Trouble shooting

The company has three main areas of operations: inflators, airbags, and seat belts. After an extensive and thorough analysis of all the data obtained during the testing in each of the areas, it was concluded that the inflator area is one of the areas with high Lab Failures. The failures are only found in a specific model and the rest of the models do not have failures. The test is performed in Hot Ambient, Full Ambient and Cold Low Ambient conditions and the failures are common in Cold Low Ambient condition.

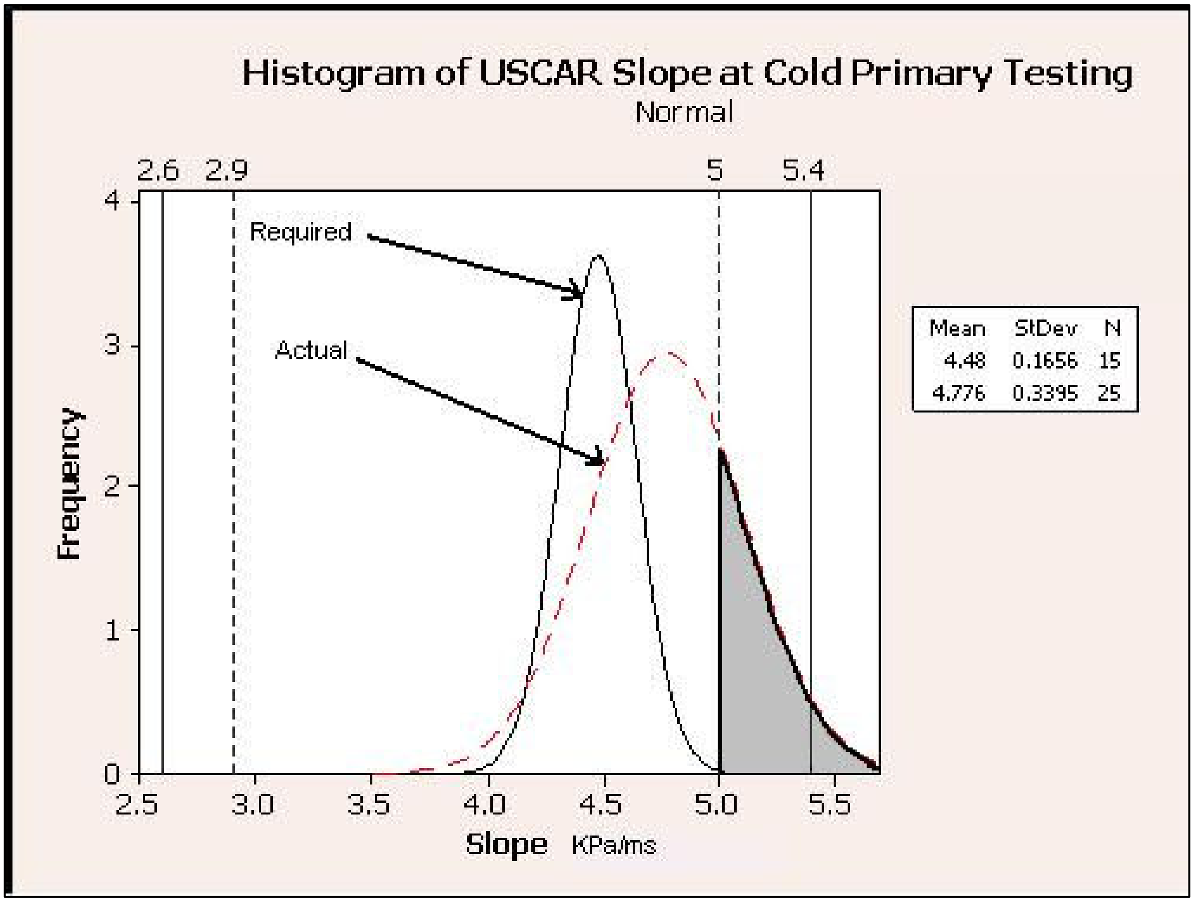

Figure 1 Histogram at Cold Primary Test

Variations of slope conditions during testing is shown in the frequency histogram(Figure 1).The histogram shows the acceptable frequency of slope conditions as against the recorded frequency, and it can be seen that the data is not close to the required parameters.

Green Y, which is the parameter measure, tested for the variation in its slope conditions. The rate of variation (KPa/ms) is measured in the time inteval between the 10% and the 50% of the peak preassure (KPa) during the test.

It has been obeserved that the pieces that are failed in the testing have more output pressure. The above chart shows that the two pieces had a big slope due to the high peak pressure in the output. The slope between the pressure at 10% and 50% pressure in 7 ms and 16 ms respectively has created a slope of 5.2. A comparison of parameters part to part is desired to identify the possible Red X (cause) candidates.

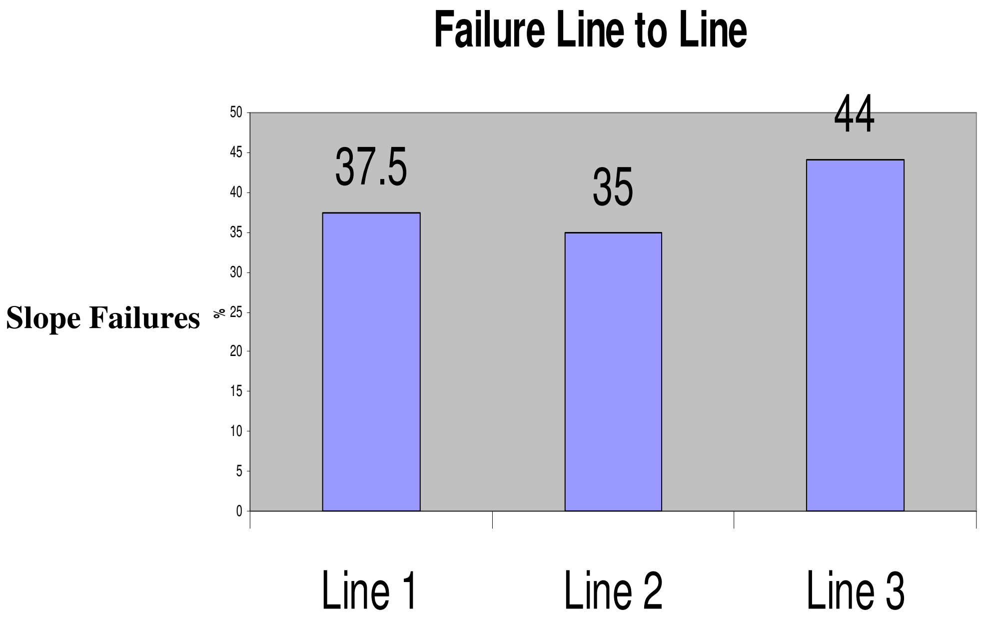

Figure 2 Failure Line to Line of production

There is no contrast in line to line (Figure 2). The slope failure occurred in all lines with the same level of failures. The difference in percentage comparing line to line is due to varitaion in the production level.

The slope failures happened only in the Cold Low ambient, there is a contrast between ambient to ambient. All the tests were confined to the same model as it was having the most of the failures. Also, location charts show the contrast between the part built and deployed in a out sourcing companyy compared to the parts built in-house.

Problem Analysis

The high slope is the mathematical calculation of the output pressure in KPa in relation to the time in ms. The green Y is the slope, which is the rate (KPa/ms) measured in the time between the 10 % and the 50 % of the peak pressure, approximately from 7ms to 16 ms, in KPa. This means how fast the pressure passes the pressure output between the gates.

Figure 3 Fault tree of possible cause of failure

The possibilities of high slope conditions presented in the building of airbags are shown in Figure 3. A decision has to be made at this time to find the strategy to find the source of the high slope conditions. The strategy selected was a defect strategy diagram, and followed by the DOE (Design of Experiments) analysis with the data collected across the testing platforms.

Data Collection

Tests were performed to measure the pressure of the airbag at the time of deployment. The data was collected using the Microsys Software (Table 1). A pictorial cross sectional view of the airbag system is provided in the Figure 4.

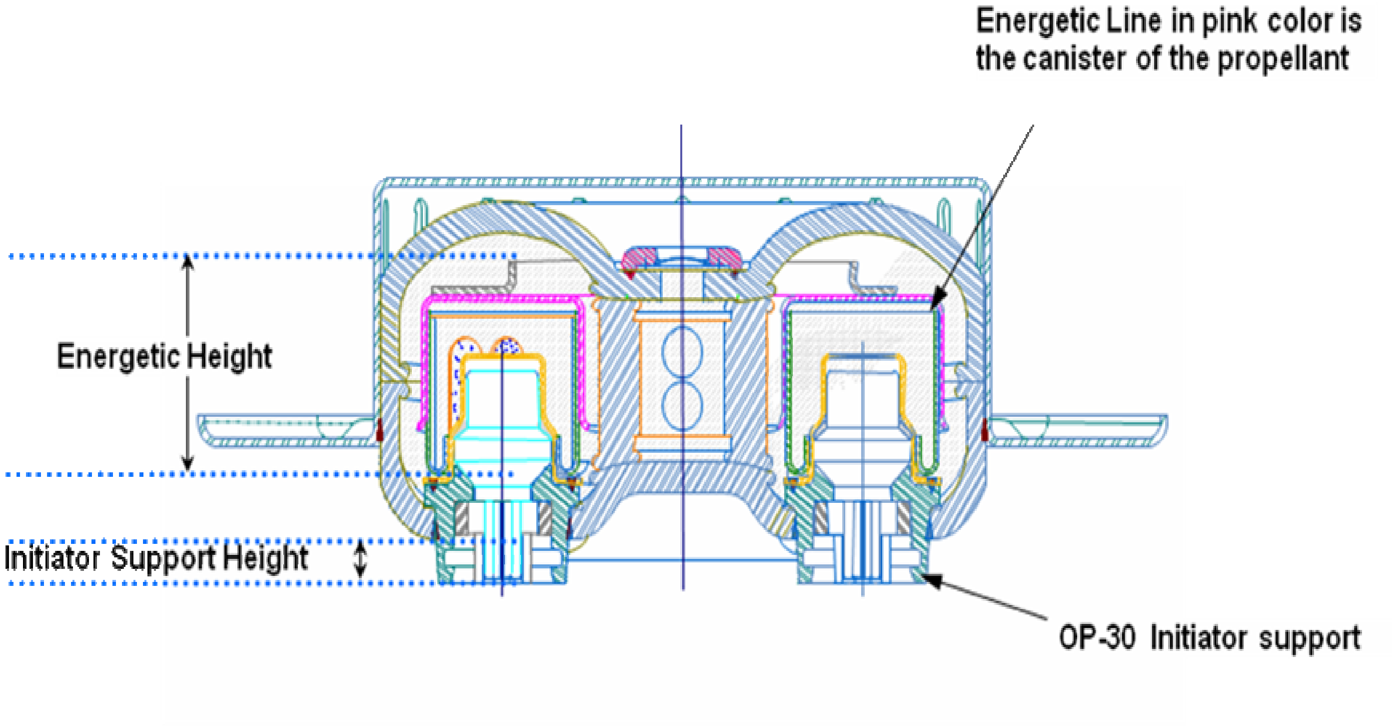

Figure 4 Airbag Deployment Systems

A DOE was run using following factors: [3]

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Factor	Low	High
OP.550 Energetic Height	A= 28.7	B= 29.5 mm
OP.530 Initiator Sup. Height	L= 1.60	H= 2.4 mm
OP.560 Gas Weight	Y= 18.2	Y= 19.8 mgs

Table 1: Data for Design of Experimentation Analysis

RUN #	INITIATOR SUPPORT HEIGHT (mm)	ENERGETIC HEIGHT (mm)	GAS WEIGHT (mg)	RUN ORDER	Slope KPa/ms
1	1.65	28.5	19.7	LBY	4.2
2	1.65	28.5	19.7	LBY	4.3
3	1.65	28.5	19.7	LBY	4.2
4	1.65	28.5	19.7	LBY	4.3
5	1.65	28.5	19.7	LBY	4.5
6	1.65	28.5	18.3	LBX	4.3

7	1.65	28.5	18.3	LBX	4
8	1.65	28.5	18.3	LBX	4.1
9	1.65	28.5	18.3	LBX	4.2
10	1.65	28.5	18.3	LBX	4.5
11	1.65	29.45	19.7	LAY	4.8
12	1.65	29.45	19.7	LAY	4.5
13	1.65	29.45	19.7	LAY	4.8
14	1.65	29.45	19.7	LAY	4.6
15	1.65	29.45	19.7	LAY	4.8
16	1.65	29.45	18.3	LAX	4.8
17	1.65	29.45	18.3	LAX	4.5
18	1.65	29.45	18.3	LAX	4.5
19	1.65	29.45	18.3	LAX	4.9
20	1.65	29.45	18.3	LAX	4.3
21	2.25	29.45	19.7	HBY	4.3
22	2.25	28.5	19.7	HBY	4.2
23	2.25	28.5	19.7	HBY	4.2
24	2.25	28.5	19.7	HBY	4
25	2.25	28.5	19.7	HBY	4.2
26	2.25	28.5	18.3	HBX	3.9
27	2.25	28.5	18.3	HBX	4.2
28	2.25	28.5	18.3	HBX	3.8
29	2.25	28.5	18.3	HBX	3.8
30	2.25	28.5	18.3	HBX	3.8
31	2.25	29.45	19.7	HAY	4.4
32	2.25	29.45	19.7	HAY	4.7
33	2.25	29.45	19.7	HAY	4.3
34	2.25	29.45	19.7	HAY	4.5
35	2.25	29.45	19.7	HAY	4.3
36	2.25	29.45	18.3	HAX	4.7
37	2.25	29.45	18.3	HAX	4.6
38	2.25	29.45	18.3	HAX	4.6
39	2.25	29.45	18.3	HAX	4.3
40	2.25	29.45	18.3	HAX	4.1

Data Analysis

Risk Assessed: The experiment was run using the high and low energetic pressed height. The test was conducted using the same energetic box and same sleeve lot to eliminate correlation between the mixing of two factors low and high energetic height and low and high initiator support height.

The DOE analysis with 95% confidence level shows that the energetic height is significant. Red X® condition confirmed:

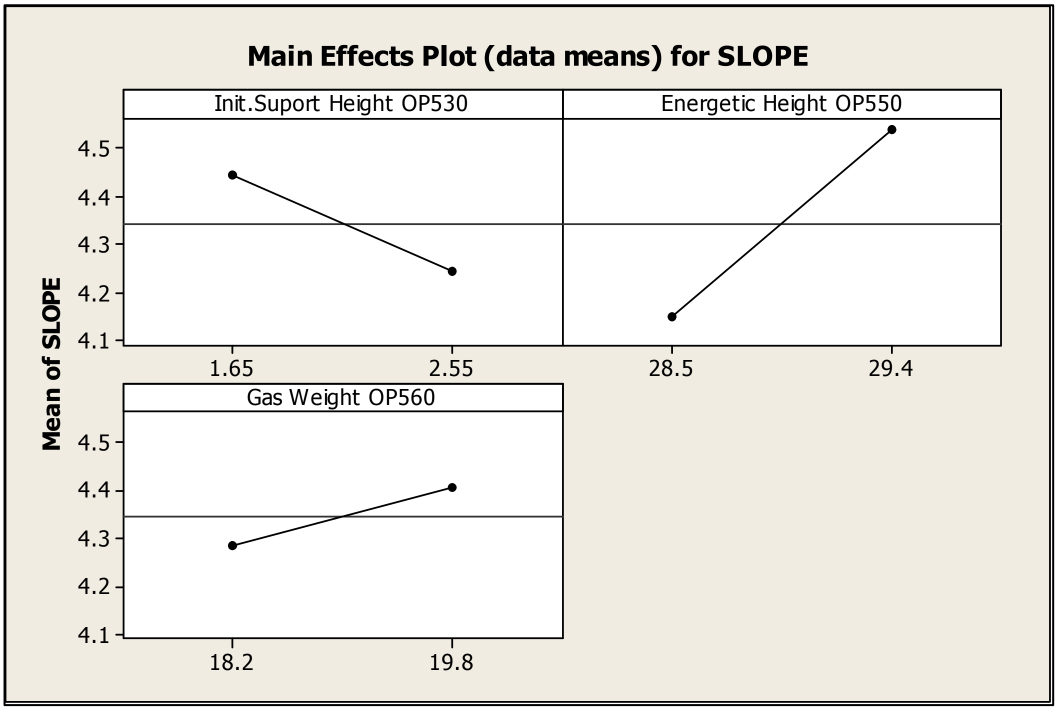

Fig.5 Main effects plot (Data means) for Slope

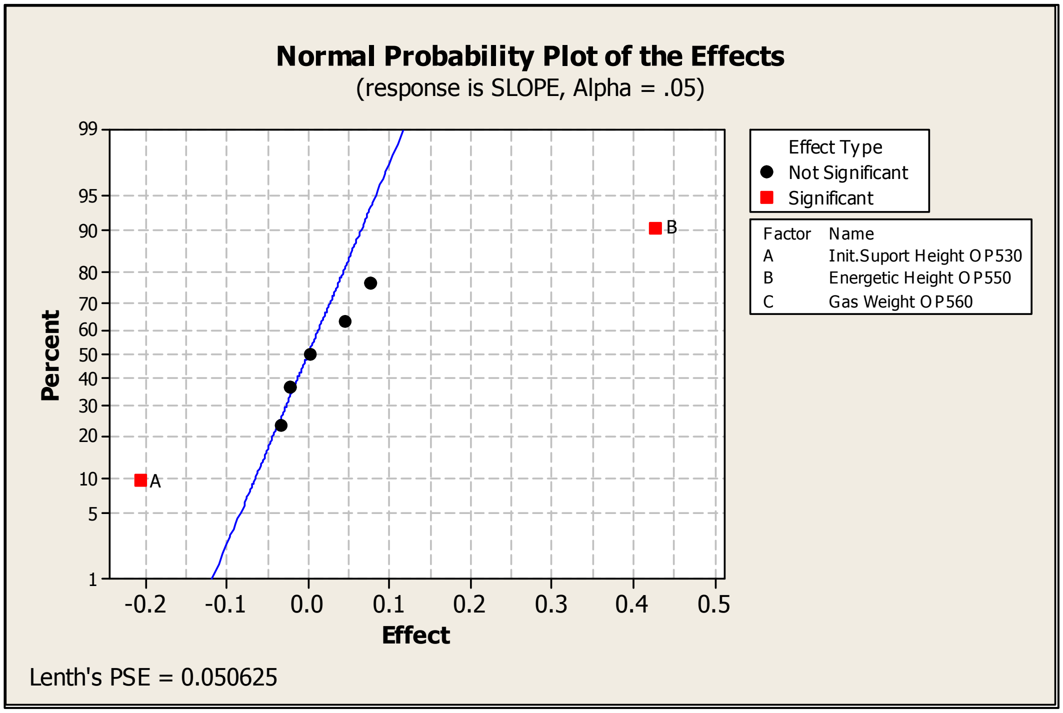

Fig. 6 Normal Probability plot of effects

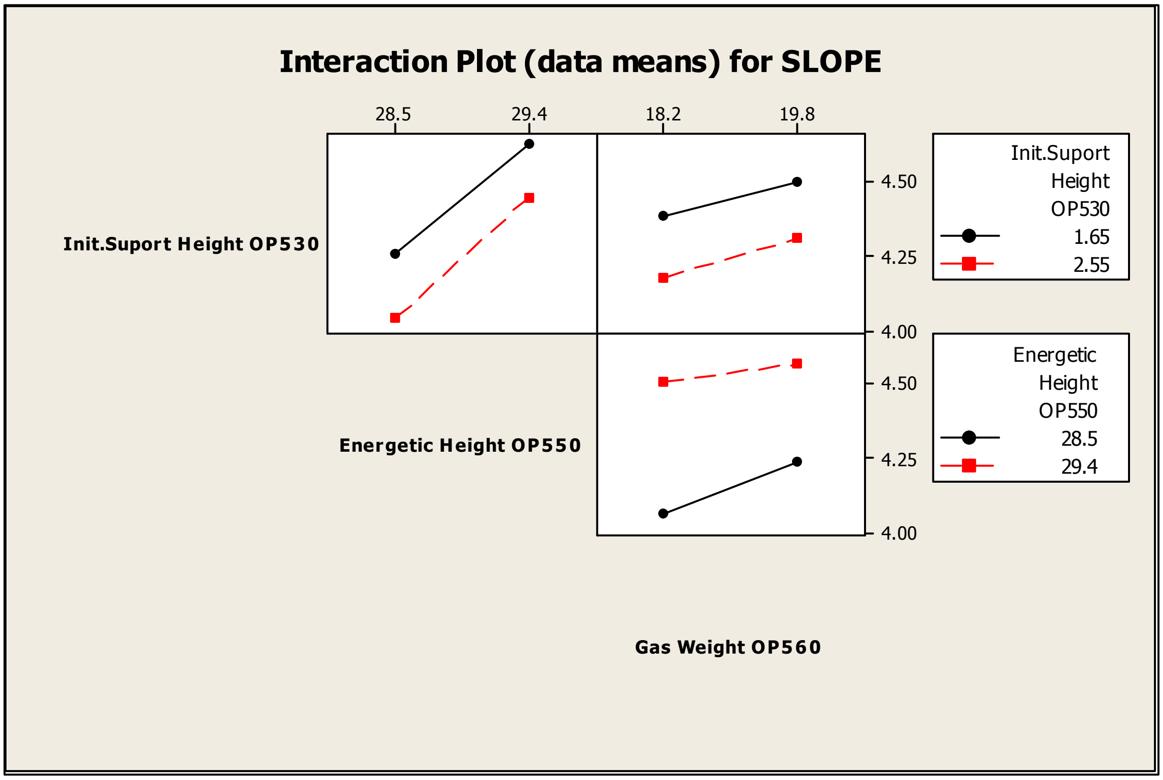

Figure 7 Interaction plot for slope

In Figure 5, it can be seen of how the main effect interacts when the mean response changes across the levels of any of the three factors selected as the main causes of the high slope condition. This plot examines the level means for each of the factors and compares the relative strength of the effects across each factor. While Figure 6 compares the relative magnitude and the statistical significance of both main and interaction effects of the energetic height, gas weight, and initiator support height. In the graph provided (Figure 7), it is evident that the initiator support height and the energetic height are the two factors that are affecting more the variation in the high slope condition presented.

Each plot displays the interaction among the three chosen factors. The interaction occurs when the change in response from the one level of a factor to another level differs from the change in response at the same two levels of a second factor. That is, the effect of one factor is dependent upon a second factor; this shows the relative strength of the effects across each of the factors.

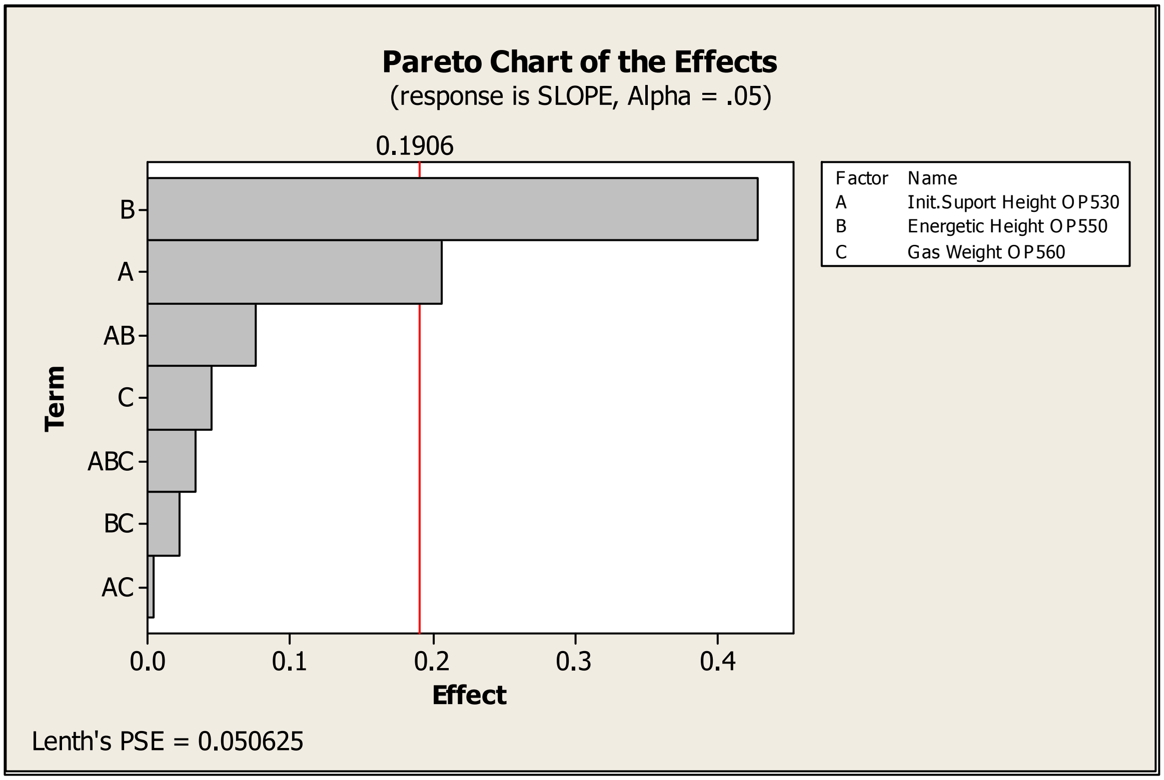

Fig. 8 Pareto chart of effects

The Pareto (Figure 8) chart is a bar chart that graphically ranks the defects obtained from largest to smallest, which helps to prioritize the quality problems and focus improvement efforts on the areas where the largest gains is made, which is the Op. 550 Initiator support height.

Results

At the beginning of the research**,** the deployment system was tested and approved by an external company. Throughout the entire investigation, it was evident that the problem persists along all the production process of the deployment systems.

The slope is the Green Y® and the energetic support height is the Red X®, and the relationship between these two parts inside the deployment system is how the energy goes through the energetic propellant, and this is the ones that are causing changes in the output slope.

After the data analysis by the DOE method, it can be concluded that the factors that cause a high slope condition in the deployment systems is the OP.550 Initiator support height. This is the main factor affecting the results of the slope at the moment of deployment, causing a malfunctioning.

A comparison between the production in Matamoros and Reynosa plants, shows that high slope conditions are only present in the Matamoros plant. One possible solution can be switching parts and subassembly from Rimir Matamoros plant to Rimir Reynosa plant.

It has been concluded that the most feasible and cheapest solution for the company would be adjusting the levels of control inside the operations mentioned above during the production process and before assembling.

Energetic Press Height	Spec. Limits 28.7 – 29.5 mm	Adjustment Limits 28.75 – 28.95 mm
Initiator Support Height	Spec. Limits 1.65 – 2.55 mm	Adjustment Limits 2.00 – 2.15 mm

If the problem is solved the savings calculated will be around $240,000.00 per each line of production.

Conclusion

The results obtained by this research will be sent to the company for the future implementation to correct or solve the problem described at the beginning of this research. The company will decide how and when this solution could be implemented.

This study gave the student ample opportunity to exercise the statistical and engineering concepts learnt in the program for the first time in a real life situation. The student also presented her work in the research symposium organized by the university. The student also had the opportunity to observe the actual production process of air bags and spent large amount of time in the shop floor performing tests and analysis. These kinds of hands on senior design projects will provide students with the valuable shop floor experiences that are very valuable in getting a job offer in the present tough job market. This research also gave an opportunity for the sponsor to independently evaluate their manufacturing process by an external party, in this case student and university.

Bibliography

1. Stephanie G. Adams, Project-Based Learning in a Statistical Quality Control Course", Proceedings of the ASEE Annual Conference and Exhibition 2000.

2. "World Motor Vehicle Production by Country: 2005 - 2007". OICA.

3. AIRBAG, el salvavidas *Revista TRÁFICO* AÑO XIV - Nº 130 Mayo-Junio 98

3. CADH Operator Training Agenda

4. Pyzdek, T, "Quality Engineering Handbook", 2003.

5. “Process Assessment and Improvement”, Springer, 1st edition, December 15, 2004.

6. Box,G. E, Hunter,W.G., Hunter, J.S., Hunter,W.G., "Statistics for Experimenters: Design, Innovation, and Discovery", 2nd Edition, Wiley, 2005.

7. Pearl, J. *Causality: Models, Reasoning and Inference*, Cambridge University Press, 2000.

8. Ferguson, George A., Takane, Yoshio. (2005). "Statistical Analysis in Psychology and Education", Sixth Edition. Montréal, Quebec: McGraw-Hill Ryerson Limited.

9. Lindman, H. R. (1974). Analysis of variance in complex experimental designs. San Francisco: W. H. Freeman & Co.