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Training in Quality Engineering concepts and skills: Case Study, simulations paper propeller using Six Sigma based methodology

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Abstract This paper is the result of the collaboration between the professors of the Department of Mechanics and the Production Management of the University of Mondragon and the 4th year students of the Karelia University of Applied Sciences in Finland. The developed case is the optimization of the flight process of a paper propeller, based on the Six Sigma DMAIC methodology. The objective was to show how to train the students of the Master in Innovation and Project Management in Mondragon University, in the acquisition of the knowledge and skills needed in (Continuous Improvement Process CIP) and Quality Engineering (QE). Student feedback reflect, that the application of simulation case, has been valid to understand the theory and acquiring skills related to the techniques of QE, specifically in standard methods of continuous improvement, statistical tools, and standardization systems.

Keywords: Training, Dynamic Learning, Quality Engineering, Six Sigma

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1 Introduction

The Continuous Improvement Process (CIP) in industrial organizations, (Carpinetti, Buosi & Gerolamo 2003), albeit not sufficient on its own, becomes a basic resource to generate a long-term competitive advantage. In this sense, universities, in order to adapt to industrial needs, have incorporated training programs in their curriculums to develop skills related to CIP and QE. The traditional approach to teaching of the aforementioned competences through lectures in the classroom, in which students passively receive information from the instructor, and do not have the opportunity to develop firsthand experience on the application of manufacturing techniques, is not the best approach (Fang, Cook & Hauser 2009). The use of new training techniques, in which the teaching of elementary concepts is combined with the application, becomes a valuable resource that allows creating an appropriate atmosphere for learning.

2 Objective

This paper is the result of the collaboration between the professors of the Department of Mechanics and the Production Management of the University of Mondragon and the 4th year students of the Karelia University of Applied Sciences in Finland. Is the summary of the best work done by five student teams, to show how be able to train students of the Master in Innovation and Project Management in Mondragon University, in the acquisition of the knowledge and skills needed in CIP and QE.

3 Methodology

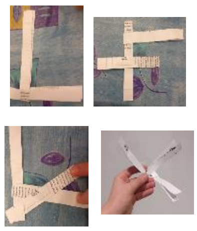
The methodology followed was based on the "Dynamic Learning" (DL) (Baird, Griffin 2006), which is a model based on learning by doing and reflecting on the process. DL establishes a framework that integrates the idea that in the present context, it is essential to perform training more quickly by integrating learning in the organization, and enabling it to occur in real time. To do this, the student's teams developed a case where they applied the improvement methodology based on the Six Sigma DMAIC (Pyzdek 2003), which we call DMAIC - 7P. This defines the arguments and routines necessary to use in each of the phases, as well as the way to integrate them in the case study, in order to acquire the knowledge in the field of QE (Eguren 2012). In the training process, after showing the theoretical concepts, the students applied these concepts in a specifically designed case, working in teams, and using provided templates developed to each phase of DMAIC-7P methodology. The developed case is the optimization of the flight process of a paper propeller; it is an adaptation of the helicopter developed by Box

(Box 1992). The researcher team, observed the work done by each team, draw conclusions of the evolution of the training process. To evaluate the acquired skills, each team gave an oral presentation, where they showed the results, and made a refection about the training process followed. After that, the teachers and research team gave feedback of the observations made and the evaluation of the work done.

4 Background

The case study is a Vortex company specialized in designing, manufacturing and selling of paper propeller for helicopters. Process of propeller manufacturing has four steps (Table 1). First, the paper is marked to a length of 297mm and a width of 20 mm. Second, the cut consists of defining the right width and cutting as straight line as possible. In folding phase, the three propels are folded from the middle thread and tied to each other from the folded end, and tightened next to each other. The characteristic that is measured is the diameter of the cutting pattern. This diameter is specified by the propeller engineering, with the following limits of minimum and maximum acceptance around the nominal diameter. The flight test consists of checking, for manufactured product, if it satisfies the fundamental requirement established by the customer, t flight ≥ Minimum (= 1,4 second), t flight ≥ Maximum (= 2,5 seconds).

Table 1: Process of propeller manufacturing

1. MARKING	2 CUTTING	3. FOLDING	4. FLIGHT TEST
			

The flight test is always done by releasing the propeller facing downwards from a height of 2 m. The fundamental characteristic of the product is that it is able to meet the requirement of the range of flight time, that no more than 2 ppm of propellers fly between 1,4 and 2,5 seconds, established by Finnanfly (customer). They are numerous complains by Finnanfly due to the products not fulfilling the optimal level of quality, so there should be quite many possibilities to improve. Faced with this situation, management chose to use the Six Sigma methodology to try to improve quality level of the product. For the application of the Six Sigma methodology, the phases are shown below were followed:

Phase1: Define

In this phase, the teams delimit the environment where the project is developed as well as the inputs and outputs involved in the process.

Table 2: Propeller high-level process map (SIPOC)

SUPPLIERS **S**	INPUTS **I**	PROCESS **P**	OUTPUTS **O**	CUSTOMER **C**
Paper material Tools (scissors, mearuring) Paper material	Raw material Tools Labor	**1. Mark** **2. Cut** **3. Assemble** **4. Test**	Helicopter propeller	Finnanfly

They must identify the Critical to Quality (CTQ) characteristics and define a metric for each of them, in order to know the starting value and the value to be achieved with the objectives. In order to visually identify and show the relationship of the components of the manufacturing process of the propeller, was performed SIPOC shown in Table 2. Team members decided that CTQ analyzed in this project was that of, fly time, as ~~is~~ characteristic of reference for the customer. The objective of this project was to improve the fly time of the propeller to obtain a defective level of less than 2 ppm. Taking into account the tests carried out and showed on Figure 1, we saw that, as a starting point, the defect rate was approximately 233.333 ppm and the capability index (Cpk) 0,27 which is really low. The impact to the business will definitely be positive, if we realise the proposed objective.

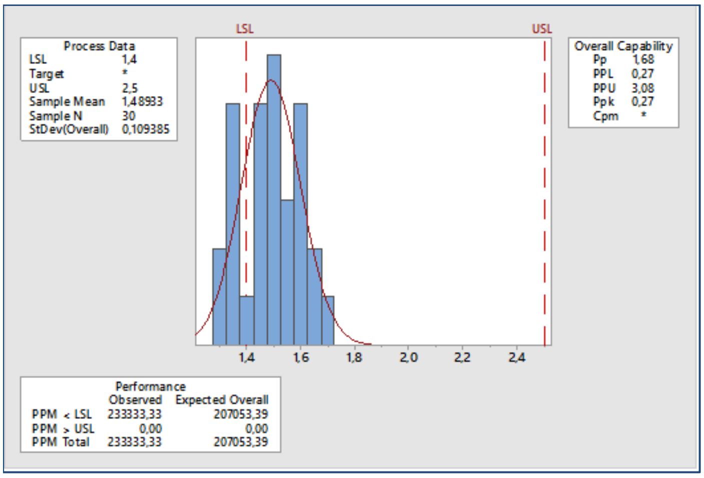


Figure 1: Fly time capability starting point

Phase 2: Measure

The objective of this phase is to give a description of the current situation of the process.

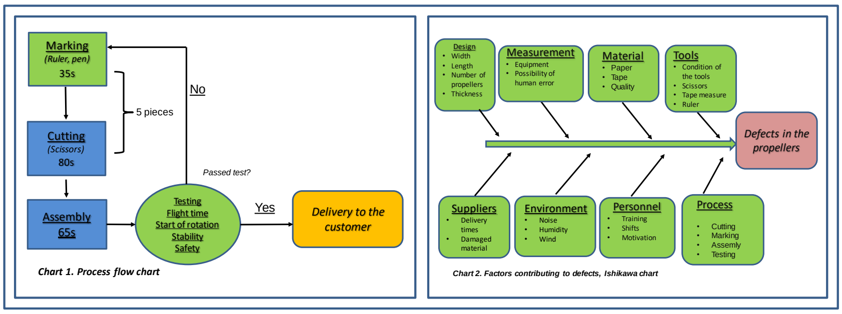


Figure 2: Propeller process flow chat and Ishikawa diagram

The team must develop the ability for data collection and establish stratification factors needed, identifying and facilitating their analysis, in order to understand the reasons of process variability. To support this phase the team used different tools such as, flow chart, Ishikawa diagram, repeatability and reproductivity (R&R). To understand the process, the team used the flow chart and Ishikawa diagram showed in the Figure 2. Figure 3 shows–the summary of the R&R study done; it shows that the measuring system variation was 14.9% of the tolerance. Taking into account the levels of acceptance of the measurement systems is in the range 10% to 30%, which is the marginal range, team considered the system as acceptable,-Even so, the system was improved through operators training.

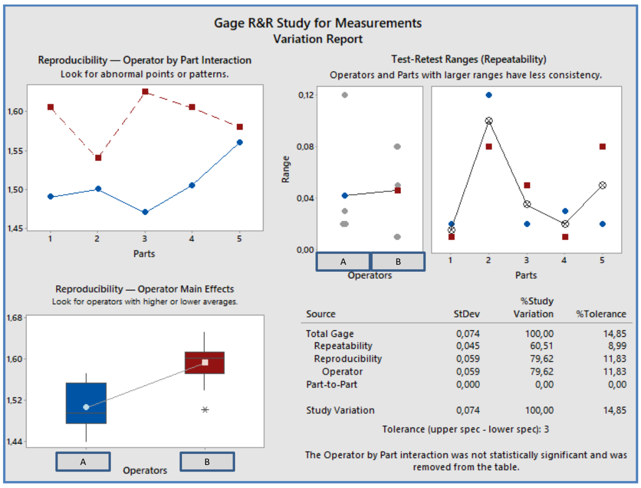


Figure 3: Summary of RR study

Phase 3: Analyse

In this phase, the team defined the hypotheses in order to improve the flight time of the propeller. The team identified different shapes and designs to improve the fly time, from which were chosen four different factors; 1. Length of the propeller blade, 2.Thickness, 3.Narrow shape and 4.Fixed blades of the propeller (with tape). To know the difference and effect of each factor, the team used the Design of Experiment (DOE). Taking into account an experimental design used, was made 16 different propellers and 2 replicates of each and tested them. Figure 4, shows of the results of the study and the mathematical model for fly time. The interaction of length and narrowness had the major effect on the flight time. As the propeller got lighter the flight time was increased. The weight loss was gained from the core of the product and thickness of the material. Longer propellers with narrow point almost stopped functioniong as the blades were heavier than the core. After testing different propeller designs, the most effective factors affecting flight time were narrowness and length of the propeller. The interaction between the length and narrowness, were the biggest factor on flight time and the narrowness and thickness was the factor, which had the biggest influence.

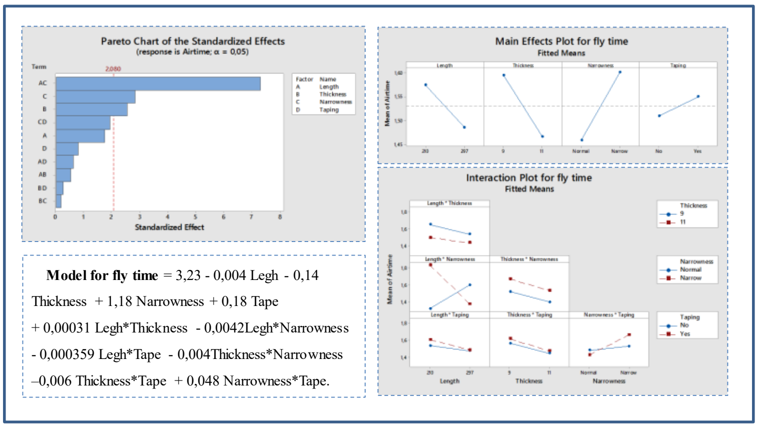
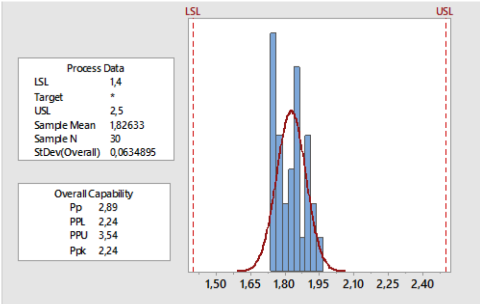


Figure 4: Results of DOE study for propeller

Phase 4: Improve

Taking into account the model identified in the DOE study, the optimal values of the analyzed characteristics of the propeller, to estimate the values of flight time, were shorter length of the propeller (230 mm), lower thickness of the material (9mm), lower mass due to the narrow core (1) of the propeller, fixed ends (1) of propeller wings. Taking into account the data in Table 3, the estimated valued for the flight time was 1.87 seconds. To validate the improvements made and the model defined, the team made 30 samples of our newly designed propeller. As also shown in Table 3, with the new propeller design, the defective level was less than 2 ppm (cpk 2,24) and flight time was over the desired 1,82, the value was quite similar of the estimate value .

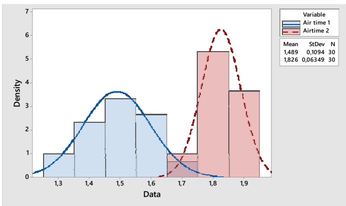
Table 3: Estimated valued for the flight time and new process capability study

Variable, from the flight time model of the propeller	Variable level	Improved propeller flight time process capability study
Length	**230**	
Thickness	**9**	
Narrowness	**1**	
Tape	**1**	
Length-Thickness	2.070	
Length-Narrowness	230	
Length-Tape	230	
Thickness*Narrowness	9	
Thickness*Tape	9	
Narrowness*Tape	1	
Estimated fly time	**1,87**	

Phase 5: Control

Once completed, the improvement plan, the effectiveness of the actions that have implemented were evaluated, and the results quantified, checking and evaluating, to assure that the improvement is sustained over time. Table 4, shows the improvement and difference between new and original design.

Table 4: Improvement and difference between new and original design

Flight time	Starting Point	Improved model	Improvement %	Graphic representation of the improvement obtained
Min	1,28	1,74	**23 %**	
Max	1,71	1,94	**36 %**	
Average	1,49	1,82	**13 %**	
Standard deviation	0,1	0,063	**37%**	
Cpk	0,27	2,24		
Ppm	233.333	0		

Phase 6: Standardize

The team should ensure that the consolidated improvements become a standard of work, managing to maintain the objectives achieved over time. To do that the new process for the manufacture of the propeller was defined. This consists of the following phases. First step: Measure the length and width of the propellers. Length = 230mm width = 20mm, and cut all three propellers. The thickness of the paper is 9µm. Second step: Once the propeller blades are cut, turn the ends of the blade against eachother and measure the narrowing part. Third step: Assembling the propeller, put the blades next to each other. The lower blade is between the other blade. Place the next blade, also between the other blade. Turn the loose end of the blade between the narrow end of the other blade. Fourth step: Tighten the blades hard, while still minding that the blades are not damaged. After tightening the blades, fix the ends of the blades together with tape, to increase the stability. propeller is ready to fly.

Phase 7: Reflection
As can be seen in Table 4, the use of the Six Sigma methodology has allowed improving the flight time. The objective of this phase is to show the results and reflect on what they learned both individually and as group.

5 Conclusions

The five teams student feedback was positive, that the application of simulation case, has been valid to understand the theory and acquiring skills, related to the techniques of CIP and QE , specifically in; standard methods of continuous improvement, statistical tools, computer software for data processing and standardization systems. Routines that were carried out were oriented towards, the use of a scientific approach, the statistical thought process and proof-based communication. Both, during the cause analysis and planning and implementing solutions phase which had a high impact on the root cause of the problems. The key element is defining the quantity of data, which is needed, and the way to obtain it. It is also necessary to develop the skill for planning an experimenting in order to obtain the maximum information with the minimum experimental effort, without forgetting the way to analyze this. The case also enhances team interaction and problem solving. This is a pilot case, that was only used in training the students in the Master in Innovation and Project Management in Mondragon University, and given its success it could be use in others degrees programs.

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