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OPTIMIZATION OF THE COMPRESSOR EFFICIENCY: A DOE APPROACH

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The refrigeration market is characterised by a constant research for high quality compressor. The need of a quick answer to the customer requirement and a low cost solution are therefore the most critical points. The development of a new product line can not always be seen as the right solution; on the contrary, the optimisation of the standard production, if possible, is a great opportunity.

In the optimisation of a mature product, the designer has to satisfy different necessities as higher performance, reliability, low costs, low noise and, above all low, impact on the product design. All these aspects are mutually linked. The great influence of the valve system on all the above mentioned items is already known and it is important to remind that a fluidodinamic optimisation of the compressor does not normally imply an increment in the product cost. The PV diagram analysis, the evaluation of the flow losses and the identification of the critical points are therefore the first step of our approach. The definition of the optimised configuration can be achieved by the use of the Design Of Experiment technique. This approach can be seen as the quicker, less expensive and most reliable way to achieve the performance gain. The DOE advantages are also related to the evaluation of the interaction among the various parameters, and therefore to the definition a of "robust design" configuration.

Introduction

The continuos improvement of performances and quality is the goal of every compressor designer. Well known terms like efficiency, sound power, reliability are so fundamental that they can not be forgotten, but the global competition has increased the importance of some other parameters: the constant awareness of the customer need and the necessity of quick answers are becoming now a key points.

When the company is facing a new market opportunity and the key point is a quick answer we have to choose a faster alternative way: the Design Of Experiment technique. This method can not be as the solution of all the problems; as all the mathematical approach is just a tool but a powerful one.

Naturally the final result is still in the designer's hands. We have to look for the key parameters and their correct identifications is mainly based on the "background

Fifteenth International Compressor Engineering Conference at
Purdue University, West Lafayette, IN, USA – July 25-28, 2000

507

knowledge" of the engineers. A clear definition of the marketing requirement is the first and probably one of the most important steps in the product development. After that a thorough understanding of the general situation an experimental and theoretical evaluation is needed. We have to evaluate the Pressure-Volume diagram, valve movement, pressure drop and acoustic transmission loss on the discharge and suction side. Each of this study can be seen as a milestone of our research. We have to evaluate every single compressor loss and try to define a Pareto chart. In other words we have to find the key parameters affecting the compressor performances, what the possible changes could be, and, at the same time, try to link them to the time in order to see what we are able to do, how much time it takes and what should be the impact on the production. The natural conclusion of this process is the choice of the parameters and therefore the definition of the D.O.E. One of the most important thing that characterised a compressor is the mutual link between different performances such as efficiency, noise level, reliability and low cost. The definition of the parameters can not be done without a look on the production process: the necessity of a component reduction is a mandatory problem. The definition of the optimised configuration must be found using, as much as possible, the standard parts.

The D.O.E approach

The propose of this paragraph is to present a quick overview on the D.O.E. technique and the reason for which this mathematical tool is used. A scientific approach and the use of statistic tools are now fundamental in order to take quick and more proper decisions. In the compressor engineering the great complexity of the phenomenon and the mutual link which characterise the different compressors performances, such as noise level and efficiency, can not be studied with the necessary precision in a very short time, hence the necessity of a reliable experimental technique which, starting from a theoretical background, can give a general vision of the subject, of the mutual dependencies of all the variables and the real key parameters.

The historical background of the experimental technique is based on the variation the of one single variable each time. The idea which characterises the new approach is the simultaneous experiment of all the variables. This approach is able to find the interaction between different variables; in the presence of this kind of interaction the contribution of different factors can not be add in a linear way. The statistic analysis of the results is made following the variance analysis (ANOVA). One of the most important point which characterises this approach is the possibility of distinguishing between the "background noise" that is present in our set of test and the real benefit given by every single variable. This aspect is perhaps the most important; defining a set of experiment based on the variation of a single parameter each time you are not able to identify clearly the background noise level and the mutual dependence.

Experimental results

The aim of our research can be summarised in the following points:

Fifteenth International Compressor Engineering Conference at
Purdue University, West Lafayette, IN, USA – July 25-28, 2000

508

1. The improvement of the product performances in terms of both cooling capacity and efficiency not just in a precise working condition but a general development of the compressor performances in the entire working range.
2. No increment on the compressor noise level.
3. The components' reduction.
4. The definition a of "robust design" configuration.

We realised a full factorial plan (3^2) characterised by the following variables:

1. Suction delimiter height.
2. Discharge delimiter height.
3. Discharge port diameter.

Table 1 : Experiment configuration

Variable	Step 1	Step 2
Delimiter discharge	Standard production	New proposal
Delimiter suction	Standard production	New proposal
Discharge port diameter	Standard production	New proposal

What here is called *New proposal* is a standard production element currently used on other compressors. The substitution of this particular is therefore a reduction in the components.

The tests were performed on a T2178GK compressor at the following LBP ASHRAE conditions:

1. Condensing temperature 54.4°C. Evaporating temperature –40°C.
2. Condensing temperature 54.4°C. Evaporating temperature –10°C.

For each configuration 2 different compressors had been tested. The underline terms in the table above represent the final compressor configuration.

As it can be seen from the PV diagram (Figures 1 and 2) the pressure rise in the discharge region implies a big flow restriction. This is the starting point of our evaluation and the base of the most important modification. Considering the improved solution the strange change in the pressure trend underline the rightness of our conclusions.

The influence of every single parameter has been evaluated and separated from the "background noise" (Figures 3, 4, 5 and 6). The final results are presented in the Figure 7. The great influence of a fluidodinamic optimisation on all the above mentioned items is evident and this goal has been achieved with a reduction in the product cost.

Fifteenth International Compressor Engineering Conference at
Purdue University, West Lafayette, IN, USA – July 25-28, 2000

509

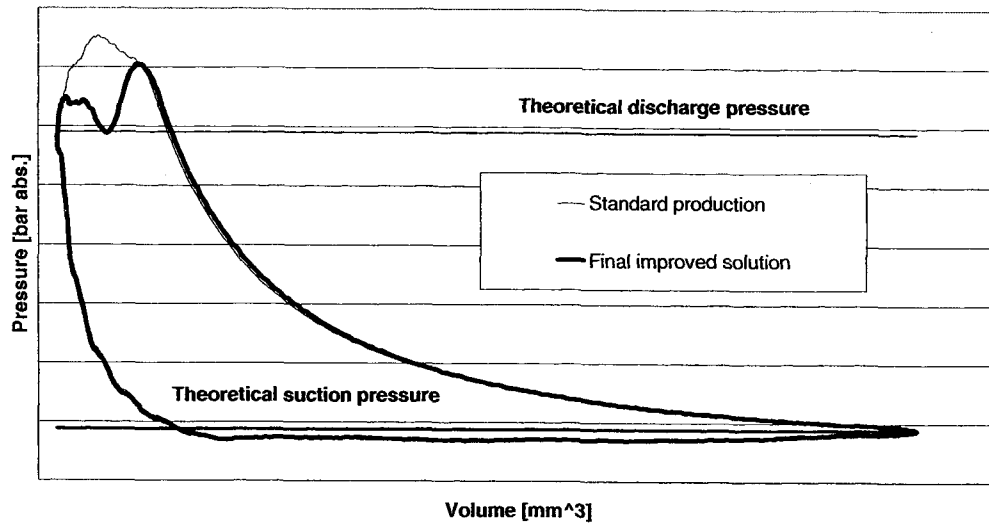**Pressure-Volume diagram**
Test conditions -10 / 54.4 °C

Figure 1: Pressure-Volume diagram Test conditions –10/54.4 °C.

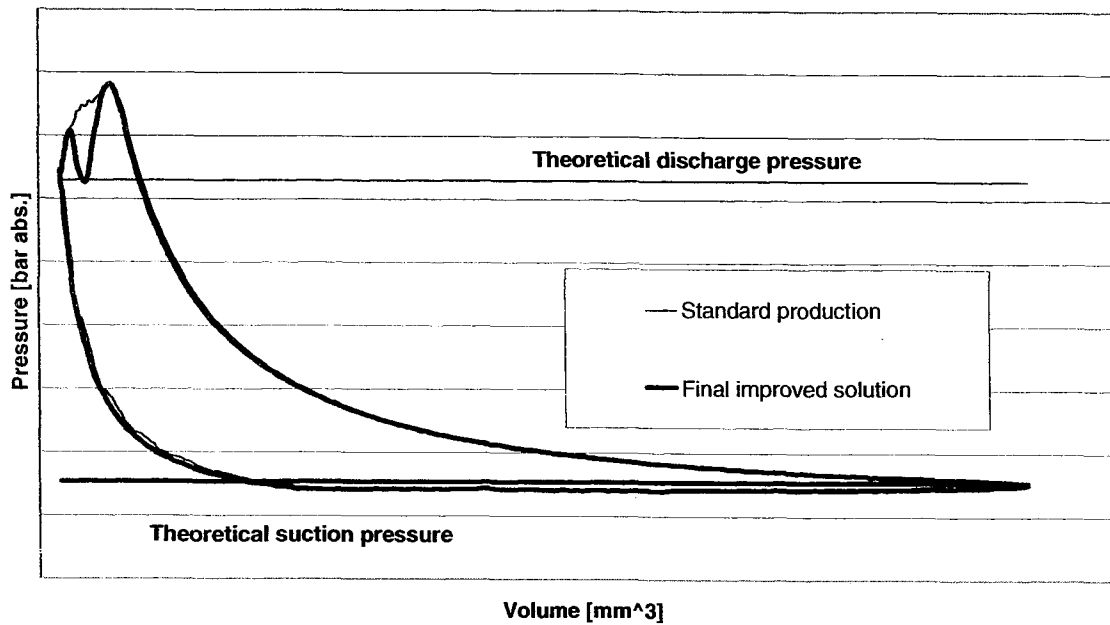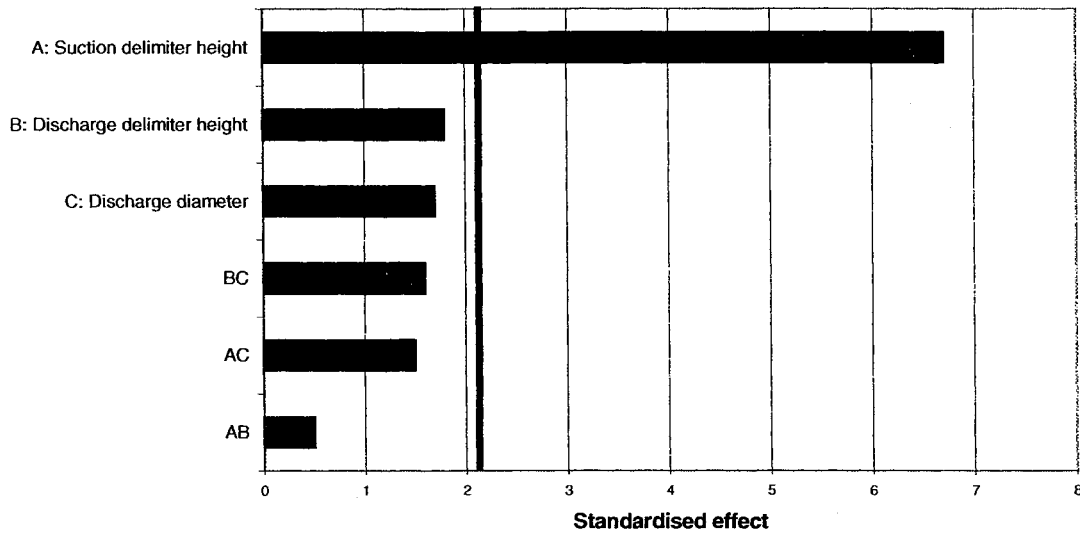**Pressure-Volume diagram**
Test conditions -23.33 / 54.4 °C

Figure 2: Pressure-Volume diagram. Test conditions –23.3/54.4 °C.

Fifteenth International Compressor Engineering Conference at
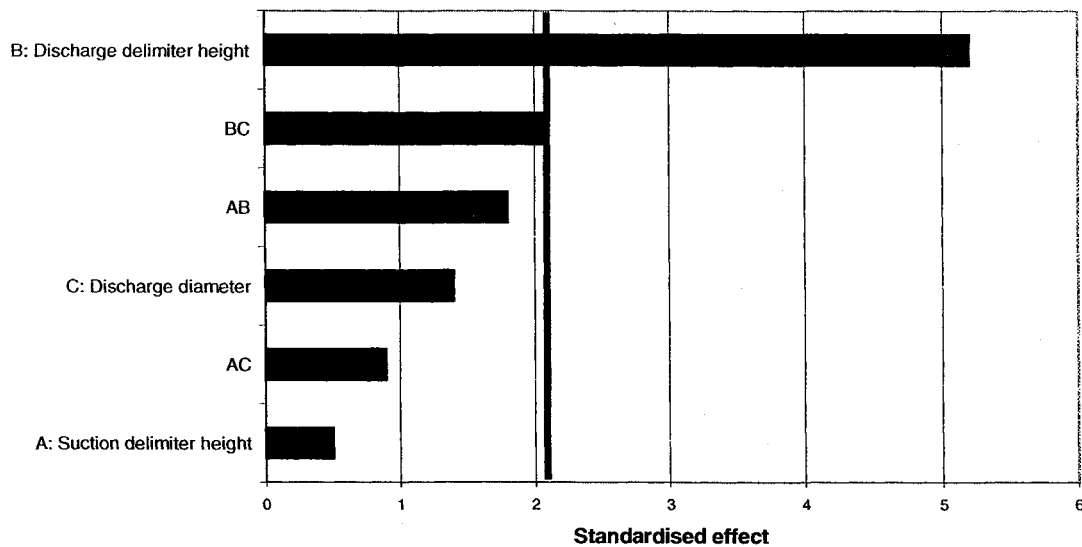Purdue University, West Lafayette, IN, USA – July 25-28, 2000

510

Standardised Pareto Chart for the Cooling Capacity at -40°C Evaporating Temperature

Figure 3: Influence of the test variables on the Cooling Capacity at an evaporating temperature of –40 °C .

The impact of the modification on the compressor performances are not just linked to the efficiency and cooling capacity but considering a general reduction of the overpressure we can easily understand that we are improving the compressor reliability in two different way: first of all as a consequence of the load reduction on the bearing but also thanking to the thermal profile improvement. The discharge temperature and therefore average compressor temperature are naturally lower than the previous ones and as a consequence the oil viscosity is higher hence an improvement of the reliability.

Fifteenth International Compressor Engineering Conference at
Purdue University, West Lafayette, IN, USA – July 25-28, 2000

511

**Standardised Pareto Chart for the Efficiency
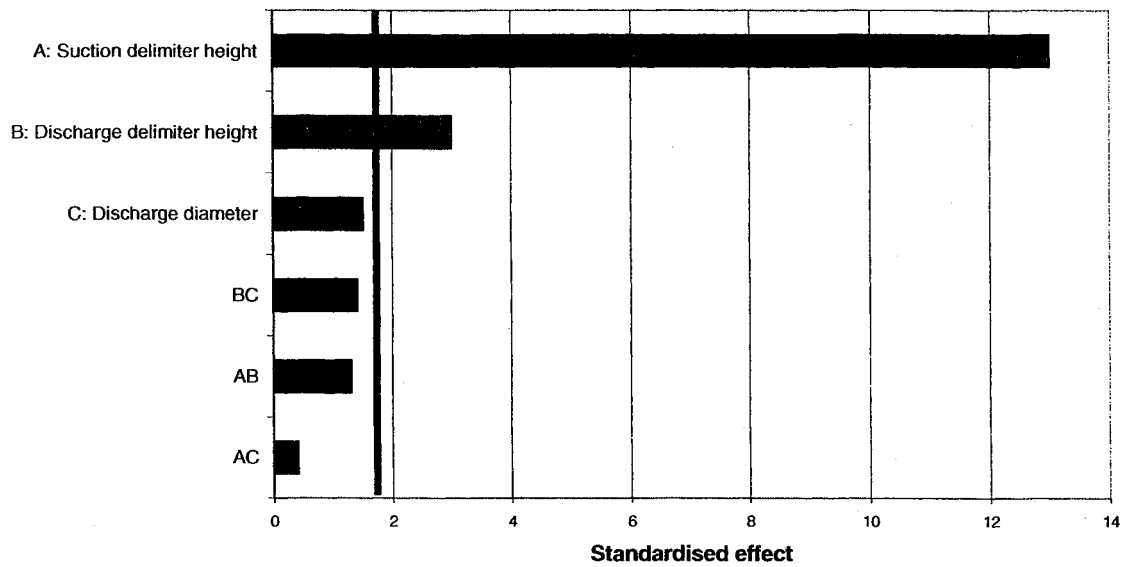at - 40°C Evaporating Temperature**

Standardised effect

**Figure 4: Influence of the test variables on the Efficiency
at an evaporating temperature of –40 °C .**

**Standardised Pareto Chart for the Cooling Capacity
at -10°C Evaporating Temperature**

Standardised effect
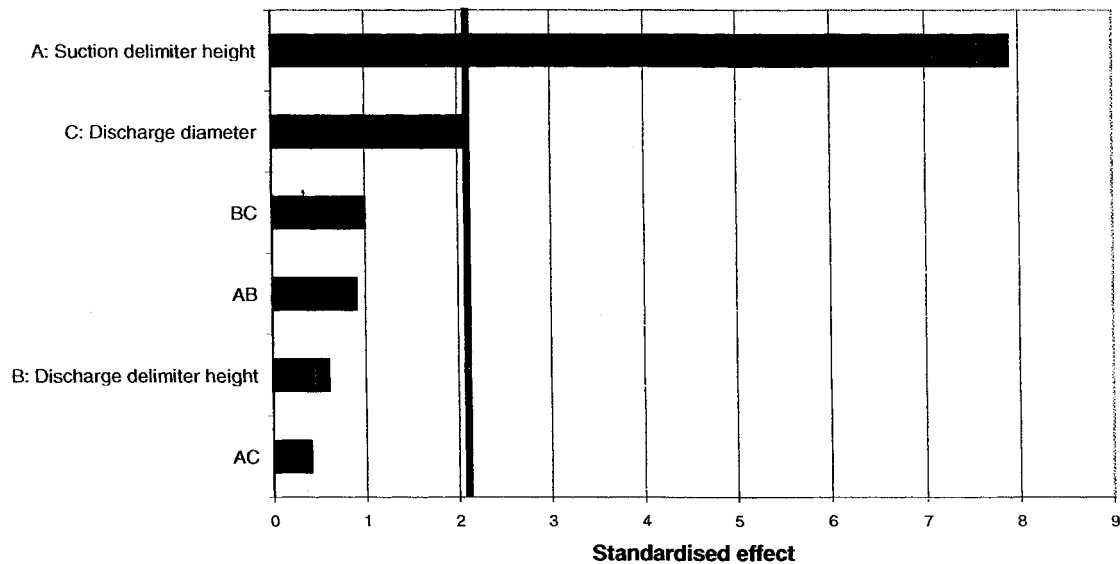
**Figure 5: Influence of the test variables on the compressor Cooling Capacity
at an evaporating temperature of –10 °C.**

Fifteenth International Compressor Engineering Conference at
Purdue University, West Lafayette, IN, USA – July 25-28, 2000

512

**Standardised Pareto Chart for the Efficiency
at - 10 °C Evaporating Temperature**

**Figure 6: Influence of the test variables on the Efficiency
at an evaporating temperature of –10 °C.**
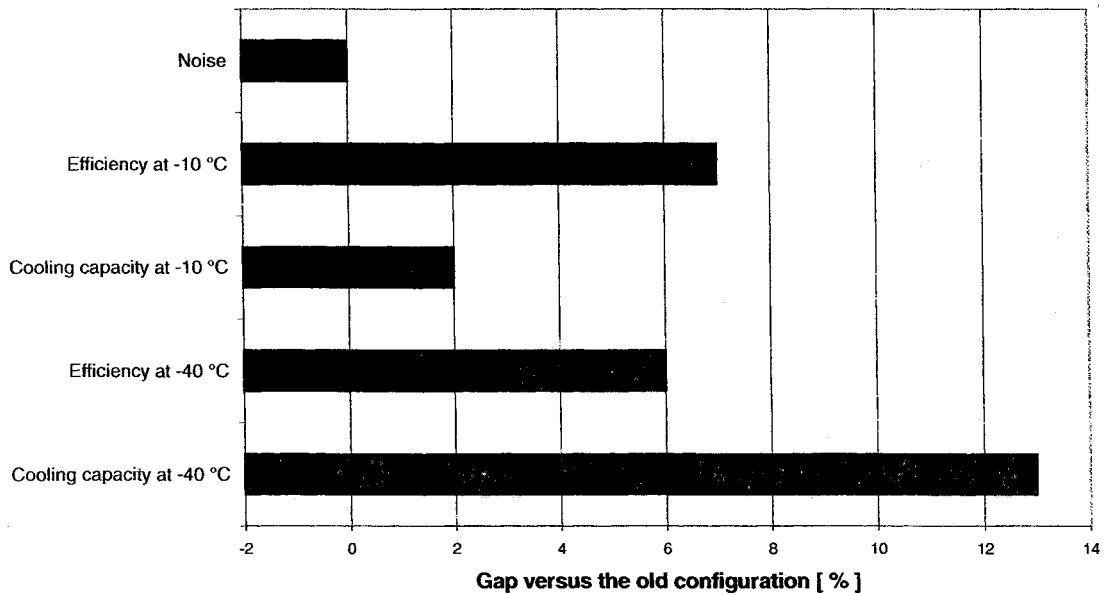
New configuration improvement

Figure 7: Summary of all the new configuration improvements.

Fifteenth International Compressor Engineering Conference at
Purdue University, West Lafayette, IN, USA – July 25-28, 2000

513

Conclusion

The research of energy efficient, less noisy, low cost and reliable compressor has always been a key trend in the refrigeration market. The new refrigerant development and the general changes in the market has increased the need of very quick answers to the customer requirements. We are certainly faced to a "mature" product, but at the same time an efficiency improvement can still be achieved and at the same time make an impact on the product costs by reducing the components used.

The optimisation of a new product can be obtained only by the identification of the real key parameters hence the necessity of an experimental and theoretical approach. The experimental evaluation of the theoretical gain can be done in several different way but the most reliable and cost effective is surely the Design Of Experiment approach.

The advantages of this method are connected with a reduction in the scheduled time and in the costs, due to the drastic reduction of experiments and at the same time you can make the separation of the real gain due to the new proposal improvements and the noise background level which characterised every set of test.

References

1. Polytechnic of Turin: Internal paper.
2. Embraco: internal paper.
3. Virgil L. Anderson, Robert A. Mclean: Design of experiments A realistic approach. Marcel Dekker, INC

Fifteenth International Compressor Engineering Conference at
Purdue University, West Lafayette, IN, USA – July 25-28, 2000

514