2002

Valve Stress Measurement In Small Commercial Compressor

M. Rosa Brusin
EMBRACO

R. Casamassima
EMBRACO

VALVE STRESS MEASUREMENT IN SMALL COMMERCIAL COMPRESSOR

Marco Rosa Brusin
Renzo Casamassima
Embraco Europe Srl
Via Buttigliera, 6 - 10020 Riva presso Chieri (To)
Italy

The need of a quick answer to the customer requirement is becoming a very critical point in the refrigeration market. In the development of a new product line or the optimisation of a mature product the valve system definition can be seen as one of key items. Due to the influence of the valve dynamic on the compressor performance the achievement of a high quality level without any cost increment is linked to a complete valve system redesign. This "design option" is related to a long and expensive life test procedure and the result in terms of "reliability confidence" is quite poor from a statistic point of view. Our goal is to reduce this time delay and to increase the degree of confidence. In order to achieve these targets the experimental measure of the valve stress can be seen as the right answer to both necessities.

INTRODUCTION

The research of new refrigerant, efficient from a thermodynamic point of view and not critical as far as the earth climate is concerned, has become important in the refrigeration market. The growing public concern has not brought only to the ban of the CFCs but also the phase-out of the of the HCFCs has been speed up. The impact of this general situation on the refrigeration market is evident. The global competition has increased the importance of "new" parameters: the constant awareness of the customer needs and the necessity of quick answers are becoming important.

In order to face the new refrigerant introduction or the new target in terms of noise, efficiency and cost reduction a complete review of all the fluid dynamic parts is becoming the key aspect of a compressor design. The valve system linked to the suction and discharge muffler can guarantee an upgrade in term of efficiency and at the same time should be addressed as one of the most important noise source. The valve system study is therefore a mandatory item not only in the development of a new compressor but also if a standard mechanism is adapted to a new working fluid. Trying to reach a better performance the valve safety margin can be influenced and therefore a deep understanding of the mechanical stress is fundamental. In the compressor engineering the great complexity of the phenomenon and their mutual link, which characterised for example the valve movement, can not be theoretically modelled with the necessary precision in a very short time, hence the necessity of a reliable experimental technique. Usually the first validation of a new mechanical part design is represented by a FEM analysis. For a suction or a discharge valve this kind of analysis are made more complex by the evaluation of the real pressure drop and the real force area which are acting on the valve system. Another important point mainly in relation to the suction valve stress analysis is represent by fact that the clamping region is generated by a gasket that is characterised by a proper deformation. This not linear belonging can generate some additional simulation problem. Basically the FEM analysis can be used as a comparative instrument in order to evaluate if the new design has a higher stress than the previous one. Considering all the above mentioned limitation a life test set can be seen as the natural conclusion of this standard procedure.

THE STRESS MEASURE APPROACH

The propose of this paragraph is to present the reason for which this experimental approach can be seen as a good alternative to the above mentioned approach. A scientific method is now fundamental to reduce the schedule time to market and, more important, to have a clear picture of the design risk linked to a certain modification. All our decision should be based on a statistical evaluation of data. Following the above mentioned "standard procedure" this analysis is usually impossible due to the limited number of compressor samples available for the life test procedure. Without a statistical evaluation of the safety margin the design risk is not completely under control.

The stress measurement technique can be seen as a way to reach a design confidence based on a statistical data evaluation (see figure 1).

The first step is the definition of the material fatigue limit. With a view to the robust design the designer should take into consideration all those aspects that can have an influence on this material characteristic like for example considering a suction or a discharge valve material a not perfect tumbling.

The second step is represented by the definition of the critical working condition. According

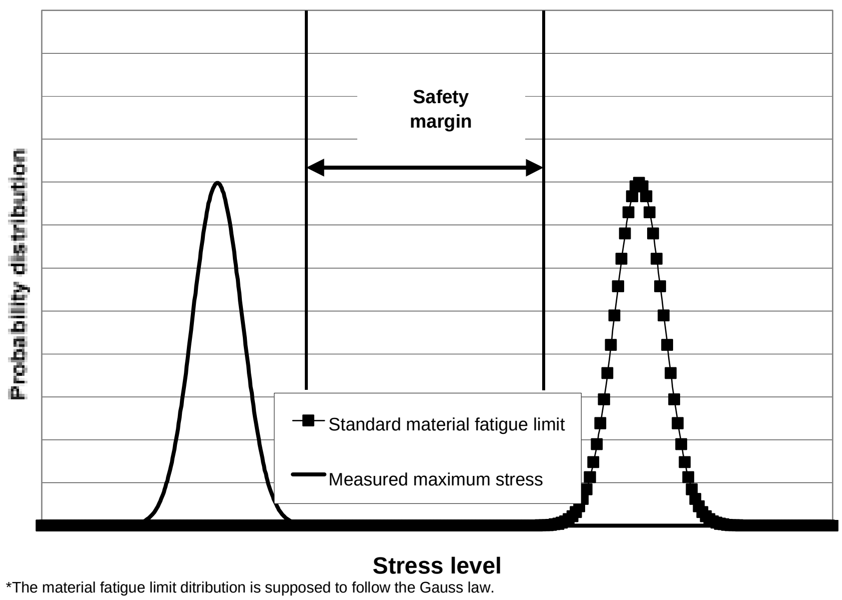

Figure 1: Stress safety margin

to all our experiments the worst conditions in terms of suction valve reliability can be summarised as follow:

1. Liquid return.
2. Balanced pressure start.
3. High mass flow.

The third step is represented by the analysis of the experimental data. The strain gage is in fact just measuring an average deformation. The designer task is to obtain from these data the real maximum stress that should be compared to the material fatigue limit.
Needless to say that the safety margin should take in consideration not only the distribution of the material fatigue limit properties and the valve stress dispersion but also the level of uncertainty linked to the stress measurement itself.

EXPERIMENTAL RESULTS

The aim of our study was the reliability validation of a new compressor version. This model has been modified in order to guarantee an improvement of the cooling capacity and efficiency in a Low Back Pressure application. This target has been reached without cost increment and with a very restrict time to market timetable.

As it was presented in the last Purdue conference the compressor development was realised according to a DEO technique. We performed a full factorial plan characterised by the following variables: suction delimiter height, discharge delimiter height, and discharge port diameter.
According to all our expectation the new version was characterised by a good improvement in terms of efficiency and cooling capacity (see figure 2 and 3) so we have just to prove the compressor reliability.
As far as the compressor reliability was concerned the only part that should be verified was the suction valve (see figure 4 and 5). Therefore a complete set of experiment was prepared try to have a better understanding of all the possible parameters that can have an influence in the valve stress.

We focused our attention in the following items:

- As was mentioned before with a view to the LBP operating condition we try to guarantee a dead volume reduction. Our target was the definition of the delimiter height not just with a view to the compressor performances but also considering the valve safety margin.
- We would like to check the influence of the flow and force area of the suction port on the valve dynamics and therefore we modified the shape of the ports (see figure 6).

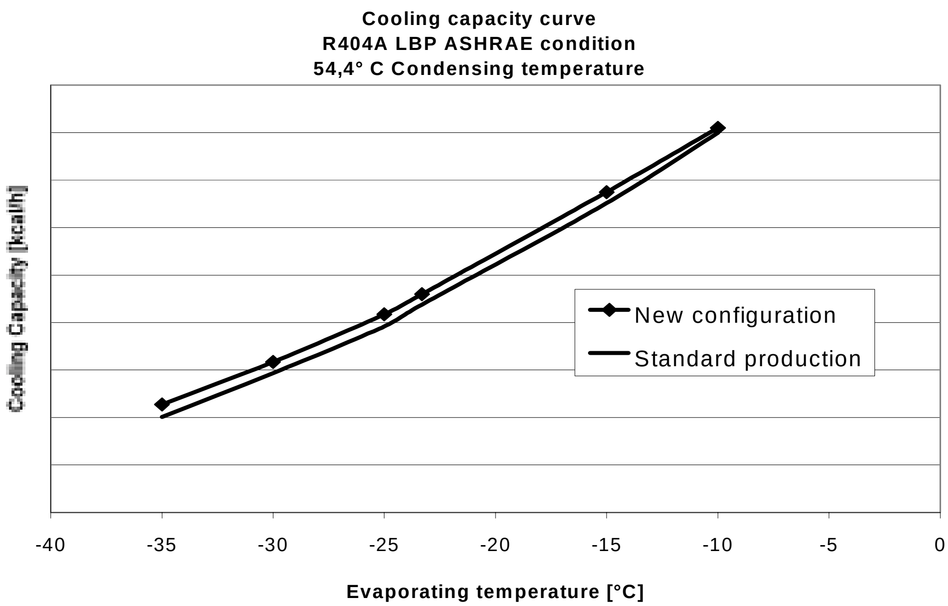

Figure 2: Cooling capacity comparison

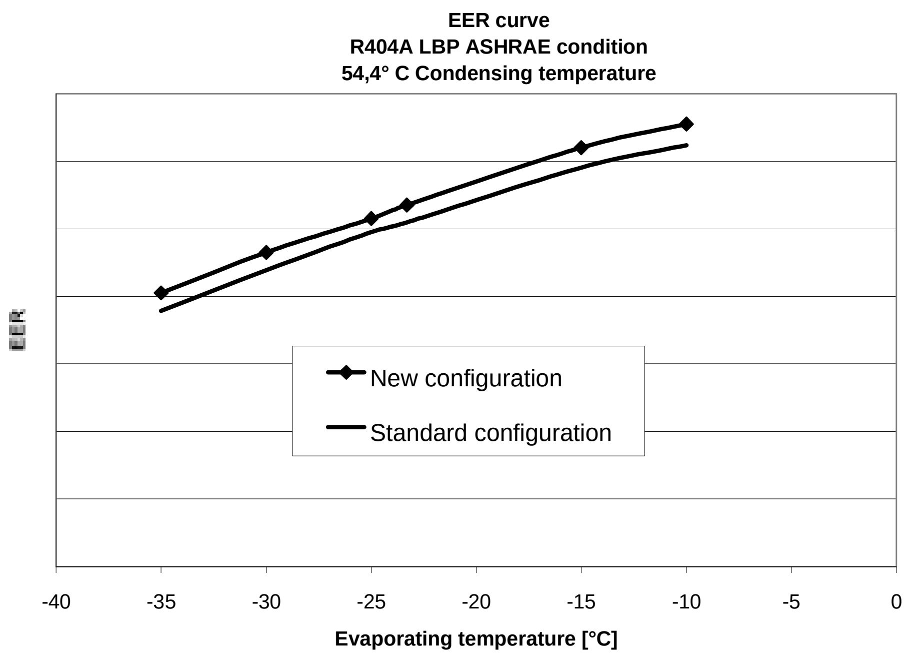

Figure 3: EER comparison

- As above mentioned the clamping region is not generated by a rigid body. The gasket is characterised by a elastic-plastic belongings. Our idea was to check the influence of this peculiarity by varying the clamping region shape by the introduction of an inclination in this boundary region.

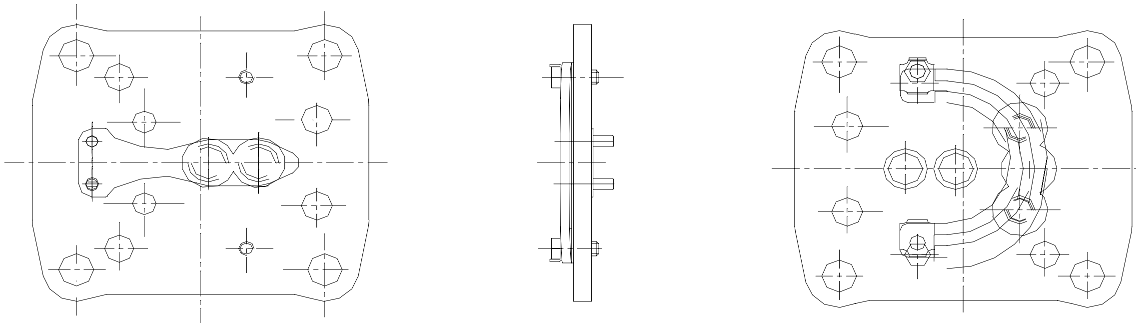

Figure 4: Valve plate configuration

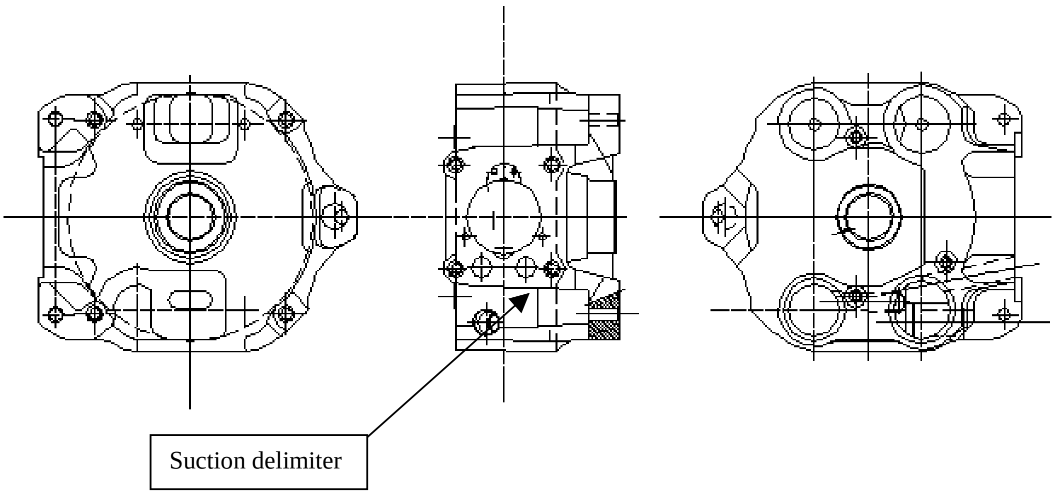

Figure 5: Crankcase configuration

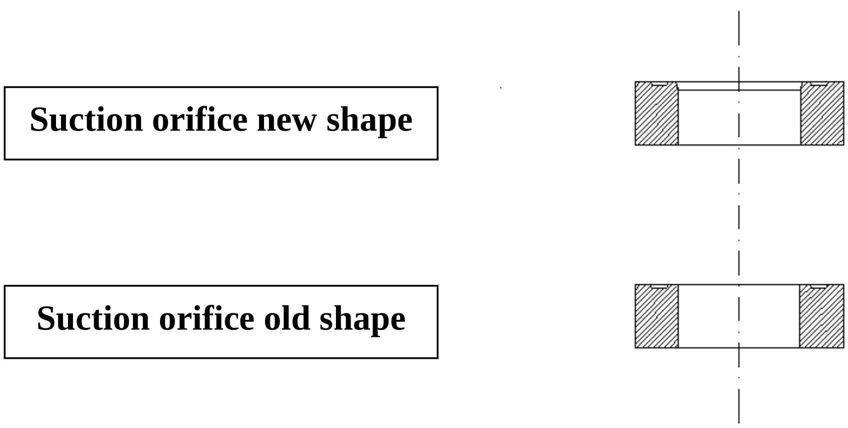

Figure 6: Suction port shape

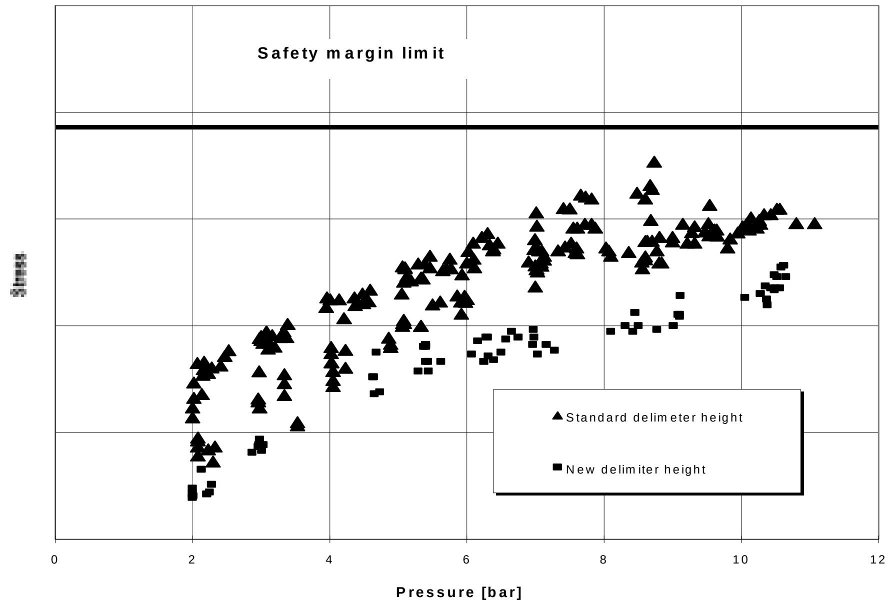

Figure 7: Maximum measured stress comparison
in a balanced pressure compressor start.

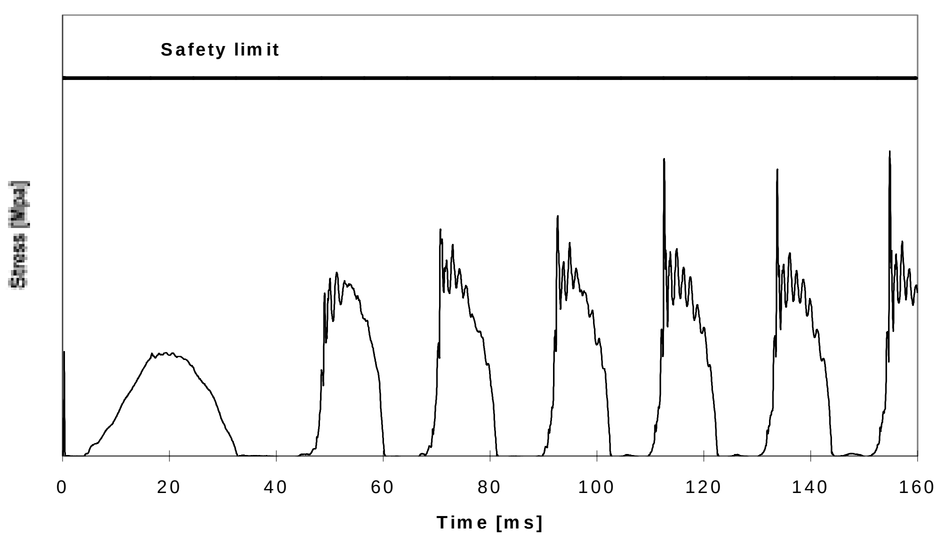

Figure 8: Standard compressor configuration: suction valve stress measure during a balanced pressure compressor start.

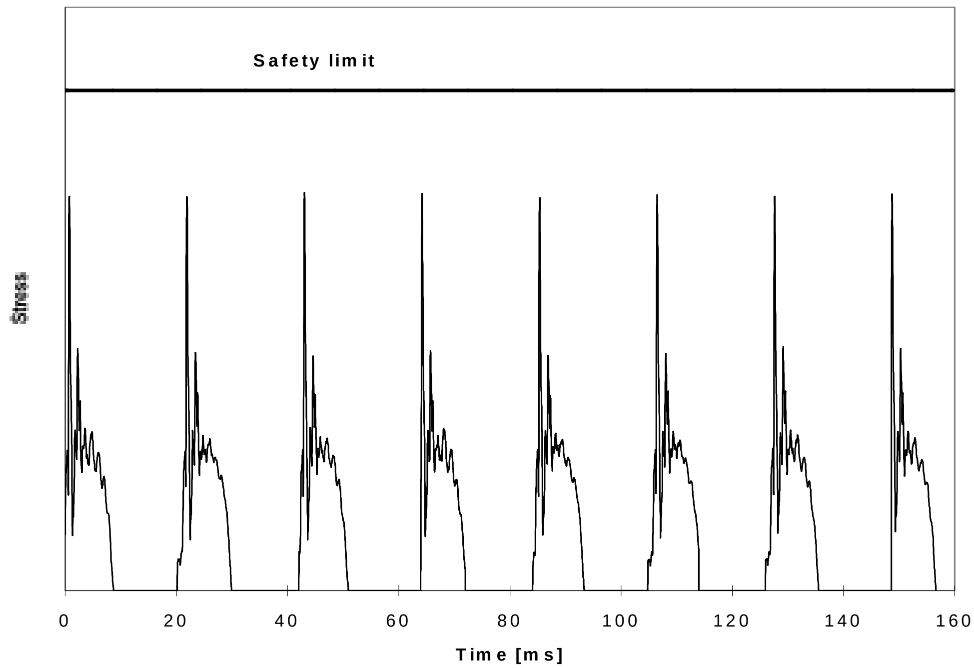

Figure 9: Standard compressor configuration: stress measure during a high mass flow operating condition.

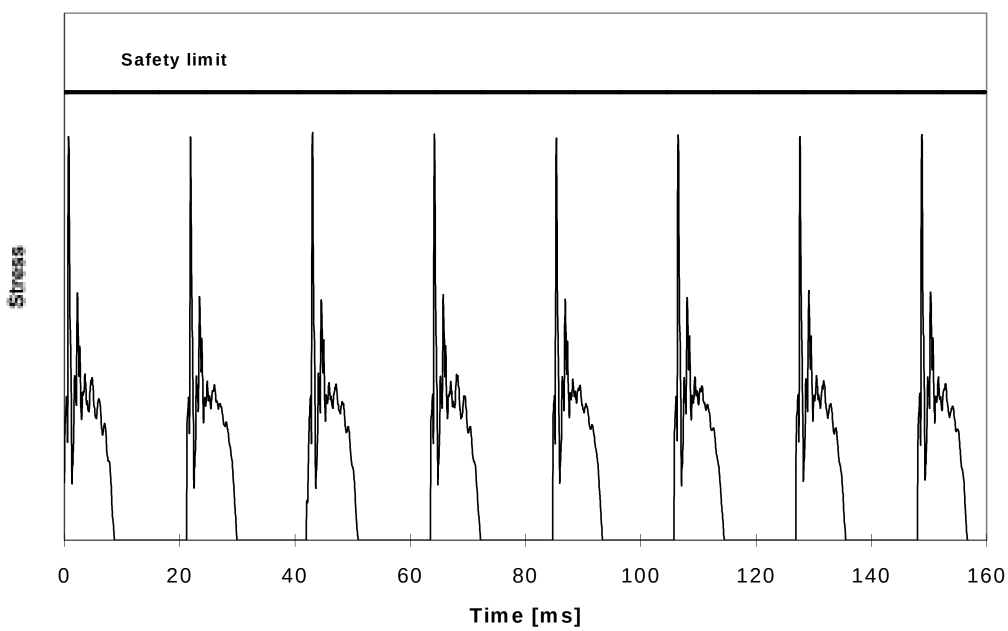

Figure 10: Standard compressor configuration: stress measure during a liquid return operating condition.

CONCLUSION

The markets ever increasing demands leads to a continuos new development in the compressor design. Starting from the domestic refrigeration area a new era has begun: the focus is to combine the compressor standard performance improvement with the customer's need of very quick answers.

The advantages of the stress measurement experimental technique are connected to a reduction in the scheduled time, due to the long period usually linked to a life test, and at the same time the statistical confidence that this approach guarantees can not be reached with a standard life test due to the limited number of samples that can be tested. A complete set of experiment has been carried out and as a final result we were able not only to define our design safety margin but also to analyse the influence of some important parameter on the valve stress.

The experimental results are summarised in the following table.

	Stress reduction
Delimiter height modification	5%
New port shape	7% (plus 5%)
New clamping region shape	10% (plus 12%)

Table 1: Stress measure results

REFERENCES

1. Embraco: internal paper
2. Optimisation of the compressor efficiency: a DOE approach - Purdue 2000
3. Polytechnic of Turin: Internal paper