FIELD PERFORMANCE TESTING TO IMPROVE COMPRESSOR RELIABILITY

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ABSTRACT

Performance testing is an important factor in equipment reliability. This paper discusses increasing the reliability of critical process compressors by field performance testing in addition to a manufacturer's shop performance test.

INTRODUCTION

When considering compressor reliability, most engineers tend to pay careful attention to the compressor's mechanical reliability and usually less thought is given to performance reliability. In fact, performance reliability is often merely taken for granted. The obvious reason for this is the fact that mechanical problems can completely shutdown a compressor, and possibly a plant, whereas partial load operation may be possible with a deficient machine. To be truly reliable, the compressor must run well mechanically, perform at 100 percent of its capacity and deliver the required head. Failure of a machine to perform as specified may result in many start-up and operational difficulties. Therefore, it is extremely important to verify the compressor performance prior to receiving the compressor, or as an alternate or in addition, to field performance test shortly after installation and prior to entering production.

SHOP PERFORMANCE TESTING

The advantage of the manufacturer's shop performance test is in the ability to correct performance deficiencies quickly and effectively without production loss at the site. The major drawback of a shop performance test, in comparison to a field performance test, is that it is rarely possible or practical to test with the design gas for reasons of cost, toxicity, flammability or lack of feasibility. In many instances process performance must be predicted from air test data or closed loop testing on alternate gases. When the gas properties differ between the design and test gases, corrections must be applied. Conflicts can arise between the manufacturer and the user due to the fact that the amount of corrections, and the exact procedure by which these correlations are best applied, are not always well defined.

Consideration should be given to incorporating both a shop performance test and a field performance test because of the advantages and possible drawbacks associated with a manufacturer's shop performance test. This is especially true for critical services in which the user has no previous experience with a certain type of compressor or particular compressor manufacturer, or where there has been a lengthy history of field performance problems associated with a similar type machine.

CODE TESTING

The basis for performance testing is the ASME Power Test Code PTC 10-1965 for Compressors and Exhausters. This code attempts to establish an inherent degree of accuracy in test results. Although the code establishes a basis for testing, the final test procedures and methods must be agreed upon by the manufacturer and the user. Very few tests are run in strict conformance to the code. Usually some deviation from the code is used to either expedite the test, hold down the cost of the test, or to accommodate the installation or facilities. Most of these shortcuts are not serious, but the user must understand fully the code requirements and where these deviations occur. During testing the operating conditions of the compressor must be maintained as steady as possible. Some small fluctuations are tolerable if within the test code limits. The code also establishes allowable deviations from compressor operating parameters that can exist during the test and still yield valid results.

FIELD PERFORMANCE TESTING

Field performance testing is incorporated when a shop performance test is not feasible or extra performance reliability is required, in which case the field test should be done in addition to the shop test. A field test requires planning be started in the design stages of the compressor installation so as to provide pressure and temperature point locations as well as a good meter run for flow measurements. The test code can be an excellent guide to planning the instrumentation during the plant design phase. One major problem with field testing is that production plants are not test stands; consequently a compromise must be made between practical and ideal code conditions. Complete field performance tests are expensive due to the energy requirements, lengthy time and the number of people involved.

The best time for a field performance test is when the compressor is new and as soon as the design gas is available. It is very important that testing be done before production plant operation is planned as the requirements for testing do not generally coincide with plant production. Proper planning is essential for conducting a meaningful test. It is desirable to obtain a complete performance map from the test which requires the ability to change the compressor load. Care must be taken to ensure that the compressor is not surged when setting conditions for the minimum flow test point. It is important to ensure that the gas entering the compressor does not contain any liquid. Liquid in the gas will adversely affect test results [1]. While testing, it is important that the process gas molecular weight remains constant and changes in gas mixtures due to knockout must be noted and taken into account. The correct knowledge of the process gas properties is essential if one is to conduct a meaningful test [2]. Gas samples must be taken during the testing to determine the volumetric analysis of the gas mixture. When the gas composition varies during the test, it may be necessary to obtain several gas samples to evaluate the composition of the gas mixtures. When the compressor handles a mixture of gases, the thermodynamic data is usually not available in the form of tables or charts and the performance calculation becomes more complicated.

FIELD PERFORMANCE PROBLEMS

The opening up of internal clearances [3], fouling of compressor blading, and improper correlation of shop performance test data will all result in the inability of the compressor to make its rated capacity at design head in the field. Fouling has the effect of reducing the pressure and capacity capabilities of the compressor to the extent that the characteristic curve actually shifts downward and to the left (similar to throttling), as indicated in Figure 1. For a process working against a constant pressure requirement, this curve shift makes it necessary to decrease the plant through-put to meet the pressure requirement, and eventually will necessitate a plant shutdown as pressure capabilities continue to decrease.

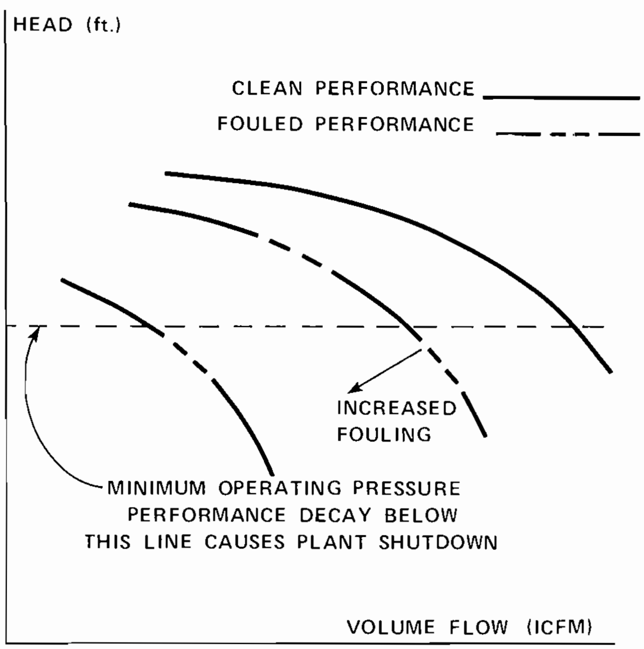

Figure 1. Effect of Fouling on Compressor Performance.

Another problem associated with fouling is the performance mismatch between stages. The characteristics of a multistage compressor are the summation of the characteristics of the individual stages. However, the composite characteristics of a multistage compressor are completely different from a single stage compressor. This is quite evident at off-design conditions since the overall performance map has a narrower operational envelope than any of the individual stages [4]. When the first stage does not operate at the design point, mismatch will occur in the second stage. The effect is cumulative with the mismatch increasing from the first to the last stage.

CASE HISTORY

An actual case history will be used to illutrate some of the items previously mentioned. The compressor handled a toxic gas and was a two-section machine with an intercooler. There had been a rather lengthy history of performance problems in similar type machines, so a series of tests were planned. The first phase of testing was a closed loop manufacturer's shop performance test using two different test gases. One met the code at an equivalent speed in terms of volume ratio requirements, while the other met the machine Mach number criteria. The second phase was performed in the field using process gas. Fortunately the field test was at least partially anticipated during the plant design and a meter run had been incorporated. Pressure and temperature taps were installed prior to testing. In the field, instrumentation was provided in the form of wattmeters to measure the horsepower of the motor driver.

The previous performance problems associated with comparable type compressors had been indicated by the machines not making their rated capacity. The process gas was known to cause fouling, but it was not certain whether fouling was creating the capacity problem or whether the compressors were simply not making the design head at rated capacity and, consequently, backing up on their performance curves to a reduced flow.

Anticipating that fouling would be at least part of the compressor performance problem, a decision was made to investigate a new impeller design as well as the original design. The new impeller incorporated an improved efficiency with a somewhat steeper performance curve. The benefit of a steep curve becomes evident when considering that as the compressor begins to foul and the pressure curve shifts downward, the inlet capacity must be reduced to meet the required pressure level. It is important from a production standpoint to minimize this capacity cutback; therefore, the steeper the head curve, the less the flow must be changed to effect the needed pressure increase as indicated in Figure 2.

The results of the field performance tests using both impeller designs, in a clean compressor, were slightly lower than the results of the shop performance tests, which indicated some error in the correction and correlation of the shop test performance. However, further field testing did indicate that incorporating the more efficient wheels lessened the effects of fouling.

CONCLUSION

The economic pressure being placed on compressor performance is constantly increasing due to increasing machine size, energy costs, and the value of the product. It is therefore expected that in the years to come the subject of performance testing will become an ever increasing factor in equipment reliability. It goes without saying that the best place to first locate a compressor deficiency problem is in the manufacturer's shop. However, consideration should be given to improve reliability by incorporating both a manufacturer's shop performance test and a field performance test for process compressors in the following application(s):

1. Critical service in which the user has no previous experience with a particular compressor manufacturer

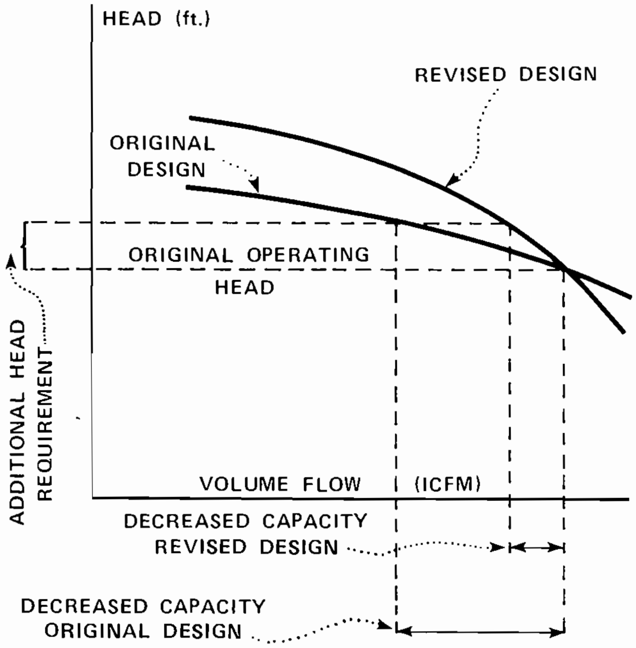

Figure 2. Performance Curve Slope Comparison of Revised Design and Original Design.

or no prior experience with a specific type of compressor.

2. When there has been a history of field performance problems on similar type compressors.
3. Compressors in critical service handling a design gas or gas mixture with poorly defined gas properties and that requires the shop test to be run on a substitute gas for which correlation errors might exist.
4. Compressors with anticipated performance changes after start-up due to the service, such as impeller fouling.

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