Optimization Of The Journal Bearing Press-Fit In Hvac Compressor: A Doe Approach

Pankaj Ahire
(PG Student, Department of Mechanical Engineering, D.Y Patil College of Engineering- Akurdi, Pune)

Prof. Pravin T. Nitnaware
(Professor, Department of Mechanical Engineering, D.Y Patil College of Engineering- Akurdi, Pune)

Abstract

The HVAC compressor which is hermetically sealed uses journal bearings to provide support to the shaft & other rotating parts mounted on it. Journal bearing used in this case is press fitted on the hub and become integral part of the hub. If the fit in the bearing & hub relaxes the bearing will start spinning freely, may walk-in or walk-out of the hub. This leads to efficiency drop in compressor & ultimately leads to compressor failure. So the purpose of this paper is to do an optimal design by using "Design of Experiments" of the Journal bearing press fit in hub. We have used design of experiments to find the optimum & important parameters with help of the Full Factorial Design with the table of orthogonal arrays from various available variables. By using the main factors & interactions, the experiments for optimal design were worked.

Key words: Full Factorial Design, Compressor, Journal Bearing

1: Introduction

HVAC (heating, ventilation, and air conditioning) refers to technology of indoor and automotive environmental comfort. Air conditioning and refrigeration are provided through the removal of heat. The refrigeration cycle uses four essential elements to create a cooling effect. The compressor pumps the refrigerant gas up to a high pressure and temperature. From there it enters a heat exchanger (sometimes called a "condensing coil" or condenser) where it loses energy (heat) to the outside. In the process the refrigerant condenses into a liquid. The liquid refrigerant is returned indoors to another heat exchanger ("evaporating coil" or evaporator). A metering device allows the liquid to flow in at a low pressure at the proper rate. As the liquid refrigerant evaporates it absorbs energy (heat) from the inside air, returns to the compressor, and repeats the cycle.

The compressor is the only moving component in any Refrigeration/ Air conditioning system and anything going wrong anywhere in the system will finally reflect on the compressor performance. It must be understood that related components and system malfunction initiate the compressor failure.

It is therefore essential to go to the root cause if the compressor fails, rather than simply replacing it with a new compressor, as the replaced compressor will also fail, if the root cause remains unattended. In such scenario, to understand the compressor failure in more detail the replication of field failures is carried out in laboratories and the compressor design are targeted to take care of such incidences. To manage the laboratory test in an optimized way we have used the Design of experiments approach to minimize the number of tests and get the right results and the find the parameters that are most affecting for failure of any component.

In this paper we are going to concentrate our study only towards one of the non-conformances and that is of Journal bearing. The common failures in case of journal bearings are bearing spun, walk-in/walk-out or combination of both in the hub where it is press fitted, which leads to compressor failure. Probable reasons of nonconformance could be due to, Failure of the press fits in bearing, Deflection of hub at end because of drive load leads to loosening of interference fit, Due to change in temperature leads to uneven expansion of Hub and Journal bearing.

Limitations to improve existing press fit are, It is very easy to say that if the bearings spun or walk-in/ walk-out increase the interference fits between the bearing & hub, however it is practically not feasible since it raises other issues like, leads to increase press force requires process change, difficult to control inner diameter of journal bearing, Higher stress of hub because of higher fit may lead to failure of hub while pressing. Increased interference may lead to higher contact stresses and hence involving risk of cracking cast iron hub.

2. Design of Experiments (DOE) Approach:

The purpose of this paragraph is to present a quick overview on the Design of Experiments (DOE) technique and the reason for which this mathematical tool is used. DOE as a methodology is used for systematically applying statistics to experimentation. It consists of a series of tests in which purposeful changes are made to the input variables (factors) of a product or process so that one may observe and identify the reasons for these changes in the output response. DOE provides a quick and cost-effective method to understand and optimize products and processes.

2.1 Full Factorial Design Approach

In this paper we have elaborated the application of the methodology of Full Factorial Design (A Design of experiments approach). Factorial design is an important method to determine the effects of multiple variables on a response. Factorial design is a quantitative approach in order to determine how much influence the factors have in an experiment on the outcome. Additionally, it is used to find both main effects and interaction effects.

Deal with a 2^n Factorial Design: Suppose there are two variables A and B and each have two levels a_1, a_2 and b_1, b_2 and need to measure combination effects of A and B (a_1b_1, a_1b_2, a_2b_1, a_2b_2). Since there are two factors, each of which has two levels, it is said as a 2 x 2 or a 2^2 factorial design. Typically, when performing factorial design, there will be two levels, and *n* different factors. Thus, the general form of factorial design is 2^n.

In order to find the main effect of A, following equation is used:

$$A = (a_2b_1 - a_1b_1) + (a_2b_2 - a_1b_2)$$

Similarly, the main effect of B is given by:

$$B = (b_2a_1 - b_1a_1) + (b_2a_2 - b_1a_2)$$

By the traditional experimentation, each experiment would have to be isolated separately to fully find the effect on B. This would have resulted in 8 different experiments being performed. Note that only four experiments were required in factorial designs to solve for the eight values in A and B. This shows how factorial design is a timesaver.

3. Experimentation:

To initiate the experimentation of the Journal bearing & Hub interaction, there were many parameters such as bearing outside diameter, hub internal diameter, surface finish, press force required to press bearing into hub, extreme temperatures which the bearing & hub has to undergo, load variations on the bearing & hub, amount of lubrication. These parameters were been identified as cause for non-conformance. From initial study, experience and bench test experimentation feasibility we concluded on taking up 3 parameters for the DOE study.

The aim of our study can be summarized as follows,

1. To improve the journal bearing retention capability into hub, which will reduce the compressor failure
2. Robust design parameters for journal bearing & hub
3. Less field returns thus a happy & satisfied customer

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

1. Hub Surface Finish (Max & Min)
2. Hub Taper (Max & Min)
3. Temperature (High & Low)

Table 1 : Experiment configuration

Surface Finish	Taper	Temperature
+	+	+
-	+	+
+	-	+
-	-	+
+	+	-
-	+	-
+	-	-
-	-	-

For the first 2 variables namely hub surface finish & hub taper the components were manufactured with the existing min & max as per the current prints dimensions. Third variable values of temperature were decided based on the initial temperature mapping of the compressor across the compressor operating envelope.

The above configuration was tested on the specially designed bench test setup so as to get the real time data for further analysis. We did not wanted any other factor from the compressor to effect to our DOE study during running on the compressor test stands.

5 components each were tested for each configuration to get the good statistical data, based on the test results, following graph is generated. The factors namely Surface finish, taper, temperature respectively marked as A, B & C.

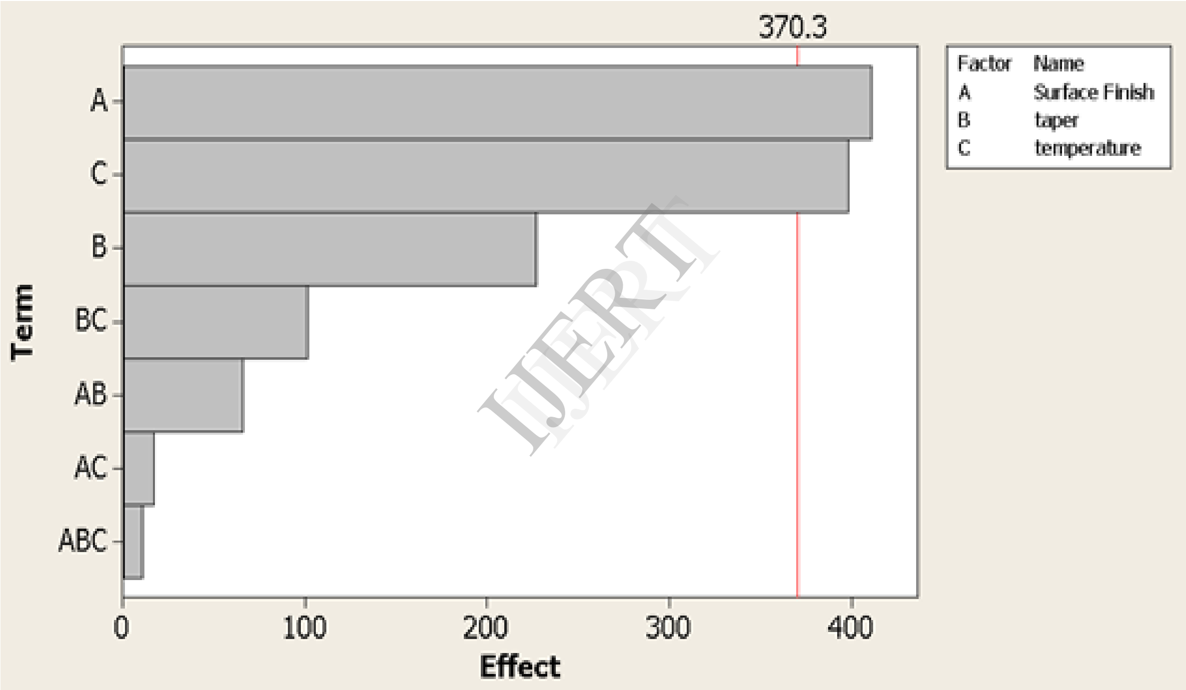

Figure 1: Pareto Chart of the Effects (Response is Retention Force)

From the Minitab analysis and Pareto graph following factors that should be focused on are,

1) Red line is threshold of significant versus not significant
2) Only shows surface finish and temperature to be significant

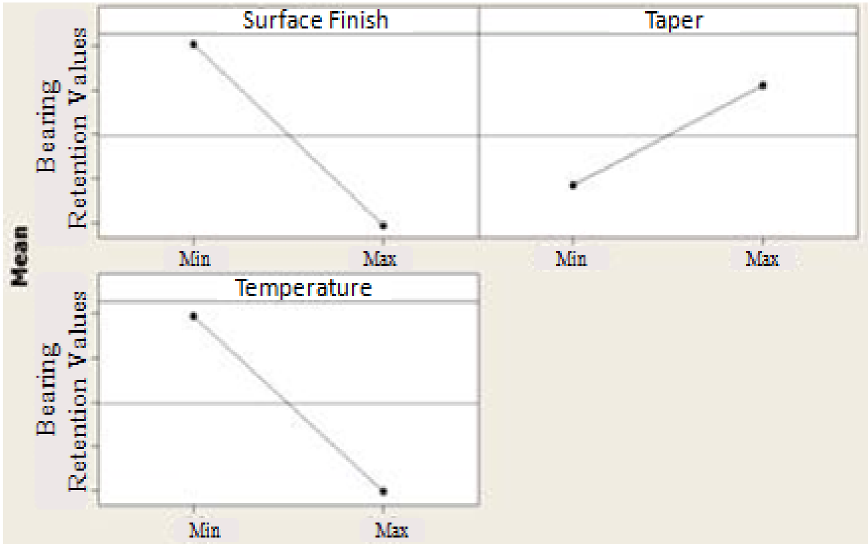

Figure 2: Main Effects Plot For Bearing Retention Values

From the above graph of Main effects it shows that Bearing Retention values increase when,

1) Surface finish is Minimum
2) Hub Taper is Maximum
3) Temperature is Minimum

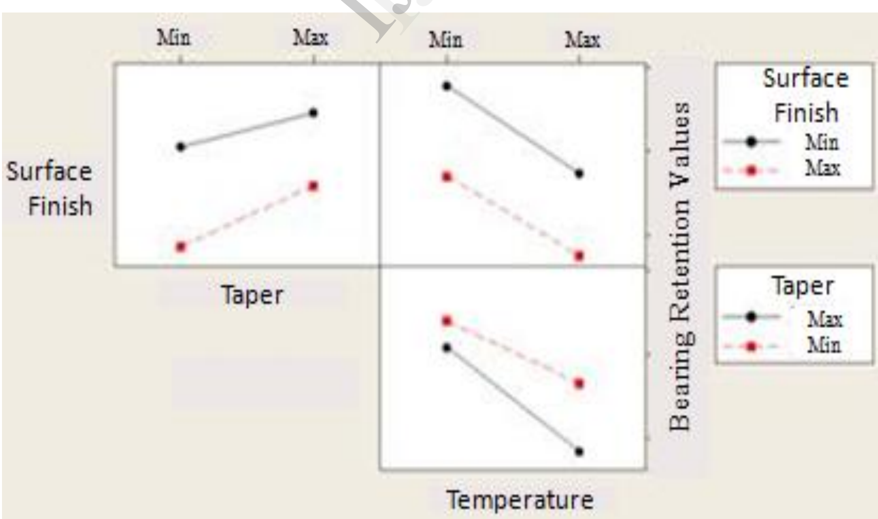

Figure 3: Interaction Plot For Bearing Retention Values

From the above graph of interaction of variables, it shows that surface finish & temperature has major impact on retention values as compared to taper.

4. Conclusion:

The optimization of the parameters was obtained the identification of the key parameters and so the necessity of an experimental and theoretical approach was taken up. The experimental evaluation of the theoretical understanding could have been done in several different ways but the most reliable and cost effective was 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 we were able to identify the important parameters.

Based on this experiment, the following conclusions may be drawn for improving the bearing retention force ultimately resulting into reduction of bearing non-conformance.

1) The surface roughness has major impact on the bearing retention force, minimum the surface finish i.e rougher surface has good retention capability.
2) Temperature is the variable having second largest impact on retention capability i.e lower the temperature good is the retention capability.

5. References:

1. M. Rosa Brusin, R. Casamassima, G. Lampugnani, "Optimization of Compressor Efficiency: A DOE Approach", International Compressor Engineering Conference, 2000.
2. C.Y. Ahn, J.W.Kim, Y.J. Huh, M.S. Lim, "High Efficiency Valve Design By Robust Design Of Experiments", International Compressor Engineering Conference, 1998.
3. Ranjit K. Roy "Design Of Experiments Using The Taguchi Approach".

.