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Calculation of Bushing\Connecting Rod Press-Fit Working Envelope

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A bushing bearing was required between the aluminum connecting rod and the wrist pin to reduce wrist pin bearing wear in a severe application. The bushing could not be machined after assembly and precise control of bearing clearance was achieved by re-sizing (using a mandrel) after assembly.

Re-sizing was a critical operation. Too much re-sizing would loosen the bushing press-fit while too little re-sizing would result in undesirable bearing clearance. A non-linear finite element analysis was performed to provide guidelines and recommendations on press-fit and re-sizing dimensions.

INTRODUCTION

The connecting rod is one of the major components in a semi-hermetic and hermetic compressor (Fig. 1). Basically, the connecting rod serves as the mechanical link between the piston and the crankshaft. A modern high-speed compressor uses cast aluminum (instead of forged steel) connecting rod because of its lighter weight.

Designed to operate at high operating temperature, engineers added a press-fit bushing between the aluminum connecting rod and the wrist pin. This bushing needed a slight re-sizing to make it work perfectly with the wrist pin.

It was found out that this 'slight' bushing re-sizing by a mandrel is a very delicate process. Too much re-sizing will loosen the bushing press-fit while too little re-sizing will result in undesirable bearing clearance and lock the wrist pin. A non-linear finite element analysis was performed to evaluate and understand this re-sizing design issue.

FINITE ELEMENT MODEL

A 2-D elastic-plastic plane stress model was constructed (Fig. 2) for this analysis. 2-D plane stress elements were used for the two press fit parts (the steel bushing and the aluminum rod), gap elements were used to simulate the gap between them.

Holes and other geometrical non-symmetries in the connecting rod were ignored to simplify the problem. The steel bushing was assumed elastic. A multi-linear stress-strain curve was included for the aluminum housing. An isotropic strain-hardening option was used in this analysis.

All gap element nodes were rotated in the global cylindrical coordinate system. Gap stiffness was set to 0.1E10.

DISCUSSION

Certain types of bearings are very difficult to machine to size and obtain the close tolerances required for a wrist pin in a reciprocating compressor. It has been found that
pressing the bushing into the connecting rod and then inserting a re-sizing mandrel can result in the type of clearances and tolerances required for this critical bearing system. However, the re-sizing operation can present problems in manufacturing.

The initial press fit generates a negative hoop stress in the steel bushing and a positive hoop stress in the aluminum housing. In the aluminum housing, maximum hoop stress occurs at the I.D. while minimum hoop stress is at the O.D. When the oversized mandrel is inserted into the bushing, the I.D. deforms plastically. The maximum hoop stress location gradually shifts from the I.D. towards the O.D. When the mandrel is withdrawn, the aluminum housing shrinks back partially (due to elastic recovery from the plastic deformation), and the net difference results in a permanent bushing bearing I.D. increase.

If the initial press fit is not correct, re-sizing may result in no bearing diameter change after the re-sizing mandrel is withdrawn, or the press fit may be lost after the mandrel is withdrawn and the bushing will work out of the connecting rod.

Fig. 3 shows the process of pressing the bearing into the connecting rod bore and re-sizing with a mandrel. The X-axis represents the amount of interference between the re-sizing mandrel and the bushing I.D. after the bushing has been inserted into the connecting rod bore. The Y-axis represents the amount of permanent increase in bushing I.D. after the re-sizing mandrel has been withdrawn. Fig. 3 shows that if one were to begin with a 0.001 inch interference fit, a resizing mandrel of 1.1 mils oversize could be inserted into the bushing and withdrawn with no permanent increase in bushing I.D. This is because no yielding has occurred in the aluminum connecting rod to this point. If a 2 mils oversize mandrel is inserted in the 0.001 inch interference fit, approximately 0.25 mils of permanent increase in bushing diameter will be noted. Insertion of any mandrel greater than about 2.6 mils oversize will result in so much yielding of the aluminum that all the initial press-fit loading will be lost, and the bushing will be loose in the connecting rod bore when the mandrel is withdrawn.

An examination of Fig. 3 indicates that larger interference fits between bushing and connecting rod are beneficial since they allow a greater range of re-sizing mandrels to be used and will result in the capability of re-sizing the bushing over a much larger range.

Fig. 4 shows the resulting contact forces from various interference fits, after re-sizing mandrels have been inserted and then withdrawn. If the contact force is multiplied by 0.15 (approximate coefficient of friction), the bushing press in or press out force can be approximated.

**CONCLUSION AND RECOMMENDATION**

It was recommended that the bushing bearing I.D. and its roundness be controlled as closely as possible to avoid major re-sizing. When re-sizing is required, it was concluded from the finite element analysis that with a press fit of 2-3 mils (diametral), and re-sizing mandrels of 1.5-2.5 mils oversize (diametral over I.D. of the bearing), a permanent bearing I.D. increase of 0.2-0.8 mils could be achieved without losing the press fit contact pressure (see Fig. 3). This provided an acceptable control of the manufacturing variables for this application.

**REFERENCES**

FIG. 1

ALUMINUM HOUSING (CONNECTING ROD)

STEEL BUSHING

GAP ELEMENT

Press-fit (1.5 mil/rd) DU Bushing/Connecting rod

FIG. 2