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REPORT RN-DR-0029

BALL BEARING THRUST REVERSAL
FEASIBILITY TEST

MASTER

SEPTEMBER 1964

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ROCKET ENGINE OPERATIONS - NUCLEAR

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ABSTRACT

Presented are the results of zero load and reversing thrust bearing tests in an electric motor driven NERVA Mark III turbopump power transmission. These tests were conducted to establish the feasibility of carrying rotor thrust in either direction without concern of zero load crossover.

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TABLE OF CONTENTS

	<u>Page</u>
I. Introduction	1
II. Summary	1
III. Conclusions and Recommendations	1
IV. Discussion	

LIST OF ILLUSTRATIONS

	<u>Figure</u>
Plumbing schematic	1
Tester set-up	2
Conditions of first eleven accelerations	3
Condition of 39 accelerations	4
Failed roller bearing	5
Inner race of failed roller bearing	6
Armalon cage of failed roller bearing	7
Roller bearing from loader end	8
Inner race of roller bearing from loader end	9
Cage of roller bearing from loader end	10
Thrust bearing	11
Inner races of thrust bearing	12
Thrust bearing cage	13

I. SUMMARY

A series of tests was conducted on a thrust bearing and two roller bearings to determine the effects of zero radial load and reversing thrust load on bearing performance. The results, for an accumulated test time of 5 hours, showed that a ball bearing could operate successfully under the stated conditions both at constant speed and during acceleration and deceleration. The test continued until failure of one roller bearing. The failure was caused by loss of clearance because of buildup of cage debris on the races. Test speeds included one hour of operation above 27,500 rpm.

II. CONCLUSIONS AND RECOMMENDATIONS

As a result of this series of tests it can be concluded that operation of a thrust bearing under zero radial load and reversing thrust load conditions is entirely satisfactory both during constant speed operation and during acceleration and deceleration. The maximum acceleration obtained was about 5000 rpm per second. This shows that one or more ball bearings can be used in conjunction with a thrust reversing requirement without the need for spring loading the bearings. Therefore, the maximum thrust carrying capacity of a pair of ball bearings can be utilized in both directions.

III. DISCUSSION

A. BEARING CONFIGURATION

The bearings used for test were:

1. Roller Bearing	P/N 290156-109 (S/N's 0000615 & 0000616)
Bearing size	SAE 210
Radial clearance	0.0019 - 0.0025
Cage material	Armalon
Number of rollers	16
Diameter of rollers	0.382 x 0.459
Race & Roller material	AISI 440C modified

III, A, Bearing Configuration (cont.)

2. Thrust Bearing	1/2 pair of P/N 290122-9 (S/N 0000027B)
Bearing size	SAE 210
Radial clearance	0.0020 - 0.0026
Cage material	Armalon
Number of balls	12
Diameter of balls	1/2 inch
Contact angle	24°
Curvature, outer race	0.51
Curvature, inner race	0.54 (gothic arch)
Ball and race material	AISI 440C

A gothic arch inner race was used to reduce the axial clearance. The gothic arch on the inner ring, rather than the outer, has the advantage that three-point contact will not occur during zero load operation because centrifugal force will keep the ball in contact with the outer race.

B. TEST SET-UP

The test was performed in bearing tester P/N 290300-9 fitted with two roller bearings and 1/2 pair of thrust bearings.

For this series of tests the axial and radial load devices and all dynamic seals were removed from the tester. Consequently, the only axial load was due to the pressure differential between the two ends of the shaft. This differential was 8 - 12 psi with, for example, a 6 GPM flow giving a nominal axial load of 100 lbs. Appropriate valving was utilized to permit reversing this flow.

A schematic of the system is shown in Figure 1. With valves V_1 and V_3 open, and valves V_2 and V_4 closed, the flow, and therefore the axial load vector, are both directed toward the motor and with all valves in the reverse setting the flow is directed from the motor toward the bearings. Figure 2 is a photograph of the tester set-up including the four valves for flow reversal.

III. B, Test Set-up (cont.)

The only radial load was due to the mass of the shaft. The latter can be either an undirectional load or a rotating load depending upon whether the dynamic loading is less than or greater than that caused by gravity, but, in any event, it will be small except in the vicinity of a critical speed. At 27,000 rpm the gravitational load will predominate.

C. RESULTS

A series of tests run on 30 April 1964 demonstrated an accumulated test time of approximately 5 hours. During the first 3-1/2 hours the thrust was reversed every one minute by reversing the flow through the bearing cavity. To simulate the thrust reversal conditions present in a thrust balancer-ball bearing system, the direction of flow through the tester was made reversible. At the end of the three and one-half hour period, a series of acceleration tests was performed to simulate a more severe thrust bearing condition. Eleven accelerations from zero to 26,000 rpm were performed. At the point of maximum acceleration (12,000 rpm), the thrust was reversed to induce scuffing which may occur when the balls lose contact with the races in the zero load condition. Thirty-nine additional accelerations were performed from 3,000 to 26,000 rpm, reversing the load at 12,000 rpm on the acceleration and also on the deceleration portion of the cycles (Figures 3 and 4). Operation was then continued for approximately one hour at speeds above 27,500 rpm, after which time the bearing temperatures rose to minus 200°F and an erratic motor current was observed.

For a brief period during the 5-hour run the pressure in the bearing cavity was lowered to below critical and this resulted in an immediate "warm-up" of the bearing temperatures.

D. POST TEST BEARING INSPECTION

Inspection of the bearings showed that the motor end roller bearing had failed because of wear of the Armalon cage. The Armalon cage wear debris deposited on the races and balls (Figures 5 and 6) had reduced the operating

III, D, Post Test Bearing Inspection (cont.)

clearance to zero. The loss of clearance apparently caused increased frictional heating and torque as evidenced by the motor current fluctuation and eventual rise. Most of the Armalon spacers between the roller pockets has been destroyed and each of the circumferential rings on the cage had cracked (Figure 7). This damage was probably caused by the jamming of one or more of the rollers because of the loss of clearance.

The other roller bearing also showed considerable wear debris on the races (Figures 8 and 9) but the build-up was insufficient to cause failure. No surface damage to the races or rollers was observed. However, cage deposits existed. Except for some wear on the pockets the cage was in good condition (Figure 10).

The thrust bearing (Figure 11) was in good condition except for some debris from the upstream failed roller-bearing. Some deposits of decomposed Armalon were also found on the races but the surfaces of both balls and races were in excellent condition (Figures 11 and 12). The cage was also in good condition (Figure 13). (This cage, as can be seen, was not of the dry lubricant coated configuration.)

FIGURE 1
PLUMBING SCHEMATIC

FIGURE 2
TESTER SET-UP

FIGURE 3
CONDITIONS OF FIRST ELEVEN ACCELERATIONS

FIGURE 4
CONDITION OF 39 ACCELERATIONS

FIGURE 5
FAILED ROLLER BEARING

FIGURE 6
INNER RACE OF FAILED ROLLER BEARING

FIGURE 7
ARMALON CAGE OF FAILED ROLLER BEARING

FIGURE 8
ROLLER BEARING FROM LOADER END

FIGURE 9
INNER RACE OF ROLLER BEARING FROM LOADER END

FIGURE 10
CAGE OF ROLLER BEARING FROM LOADER END

FIGURE 11
THRUST BEARING

FIGURE 12
INNER RACES OF THRUST BEARING

FIGURE 13
THRUST BEARING CAGE