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FIXED-WHEEL GATE BEARING STUDIES

Progress Report

by

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ABSTRACT

Tests to determine friction coefficients and bearing behavior in 3 types of bearings--2 self-lubricating and 1 plain bronze--show that increased allowable bearing pressures of 6,000 psi and a design coefficient of friction of 0.10 can be used for one of the self-lubricating-type wheel bearings (Type B). Antifriction roller bearings were studied because reductions in wheel-bearing friction forces gained from raising allowable bearing pressure may not always be sufficient to permit gravity closure. Although antifriction bearings cost more, there are circumstances in which the higher bearing cost could be offset by other overall design or economic considerations. Since bearings must support heavy radial loads as well as thrust loads, only tapered roller and self-alining spherical roller bearings were studied. Self-alining spherical roller bearings were chosen because the self-alining feature compensates for deflections caused by hydraulic load and for installation and fabrication misalinements. Fixed-wheel gate design on one job using antifriction self-alining spherical roller bearings saved 12,000 pounds of gate weight and 23,000 pounds in hoist capacity. Operation and maintenance experience from this gate will help evaluate reliability of these bearings.

DESCRIPTORS-- *fixed wheel gates/ *bearings/ *friction tests/ closing/ gate hoists/ weight/ bronze/ stainless steel/ corrosion/ lubrication/ design criteria/ *friction/ economies/ underwater/ bearing capacities/ laboratory tests/ coefficients/ bearing values/ corrosion control/ submergence/ gates/ performance tests/ wheels/ reliability/ horizontal loads/ gate seals

IDENTIFIERS-- antifriction bearings/ *bearing behavior/ wheel loads/ radial loads/ thrust loads/ *friction coefficients/ self-alining bearings/ roller bearings/ spherical roller bearings

INTRODUCTION

For fixed-wheel gates which are required to close by gravity, the frictional forces must be less than the gate weight. Extra weight has been added to some gates to insure closure, but this practice increases gate and hoist costs. Direct benefits can be derived by reducing gate friction forces.

Frictional forces on a fixed-wheel gate consist of seal friction, sliding friction of guide shoes, wheel rolling friction, and wheel bearing friction. Wheel bearing friction, which usually accounts for a large portion of the total, is calculated from the formula:

$$F = \frac{PfR_1}{R_2} = \frac{Pf}{R_2/R_1},$$

where

F = wheel frictional force
P = wheel load
f = coefficient of friction
R_1 = wheel pin radius
R_2 = wheel radius

The wheel frictional force, F, can be reduced by decreasing f and by increasing the wheel/pin ratio, R_2/R_1. R_2 is generally as large as the size of the gate and gate slot will permit and is, therefore, fixed for any particular installation. R_1, however, can be reduced if the bearing pressure between the bearing and the pin can be increased.

The purpose of this study is to determine economical means of reducing the wheel bearing friction.

STUDIES

Three general types of bearings were investigated: self-lubricating plain bearings, SAE 64 plain bronze bearings, and antifriction roller bearings. A study of the technical literature and catalogs of commercially available bearings indicated that two self-lubricating bronze bearings merited consideration. One of these self-lubricating bearings, Type B, has been used by the Bureau of Reclamation and has proved quite reliable for underwater service.

The manufacturers of the two self-lubricating-type bearings were contacted and supplied bearings for a test program performed by our Research Division. To evaluate the effectiveness of self-lubricating inserts properly, plain SAE 64 bronze bearings were also tested.

The Research Division tested the bearings and determined the coefficient of friction and bearing behavior at 2,700-, 4,000-, 6,000-, and 10,000-pounds-per-square-inch bearing pressure (based on projected area) for the following lubrication conditions:

1. Ungreased, dry
2. Greased, dry
3. Ungreased, submerged in water
4. Greased, submerged in water

The results are summarized in Table 1. These results indicate that the Type B bearings have a lower coefficient of friction than Type A or plain bronze. Their performance indicates that the allowable bearing pressure can be raised from 4,000 to 6,000 pounds per square inch, thereby permitting an increase in the wheel/pin ratio and reducing the wheel bearing frictional force. The design coefficient of friction, however, will be kept at 0.10 to allow for possible misalinement in installation and the effects of foreign materials and age on the bearings.

Since the reductions in wheel bearing frictional forces gained from raising the allowable bearing pressure may not always be sufficient to permit gravity closure, a study of antifriction roller bearings was undertaken. Despite the recognized higher cost of antifriction roller bearings, the study was initiated as there are circumstances in which the higher bearing cost could be offset by other overall design or economic considerations.

As the bearings must withstand thrust loads in addition to heavy radial loads, only tapered roller and self-alining spherical roller bearings were investigated. Layouts indicated spherical roller bearings offered advantages over tapered roller bearings, as the self-alining feature compensates for deflections caused by the hydraulic load on the gate and for fabrication and installation misalinements of the gate and track. The coefficient of friction for either type would be the same; and while a precise value was not checked, a coefficient of 0.01 was used as it is deemed conservative enough to cover some of the variables involved in submerged installations.

To minimize the possibility of bearing failure due to corrosion, AISI 440-C stainless steel, which has excellent corrosion resistance and can be heat treated to give capacities similar to those of conventional bearing steels, was used for the bearings. A tangential seal operating on a spherical seal seat excludes water from the bearing and retains grease while permitting the wheel and outer bearing race an angular misalinement rotation of plus or minus 1-1/2°.

To facilitate field installation, a pedestal type of wheel assembly was developed (see Figure 1), which can be completely shop assembled and shipped as a unit. This design makes it possible to keep the bearing clean by eliminating field assembly of the wheel bearing parts. It also provides an easy method of alinement of the wheel surfaces by shimming under the pedestals.

RESULTS

The studies indicated that a design bearing pressure of 6,000 pounds per square inch on the projected bearing area can be used for Type B bearings. Small savings in weight have been made by using the higher bearing pressures on the penstock gates for Yellowtail Dam, purchased under Invitation No. DS-6039, and on the penstock gates, Invitation No. DS-6179, for Morrow Point Dam.

The studies of the antifriction roller bearings indicated that use of antifriction wheel bearings will permit practically any gate to close by gravity without the addition of supplemental weight. Antifriction bearings were used on the fixed-wheel gates for the Main Canal Headworks, Navajo Indian Irrigation Project, Invitation No. DS-6087, resulting in elimination of 12,000 pounds of supplemental cast-iron weights which would have been necessary to close the gate by gravity. In addition, the hoist capacity was reduced by 23,000 pounds. The operating and maintenance experience gained at this installation will be employed in evaluating the reliability of antifriction bearings and the service required to keep them in proper working order.

FURTHER STUDY

Recently a new bearing using fluoro-carbon fabric bonded to a steel backing has been developed. These bearings appear to have the advantage of high bearing capacity and reduced coefficient of friction. It is planned to test and evaluate these bearings.

ACKNOWLEDGEMENTS

The Division of Research in the Office of Chief Engineer, Denver, Colorado, performed the laboratory testing of the self-lubricating and SAE 64 bronze bearings.

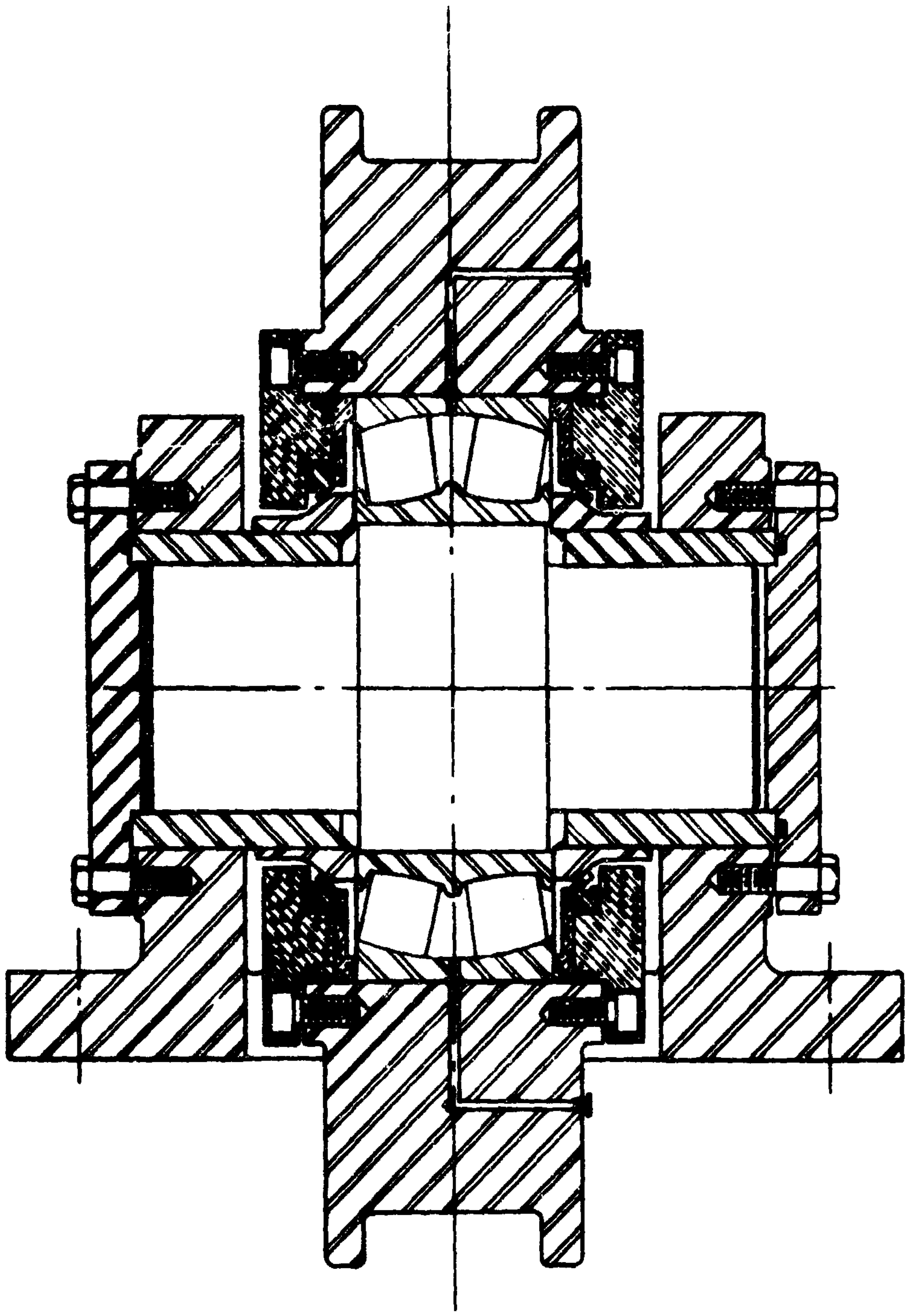
REFERENCE

1. "Fixed-wheel Gates for Penstock Intakes," Journal of Power Division, ASCE, October 1957, pp. 1420-4, S. J. Skinner.

Table 1

SUMMARY OF FRICTION TESTS OF SELF-LUBRICATING BEARINGS
TYPES A AND B, AND SAE 64 BRONZE BEARINGS
Coefficients of Friction

Bushing	Lubrication	Bearing pressure, pounds per square inch				Condition at end of test
		2,700	4,000	6,000	10,000	
Type A	Dry	0.049-0.097	0.079-0.107	0.084-0.154	0.095-0.162	Bad scoring
Type B	Dry	.048- .076	.060- .069	.040- .066	.044- .067	Slight scoring
SAE 64	Dry	.077- .173	.102- .186	--	--	Seized at 6,000 pounds per square inch
Type A	Greased	.007- .047	.023- .061	.068- .134	.056- .130	Some scoring
Type B	Greased	.014- .033	.013- .047	.015- .064	.030- .062	Smooth
SAE 64	Greased	.060- .080	.046- .091	.093- .129	.073- .126	Slight scoring
Type A	Submerged in water	.081- .145	.101- .127	.072- .125	.065- .131	Good
Type B		.029- .057	.016- .056	.028- .056	.034- .051	Slight score
SAE 64		No test	No test	.088- .149	.074- .174	Scored
Type A	Greased and submerged in water	.050- .062	.061- .070	.074- .123	.077- .120	OK
Type B		.016- .042	.034- .051	.017- .044	.030- .056	OK
SAE 64		.045- .097	.048- .094	.072- .139	.081- .123	OK



WHEEL ASSEMBLY

9- BY 12-FOOT FIXED-WHEEL GATE

MAIN CANAL HEADWORKS
NAVAJO INDIAN IRRIGATION PROJECT

Figure 1

GPO 846-488

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