NOTICE

**CERTAIN DATA
CONTAINED IN THIS
DOCUMENT MAY BE
DIFFICULT TO READ
IN MICROFICHE
PRODUCTS.**

MLM--3674

DE91 006280

MLM-3674

Bearing Staking Process Investigation Using a Designed Experiment

K. P. Armstrong

Issued: December 21, 1990

MOUND

operated by
EG&G MOUND APPLIED TECHNOLOGIES
P.O. Box 3000, Miamisburg, Ohio 45343-3000

for the

U. S. DEPARTMENT OF ENERGY

Contract No. DE-AC04-88DP43495

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Contents

	<u>Page</u>
ABSTRACT	3
BACKGROUND	3
PRELIMINARY WORK	3
DESIGNED EXPERIMENT	5
RECOMMENDATIONS	10
APPENDIX A - PHOTOGRAPHS OF SECTIONED UNIT PRELIMINARY	11
APPENDIX B - FORCE DISPLACEMENT CURVES FOR BEARING	13
APPENCIX C - RAW TEST DATA	17
APPENDIX D - STATISTICAL ANALYSIS	19
APPENDIX E - PHOTOGRAPHS OF SECTIONED WHEELS	21
DISTRIBUTION	30

Abstract

A designed experiment was performed on the staking operation of a miniature precision bearing. Three variables were controlled during the experiment: staking force, tool diameter, and bearing-to-wheel fit. The study showed that the current staking tool diameter is highly sensitive to staking force and to bearing-to-wheel fit, whereas a smaller diameter tool is not. The study also shows that, with the current process, bearing movement under a 100-Newton (N) force can be estimated at 0.009 in. to 0.0029 in. The current specification is 0.002 in. and should be revised to 0.0035 in.

Background

Miniature precision bearings are used to aid in the movement of a small wheel (see Figure 1). These bearings are "staked" in place by deforming material around the flange of the bearing. Past experience has shown that the bearing staking operation was plagued with rework because of the amount of variation in force required to hold the wheel bearing in place. The bearing was tested after staking by subjecting it to a 100-N push-out test and bearing movement was recorded. Any movement greater than 0.002 in. required a restaking of the bearing at a higher pressure.

Preliminary Work

One wheel was staked using the current process. Conditions for the stake process were:

Stake force = 5200 N
Penetration = 0.0057 in.
Bearing o.d. = 0.1705 in.
Wheel i.d. = 0.1732 in.
Stake tool diameter = 0.1826 in.
Bearing flange depth in wheel = 0.0068 in.

The wheel was taken to Analytical where it was sectioned and photographed. Sectioning was done throughout the least concentric portion of the stake. Appendix A shows both 50X and 100X photos of the staked region.

Analysis

From the photos it appeared that the stake penetration was insufficient. It was also evident that variations in stake diameter significantly affected the way in which material was moved. That is, lower stake diameters may move more material above the flange and may be less likely to damage the bearing.

Figure 1 - Wheel and Bearing

Designed Experiment

To optimize the process a designed experiment was conducted with the following variables, constants, and evaluation criteria.

Variables: 1) Staking tool diameter (inches):

Maximum value (Old size) 0.1826

Minimum value (New size) 0.1791

2) Staking Force:

Minimum (Old process) 5000 N

Maximum (New process) 5600 N

3) The difference between the bearing flange
outer diameter and the wheel counterbore
inner diameter (i.d./o.d. delta) in inches:

Minimum Delta

Wheel No.	Bearing No.	i.d./o.d. Delta
8	1	0.0009
5	7	0.0008
4	3	0.0008
1	5	0.0015
7	4	0.0018

Maximum Delta

Wheel No.	Bearing No.	i.d./o.d. Delta
9	8	0.0026
3	9	0.0025
10	2	0.0029
2	6	0.0024
6	10	0.0030

Constants:	Operator	Chart calibration
	Press	Staking base
	LVDT	Load cell
	Wheel QC	Bearing QC

Evaluation Criteria

Each bearing was pushed out from below with a force of 100 N. The force and displacement was recorded on a chart recorder and is shown in Appendix B. Bearing height before and after pressing was recorded and the difference between these was the output evaluated. Wheels were sectioned to determine (if possible) the amount of material moved over the bearing flange and the damage (if any) to the flange.

Test Sequence and Results

Testing was performed in accordance with an Orthogonal Array L4 Matrix as shown below:

Test No.	Tool size	Force	i.d./o.d. Delta	Bearing Movement
1	MIN	MIN	MIN	0.0025
2	MIN	MAX	MAX	0.0009
3	MAX	MIN	MAX	0.0084 ^a
4	MAX	MAX	MIN	0.0025
5	MIN	MIN	MIN	0.0027
6	MIN	MAX	MAX	00.27
7	MAX	MIN	MAX	0.0076 ^a
8	MAX	MAX	MIN	0.0029

^a Bearing pushed completely out.

Force displacement traces for both the bearing staking operation and the bearing push-put tests are shown in Appendix B. Raw test data is presented in Appendix C.

Analysis

A statistical analysis of the data is shown in Appendix D. Analysis of the effect of each variable shows that tool size and staking force have about an equal effect on bearing movement. The tolerance stack-up of the bearing and wheel have a considerable effect but not as great as the other two variables

Below is a listing of the variable and its effect:

Variable	Effect
Tool size	0.00315
Force	-0.00305
i.d./o.d. Delta	0.00225

Plots of the various interactions are shown in Figures 2 and 3. These indicate that the current tool diameter (0.1826 in.) is very sensitive to

Figure 2 - Staking Force

Figure 3 - Tool Diameter/Dimensional Interaction

both the force used to stake the bearing and the difference between the bearing o.d. and wheel i.d. The smaller diameter tool (0.1791 in.) is not as sensitive to these two variables and would provide for a more robust process. In addition, it is apparent that an optimization of the current process still would not provide for less than 0.002 in. bearing movement under the 100 N push-out condition. One cure for this may be to increase the staking force to increase the penetration of the stake. Figure 4 shows an extrapolated version of Figure 2 to provide a rough guess (6000 N to 6800 N) as to where we might begin the next series of experiments to minimize bearing movement.

Figure 4 - Extrapolated Figure 2

Recommendations

- 1) Until the next series of experiments are completed the staking tool should be changed to the smaller diameter tool (0.1791 in.). This would make the stake less sensitive to both the bearing and wheel tolerances and the stake force.
- 2) Although the current system is capable of 5600 N for accuracy and wear and tear, the staking force should be increased to around 5200 to 5400 N. Data would indicate that a smaller diameter tool will provide a relatively good stake at forces less than the 5600 N maximum.
- 3) The 100-N push-out test should be maintained, but the allowable bearing movement for a good stake should be more like 0.0035 in. From the sectioning photographs, it can be concluded that even 5600 N does not provide enough penetration to move material at the bearing flange. From the results, it is estimated that the material 0.0009 in. to 0.0029 in. above the flange may not be disrupted.
- 4) A further study needs to be run using smaller diameter staking tools and higher pressures. This will require purchasing a larger load cell and fabricating a staking tool.
- 5) Further investigation needs to be done to resolve the two distinct force/displacement curves for bearing staking units with tight tolerance stack-ups (test 1, 3, 5, and 7) and units with loose tolerance stack-ups (test 2, 4, 6, and 8).

Appendix A
Photographs of Sectioned
Unit Preliminary

Figure A-1 - Photographs of unit sectioned during preliminary investigation.

Appendix B
Force Displacement Curves
for Bearing

Figure B-1 - Force displacement curve for staking test

Figure B-2 - Displacement curves for push out test

Appendix C

Raw Test Data

Measurement raw data (wheels):

Wheel I.d. Highest to lowest:

Wheel no.	Dia
9	.1739
3	.1738
10	.1738
2	.1733
6	.1733
8	.1733
5	.1732
4	.1732
1	.1731
7	.1731

Measurement raw data (bearings):

Bearing o.d. Highest to lowest:

Bearing no.	Dia
1	.1724
7	.1724
3	.1724
5	.1716
4	.1713
8	.1713
9	.1713
2	.1709
6	.1709
10	.1701

Test data

Test number	Bearing depth (initial)	Bearing depth (After 1000N)	Delta Bearing Depth
1	.0083	.0058	.0025
2	.0069	.006	.0009
3	.0084	0.000	.0084 Total push out
4	.0078	.0053	.0025
5	.0076	.0049	.0027
6	.0083	.0056	.0027
7	.0076	0.000	.0076 Total push out
8	.0076	.0047	.0029

Test details

Test number	Wheel number	Tool	Force
1	1	min	5000
2	9	min	5600
3	3	max	5000
4	5	max	5600
5	4	min	5000
6	10	min	5600
7	2	max	5000
8	8	max	5600

Appendix D

Statistical Analysis

Data analysis

Run number	Results	Average	Standard Deviation	S/N
1	.0025, .0027	.0026	.0001414	51.69
2	.0009, .0027	.0018	.0012728	53.93
3	.0084, .0076	.0080	.0005657	41.97
4	.0025, .0029	.0027	.0002828	49.81

Variable	Average min	Average max	Effect
Tool size	.00220	.00535	.00315
Force	.00530	.00225	-.00305
I.D./O.D. Delta	.00265	.00490	.00225

Appendix E

Photographs of Sectioned Wheels

Figure E-1 - Photograph (100X) of sectioned wheel, test No. 1, wheel No. 1, left.

Figure E-2 - Photograph (100X) of sectioned wheel, test No. 1, right.

Figure E-3 - Photograph of sectioned wheel, test No. 2, wheel No. 9, left.

Figure E-4 - Photograph of sectioned wheel, test No. 2, wheel No. 9, right.

Figure 5 - Photograph of sectioned wheel, test No. 3, wheel No. 3, left.

Figure E-6 - Photograph of sectioned wheel, test No. 3, wheel No. 3, right.

Figure E-7 - Photograph of sectioned wheel, test No. 4, wheel No. 5, left.

Figure E-8 - Photograph of sectioned wheel, test No. 4, wheel No. 5, right.

Figure E-9 - Photograph of sectioned wheel, test No. 5, wheel No. 4, left.

Figure E-10 - Photograph of sectioned wheel, test No. 5, wheel No. 4, right.

Figure E-11 - Photograph of sectioned wheel, test No. 6, wheel No. 10, left.

Figure E-12 - Photograph of sectioned wheel, test No. 6, wheel No. 10, right.

Figure E-13 - Photograph of sectioned wheel, test No. 7, wheel No. 2, left.

Figure E-14 - Photograph of sectioned wheel, test No. 7, wheel No. 2, right.

Figure E-15 - Photograph of sectional wheel, test No. 8, wheel No. 8, left.

Figure E-16 - Photograph of sectioned wheel, test No. 8, wheel No. 8, right.

-END-

DATE FILMED

02 / 27 / 91