Nasa CR 65593

MIDWEST RESEARCH INSTITUTE

425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 - - AREA CODE 816 - LOGAN 1-0202

23 January 1967

NASA Manned Spacecraft Center
Advanced Spacecraft Technology Division
Houston, Texas 77058

Marked for: J. H. Kimzey (Bldg. 420)
Contract NAS9-3623

Subject: Quarterly Report No. 2, MRI Project No. FS-132-E (Contract NAS9-3623), "Cold Molecular Welding Study," for the period 15 September - 15 December 1966.

Gentlemen:

The objective of this program is to obtain a better understanding of cold-welding evaluation techniques and to determine the effects of certain test parameters not investigated under the original NASA Contract No. NAS9-3623 (MRI Project No. 2817-E).

The program consists of four investigations (beryllium-copper pellets on 321 stainless steel wear plates):

1. The reproducibility of test results under identical experimental conditions;

2. A comparison between sliding tests in ultra-high vacuum, dry air, and ambient air;

3. The effect of alternate sliding and resting of the metal couples for two sliding durations between stops: (a) one revolution and (b) 1/12 revolution; and

4. The effect of time at rest on the static coefficient of friction.

Program Activities

This report presents the results of the first three investigations which have been completed, the data are given in Tables I through III. Interpretation and discussion of the results will be given in the final report; however, there are some visual observations of the tests which are given as follows:

1. Loose wear debris was always present after tests in air; however, loose wear debris was never present after tests in vacuum.

2. Visual estimates of the area of the pellet material attached to the wear track at the point of static contact indicate a contact area of 1 to 2 percent of the projected area of the pellets; this localized contact area is distributed over an average of 50 points per each of the 3 pellets. A calculation, based on the load and the yield strength of the beryllium-copper pellets, indicates that a contact area of approximately 1 percent of the projected area should carry the load. A calculation, based on the shear strength of the beryllium-copper and the break-away torque, corresponds to shearing approximately 1 percent of the projected area of the pellets. It appears that these results agree with the theory developed by Bowden and Tabor for the adhesion of metal surfaces.*

3. It appears that the relative motion between the specimens at the time of initial contact breaks through the oxide layers on the specimens, permitting metal-to-metal contact and promotes welding.

4. Break-away of the pellets and their subsequent motion over new areas of the wear track tear small, irregular fragments (0.001 to 0.003 in. diameter) from the pellets. These fragments of pellet material are firmly deposited onto the wear track.

5. Subsequent passage of the pellets over these deposits apparently causes a build-up of pellet material on the wear track; islands are formed which have lengths about five times their height and width.

---

* Bowden, F. P., and D. Tabor, "The Friction and Lubrication of Solids, Part II," p. 52, Oxford (1964).

6. Eventually, after 10 to 30 passages of pellets over an island, it is torn away by failure of the wear plate material. Sometimes, a piece of wear plate is torn out immediately; at other times, the wear plate material seems to fracture and slip, then weld to itself.

7. Further motion of the pellets over the wear track results in increasingly greater variations in the friction measurements as the transfer of material back and forth between the pellets and wear track occurs in a random manner.

Future Work

It is expected that all of the scheduled tests will be completed by mid-January and preparation of a final report will be started immediately.

Mr. C. E. Moeller, Project Leader, is responsible for the over-all project activities. Mr. Joe Bossert directed the preparation of specimens and operation of the equipment. Mr. Harvey Montgomery polished all specimens and operated the equipment. The writer furnished guidance to the over-all program.

Very truly yours,

MIDWEST RESEARCH INSTITUTE

Approved:

Harold L. Stout

Harold L. Stout, Director
Engineering Division

for Vern Hopkins, Head
Materials Section
Engineering Division

(2 copies of report submitted)

cc: NASA Manned Spacecraft Center
Management Services Division
Houston, Texas 77058
Marked for: BM6/Library Services
Retha Shirkey
Contract NAS9-3623
(4 copies of report)

TABLE I

REPRODUCIBILITY TESTS - 10^{-9} TORR

Three Beryllium - Copper Pellets on SS321 Plate
1,000 psi Contact Pressure
Plate Temperature 200°C
Velocity 0.4 in/sec

Test	Break-away Friction	Sliding Friction first 30°	Sliding Friction 0 to 0.5 hr.	Sliding Friction 0.5 to 5 hr.	Sliding Friction 5 to 24 hr.
R1	0.5	0.5 - 0.6	0.9 - 3.1	0.6 - 2.0	0.4 - 2.8
R2	1.5	0.5 - 0.6	0.4 - > 4.9 (32 min.)	-	-
R3	0.5	0.5 - 0.6	0.4 - 0.9	0.4 - 1.0	0.4 - 0.7
R4	0.5	0.6 - 0.7	> 4.9 (10 min.)	-	-
R5	3.1	0.4 - 0.5	0.6 - 2.7	0.4 - 2.3	0.4 - 2.8
R6	0.7	0.4 - 0.9	> 4.9 (15 min.)	-	-

TABLE II

TESTS IN ATMOSPHERE - 760 TORR

Three Beryllium - Copper Pellets on SS321 Plate
1,000 psi Contact Pressure
Plate Temperature 200°C
Velocity 0.4 in/sec
Tests A1 - A3 - Air with Relative Humidity 40 - 60 percent
Tests DA1 - DA3 - Air with Relative Humidity < 10 percent

Test	Break-away Friction	Sliding Friction first 30°	Sliding Friction 0 to 0.5 hr.	Sliding Friction 0.5 to 5 hr.	Sliding Friction 5 to 24 hr.	Comments
A1	0.8	0.6 - 0.8	0.6 - 1.3	0.6 - 1.3	0.6 - 1.3	Pellets worn away at 17 hr.
A2	0.9	0.6 - 0.9	0.6 - 1.1	0.6 - 1.1	-	Pellets worn away at 4.5 hr.
A3	0.7	0.6 - 0.7	0.4 - 0.9	0.4 - 0.6	-	Pellets worn away at 6 hr.
DA1	0.6	0.6 - 0.8	0.4 - 0.8	-	-	Pellets worn away at 0.5 hr.
DA2	0.7	0.7 - 0.8	0.5 - 1.2	-	-	Pellets worn away at 0.6 hr.
DA3	1.0	0.8 - 1.0	0.5 - 1.4	0.2 - 1.00	-	Pellets worn away at 4.5 hr.

TABLE III

INTERMITTENT SLIDING TESTS - 10^{-9} TORR

Three Beryllium - Copper Pellets on SS321 Plate
1,000 psi Contact Pressure
Plate Temperature 200°C
Velocity 0.4 in/sec

One Revolution

Test	Break-away Friction	Sliding Friction 360°	Break-away Friction	Sliding Friction 360°	Break-away Friction	Sliding Friction 360°	Break-away Friction	Sliding Friction 360°
I1	0.5	0.5 - 1.0	1.1	0.9 - 1.2	0.9	0.8 - 1.0	0.9	0.8 - 1.0
I2	0.5	0.4 - 0.9	0.7	0.6 - 0.8	0.7	0.6 - 0.9	0.9	0.6 - 0.9
I3	0.3	0.4 - 1.2	> 4.9	-	-	-	-	-
I4	0.4	0.4 - 0.7	0.8	0.6 - 0.9	1.0	0.9 - 1.0	0.8	0.5 - 1.0
I5	1.4	0.4 - 1.4	4.2	0.7 - 3.5	4.3	3.0 - 4.9	1.2	1.0 - 4.8
I6	0.4	0.3 - 0.8	0.6	0.5 - 0.9	0.6	0.4 - 0.8	0.9	0.4 - 0.8

One-Twelfth Revolution

Test	Break-away Friction	Sliding Friction first 30°	Break-away Friction	Comments
S1	0.5	0.5 - 0.8	-	Evidence of scrubbing on contact
S2	0.7	0.7 - 0.9	0.9	"
S3	0.9	0.8 - 0.9	1.6	"
S4	0.4	0.4 - 0.5	0.5	"