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Gulf General Atomic
Incorporated

P.O. Box 608, San Diego, California 92112

INFORMAL AEC RESEARCH
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FRICITION AND WEAR TESTS ON TOP REFLECTOR KEYED PLENUM
ELEMENT MATERIALS OF THE FT. ST. VRAIN HTGR

by

P. D. Hedgecock

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1. SUMMARY

On the HTGR being built at Ft. St. Vrain for the Public Service Company of Colorado, the top reflector keyed plenum element assemblies are located atop the core and consist of many hexagonally shaped, stainless steel precision castings nested together in such a way that differential motion from thermal expansion can be accommodated by a system of keys and grooves between castings.

The resulting relative motion generates friction forces between castings, and the potential exists for galling or seizure where the friction and wear characteristics of the coupled surfaces are particularly bad. In an atmosphere of helium at elevated temperatures, friction and wear problems are generally aggravated by the inability of a surface to retain the oxide film that usually provides a form of lubrication. It has been established by Grebetz¹ that self-welding could occur when a friction couple of AISI 347 stainless steel to itself was tested in such an environment. Accordingly, it became necessary to examine the friction and wear behavior of proposed surface combinations under near-simulated service conditions of atmosphere, temperature, contact pressure, and total anticipated sliding distance.

Combinations of concern were:

1. Cast AISI 347 stainless steel with LC-2 chromium carbide coating rubbing upon itself.
2. LC-2 coated AISI 347 rubbing upon Tufftrided (liquid salt bath nitrided) AISI 1020.
3. Malcomized (nitriding process) A286 (substitute for AISI 347) rubbing upon itself.

4. Nitrided Nitralloy 135M steel rubbing upon Malcomized AISI 347 steel.

The environmental conditions were:

Atmosphere - atomic grade helium at atmospheric pressure

Temperature - 760°F

Contact pressure - 1000 psi

Sliding distance - 2400 in.

The results of the test program show that, of the combinations tested, the chromium carbide coated AISI 347 steel rubbing upon Tufftrided AISI 1020 steel gave the least amount of wear and the most consistently low friction coefficient.

2. APPARATUS AND TEST PROCEDURE

Tests were performed in the Mark II friction and wear apparatus described by Stansfield,² the loading details of which are shown schematically in Fig. 1. The test atmosphere was atomic grade helium at 2 psig containing less than 5 ppm moisture. At the start of each test, a 5×10^{-5} torr vacuum was pulled twice with an intermediate back-fill of helium before final pressurizing with helium.

Specimens were placed in contact as shown in Fig. 1. The correct dead-weight was applied via the lower arm to produce the desired contact pressure. The total stroke of the plate relative to the slider was 1/4 in. Therefore, a complete forward and backward stroke gave 1/2 in. of relative motion per cycle. Specimens were weighed before and after testing. Each test couple was tested in triplicate. The conditions of test were as follows:

Temperature - 760°F

Atmosphere - atomic grade helium at 2 psig

Contact Pressure - 1000 psi

Sliding Distance - 2400 in.

Figure 1. Detail of specimen holding and loading device in friction and wear apparatus

3. TEST MATERIALS

Test material combinations were as follows:

1. LC-2 chromium carbide coated cast 347 stainless steel versus itself.
2. LC-2 chromium carbide coated cast 347 stainless steel versus Tufftrided AISI 1020 steel.
3. Malcomized A286 steel (substitute for AISI 347) versus itself.
4. Nitrided Nitralloy 135M steel versus Malcomized cast AISI 347 steel.

Some difficulties were experienced with the Malcomizing of cast AISI 347 steel and, although sufficient specimens were obtained for one test group, there were not enough specimens to conduct all the planned tests. Accordingly, a group of wrought A286 steel specimens were satisfactorily Malcomized and substituted for AISI 347 specimens.

The nominal chemical compositions of the test materials are shown in Table 1. The LC-2 chromium carbide coating is a proprietary development of the Linde Division of Union Carbide Corp. and was applied with a detonation gun to the requirements of Gulf General Atomic Specification RG-2-60. Tufftriding is a proprietary liquid salt bath nitriding process licensed by the Kolene Corp.; it was applied to the requirements of Specification RG-2-80. Gas nitriding was applied to the requirements of Specification RG-2-81.

4. TEST RESULTS

4.1. WEAR RATES AND COEFFICIENTS OF FRICTION

The wear rates and coefficients of friction for the various specimens are depicted as follows:

TABLE 1

NOMINAL CHEMICAL COMPOSITION OF CANDIDATE TEST MATERIALS

Material	Element (wt.%)											
	C	Mn	Si	S	P	Ni	Cr	Al	Mo	Cb	Ti	V
AISI 347	0.08 max.	2.0	1.0	0.030 max.	0.045 max.	12.0	18.0	----	----	1.35 max.	---	---
Nitralloy 135M	0.4	0.6	0.3	0.040 max.	0.040 max.	----	1.6	1.1	0.35	----	---	---
AISI 1020	0.2	0.5	---	0.050 max.	0.040 max.	----	----	----	---	----	---	---
A286	0.08 max.	1.5	1.0 max.	0.030 max.	0.040 max.	25.0	15.0	0.35 max.	1.3	----	2.0	0.3

1. LC-2 Chromium Carbide/LC-2 Chromium Carbide, Table 2 and Fig. 2.
2. LC-2 Chromium Carbide/Tufftrided AISI 1020, Table 2 and Fig. 3.
3. Malcomized A286/Malcomized A286, Table 2 and Fig. 4.
4. Nitrided Nitralloy 135M/Malcomized AISI 347, Table 2 and Fig. 5.

4.2. APPEARANCE OF SPECIMENS AFTER TEST

Figures 6 through 9 show half-sections of the wear track on the plates for the above material combinations. Figures 10 and 11 show metallographic sections of the worn portion of the Malcomized AISI 347 plate used in the last combination above. Figures 12 and 13 show metallographic sections of the worn portion of the Tufftrided AISI 1020 plate used in the second combination above.

5. DISCUSSION OF RESULTS

Table 2 shows clearly that the wear rate of the LC-2 chromium carbide/Tufftrided AISI 1020 combination is lower by a factor of 10 than the next lowest material combination. Furthermore, the measured friction coefficient of this combination, as shown by Fig. 3, shows the lowest and most consistent friction coefficient, averaging around 0.5. A comparison of Figs. 6 through 12 substantiates the above remarks, since it may be seen that the wear scars on the test materials are minimal on the LC-2 chromium carbide/Tufftrided AISI 1020 combination. A cross section of the Tufftrided layer indicates that only the surface asperities have been smoothed down, and the compound layer is still in good condition. The Malcomized cast 347 stainless steel exhibited chipping of the hard, brittle nitrided layer.

6. CONCLUSIONS

The selection for the keyed plenum elements of chromium carbide coating on cast 347 stainless steel and Tufftrided AISI 1020 steel for the keys is

TABLE 2

MEASURED AVERAGE WEAR RATES OF TEST MATERIAL

Slider/Plate Combination	Wear Rate (lb. ft. ⁻² in. ⁻¹ x 10 ⁻⁶)	
	Slider	Plate
LC-2 chromium car- bide slider LC-2 chromium car- bide plate	2.34	4.48
LC-2 chromium car- bide slider Tufftrided AISI 1020 plate	Not measurable	0.16
Malcomized A286 slider Malcomized A286 plate	30.5	22.9
Nitrided Nitralloy 135M slider Malcomized 347 plate	11.75	1.85

Figure 2. Relationship between friction coefficient and sliding distance for chromium carbide sliding on chromium carbide

Figure 3. Relationship between friction coefficient and sliding distance for chromium carbide sliding on Tufftrided AISI 1020

Figure 4. Relationship between friction coefficient and sliding distance for Malcomized A286 sliding on Malcomized A286

Figure 5. Relationship between friction coefficient and sliding distance for nitrided Nitralloy 135 sliding on Malcomized AISI 347

MC33109-6

Figure 6. Half-section of wear track on LC-2 chromium carbide-coated cast AISI 347 steel

MC33109-7

Figure 7. Half-section of wear track on Tufftrided AISI 1020 steel plate

MC33109-8

Figure 8. Half-section of wear track on Malcomized A286 steel plate

MC33109-9

Figure 9. Half-section of wear track on Malcomized AISI 347 steel plate

M29686-1

(200x)

Figure 10. Metallographic section (unetched) of wear track on Malcomized AISI 347 steel plate. Note chipping of brittle, nitride layer.

M29686-2

(200x)

Figure 11. As in Fig. 10 but etched

M24467-1

(200x)

Figure 12. Metallographic section (unetched) of wear track on Tufftrided AISI 1020 steel plate. Compound layer is intact and only rough asperities have been smoothed down.

M24467-2

(200x)

Figure 13. As in Fig. 12 but etched

based on the fact that, of all the combinations tested, this one gives the lowest wear rates and lowest, most consistent friction coefficient under simulated service conditions.

7. RECORDS AND PERSONNEL

The experimental work was performed by R. Hansen under the direction of J. Grebetz. Experimental data are recorded in Gulf General Atomic Notebook #4037. The data were reduced and reported by P. D. Hedgecock.

8. REFERENCES

1. Grebetz, J. C., "The Unlubricated Friction and Wear Behavior of Structural Materials in Helium at 800°C," Gulf General Atomic Report GA-8697, 1968.
2. Stansfield, O. M., "Friction and Wear in PSC Carbon and Graphite Core Support Materials," Gulf General Atomic private communication, 1967.