AIR/OIL SEALS R&D AT ALLIEDSIGNAL

M. Rifat Ullah
AlliedSignal Engines
Phoenix, Arizona

TRANSCRIPT ... Air/Oil Seals IR&D at AlliedSignal

Presenter: M. Rifat Ullah, Ph.D., P.E
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Abstract: AlliedSignal aerospace company is committed to significantly improving the reliabilities of air/oil seals in their gas turbine engines. One motivation for this is that aircraft cabin air quality can be affected by the performance of mainshaft air/oil seals. In the recent past, coking related failure modes have been the focus of air/oil seal R&D at AlliedSignal. Many significant advances have been made to combat coke related failures, with some more work continuing in this area. This years R&D begins to address other common failure modes. Among them, carbon seal "blistering" has been a chronic problem facing the sealing industry for many decades. AlliedSignal has launched an aggressive effort this year to solve this problem for our aerospace rated carbon seals in a short (one to two year) timeframe. Work also continues in developing more user-friendly tools and data for seal analysis & design. Innovations in seal cooling continue. Nominally non-contacting hydropad sealing concept is being developed for aerospace applications. Finally, proprietary work is in planning stages for development of a seal with the aggressive aim of zero oil leakage.

CHART #1

AIR/OIL SEALS R&D AT AlliedSignal

Presented at SEALS/SECONDARY FLOW WORKSHOP at
NASA Lewis Research Center, Cleveland --- October 16, 1997

Contact: M. Rifat Ullah, Ph.D., P.E. (602) 231-1084

Good morning. This morning I will try to give you a feel for the work we're doing at AlliedSignal in improving the reliability and performance of mechanical seals for aerospace applications. AlliedSignal is highly committed to improving seal reliabilities since it can impact the quality of cabin air in passenger aircrafts. That is, leaking engine seals can be a major source of customer dissatisfaction, and AlliedSignal is in the forefront of resolving these chronic problems.

CHART #2

Effect of recent R&D on coking related failures

Examples:

- 1200 Engines of TFE731 have been retrofitted with the patented Ceramic Ring Seal at 4 locations ... Chronic Odor-In-Cabin has Disappeared!
- TPE331 Compressor Seal ... B1 Life has increased by 10 times

In the past years I've indicated to you the work that we were focused on. The primary focus in recent years has been to attack seal failures related to Coking. I am pleased to tell you that many advances have been made in this area. We now have a critical understanding of how coke formation mechanism works, and more importantly, how to attack that mechanism.

I can give you at least two specific examples where our recent seal R&D efforts have resulted in major advancements in aerospace engines products. 1200 engines of TFE731 have been retrofitted with the patented ceramic ring seal at 4 locations in the mainshaft of the engine. Virtually all seals that have been put in the real world are working superbly. Bottomline: The chronic problem of Odor-In-Cabin associated with this very popular engine for business jets has disappeared.

Another example is the compressor seal in the TPE331. Results from seal thermal management R&D were used to attack the coking problem for this seal. The B1 life has increased by about 10 times, a major accomplishment.

CHART #3

1997 Air/Oil Seal Programs

1997 PROGRAMS	COLLABORATORS w/ AS
• Carbon Seal Blister Prevention	Morgan, CMU, WMU, et.al.
• Analytical Tools & Data	MSTI, ASU
• Hydropad Seal	Rexnord
• Zero Oil Leakage Concept	MSTI
• Coning Deformation Resistant Seal	(none)
• Banded Carbon Dimensional Instability	ASU

This year we have launched a number of new initiatives in air-oil seal R&D. Here is a list of the various programs we have started. The problems we are attacking are quite complex. Whenever necessary, we form strategic partnerships and collaborations to solve our seal problems. This list indicates some of our outside collaborators, such as Carnegie-Mellon University, Morgan carbon company, Mechanical Seals Technology Inc., etc. Due to the lack of time, I will not go through each of these topics that we're currently engaged in. However, I will briefly talk about one of the programs that we're working on at the moment ... namely, Carbon Seal Blister Prevention.

CHART #4

Carbon Seal Blistering …
… Quick Background

- **Damage on Sealing Surface of Carbon; typically Face Seals**
- **Nature of Blistering studied since early 70's.**
- **Emphasis been on Industrial Seals. Aerospace seals have not been studied.**
- **Leading theory due to Strugala (1972) … sudden expansion of oil trapped in pores can cause damage**
- **Other theories include Intense Shear, etc.**
- **In 1st Phase, AlliedSignal chose to focus on the Carbon Material itself, instead of System variables**

Here's a quick background on Carbon Blistering. First of all, "blisters" and "blister-like indications" are a kind of damage on the sealing surface of the carbon, typically evident in many mechanical face seals. In this discussion, when I say "blister" it can mean all types of indications that resemble "blisters". Here is a picture of a blistered surface … the sealing surface looks like it has 'pot-holes' in it. Blisters at the wrong location can compromise sealing integrity, though not all seals that blister are guaranteed to leak, as far as we can tell so far.

The nature of blistering has been studied since early '70s. The seminal work was published by Strugala in '72. The emphasis so far has been on "industrial seals", for example pump seals, or refrigerant seal, etc. Aerospace seals have not yet been studied to our knowledge. The leading theory is still due to Strugala (1972), which theorizes that sudden expansion of oil trapped in pores can cause blister-like damage in carbons. The sudden expansion can be a result of engine start-up, with attendant frictional heating and temperature rise. Other theories include intense shear as a mechanism that can produce blistering.

Currently, STLE sponsored research is also ongoing at Western Michigan University, with Professor Phil Guichilaar as the PI. AlliedSignal is also among the sponsoring consortium of some 15 companies supporting that work. That work is also principally aimed at slower speed industrial seals. What we learn from that work, we're readily implementing in our own independent blistering work for aerospace seals.

In the first phase of our work (this year), we chose to focus on the heart of the problem --- the Carbon material itself; as opposed to inclusion of "system variables", meaning, everything else that works in concert with the carbon. This has been done to efficiently arrive at a practical solution to this problem.

CHARTS #5 & 6

Here are a couple of pictures showing blister damage on the sealing face of carbon-graphite.

SEM Photograph of Blistered Area of Carbon Seal

(Magnification = 510X)

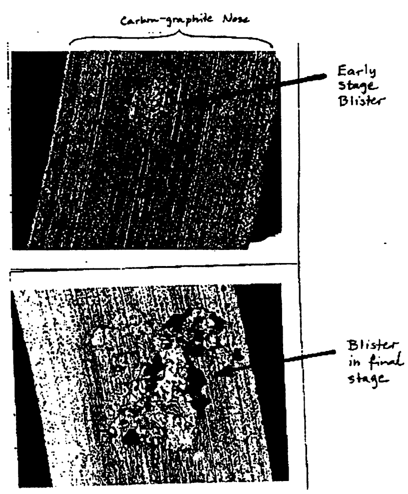


CHART #7

Carbon Seal Blistering …
… Main Goals

In Order of Practical Importance:

- Identify and Rank Aerospace Carbon Grades
- Identify and Measure Key Carbon Properties
- Determine Mechanism(s)

The main goals of this work. In the order of practical importance:

- Identify and rank selected aerospace carbon grades
- Identify and measure key carbon properties
- Determine mechanism that causes blistering.

CHART #8

Carbon Seal Blistering ... APPROACH

PHASE-1 ... includes

- Investigate Carbon **Microstructure**
- Microdamage **Modeling** to form Hypotheses
- Determine & Measure **Key Carbon Properties**
- Fabricate Aerospace **Blister Rig**
- Rank **Blister Resistance** of selected Carbon Materials
- Define a new **Composite Property** "Blister Resistance", for Aerospace Seal Designs
- Determine **Mechanism** that causes Blisters in Aerospace Seals

In the first phase of our blistering work, the approach includes the following. We began by looking at the carbon microstructure of some common grades we use, and at seals from various engines. We also began working with Carnegie-Mellon's Professor Paul Steif on micro-damage modeling of for carbon. The aim is to arrive at plausible hypotheses to guide our work. From that we began determining some key material properties that might govern blistering. We are also constructing a special aerospace blister rig, with which we intend to perform controlled tests on selected carbon and alternative materials. We would like to rank the selection, which will be the least we will do. Based on the rest of the work, we are working on defining a new composite material property which we may call "Blister Resistance Number" for aerospace rated carbons. And finally, we aim to determine the mechanism that causes blistering in aerospace carbon seals.

CHART #9

Carbon Seal Blistering ...
... Some Inferences

PHASE-1 ... WORK IN PROGRESS

- Appears Carbon Microstucture can have strong influence
- Grain size can be important
- Size of Pores & Pore Distribution can be important
- Key Carbon Properties can include: Fracture Toughness, Permeability, etc.
- ... work in progress ...

Here are some inferences that we can tell you about, in this work that in progress. It appears that carbon microstructure can have a strong influence on this problem. For example, the nominal apparant "grain size" can be important, even though it is not easy to determine or even define a "grain" of carbon-graphite. From our modeling work, we determine that pore size and pore size distribution can be important. Also from our work we're deducing that key carbon properties can include fracture toughness and permeability, among others. It is important to stress that when we say fracture toughness, we mean a "short crack toughness" and not the conventional K1c.

CHART #10

More Collaborations Welcome

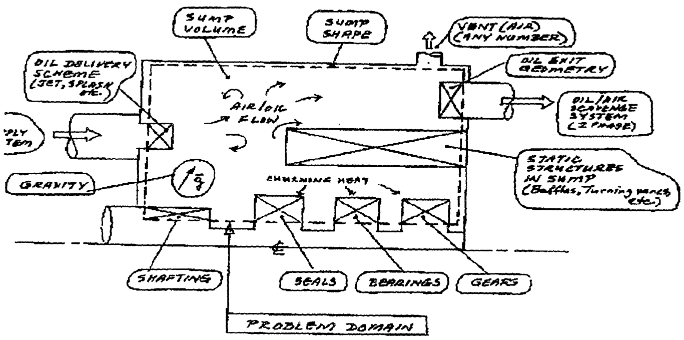
1998 Work Element	Principal Expertise Needed (BOLD= outside collaboration needed)
Carbon Blistering	Seal Rig Tests; Small-scale Bench Tests; **Analytical modeling ... Applied Mechanics, Thermal sciences**
Tools & Data	Seal software; **Experimental Convective Heat Transfer**
Hydropad Seal	Seal Rig Tests
Zero Oil Leakage Concept	Seal Innovation; Specialized Seal Rig Tests
Ceramic Face Seal Rotor	Design of Ceramic components
Banded Carbon Dimensional Instability	Analytical modeling ... Applied Mechanics, Thermal sciences
Sump & Gearbox Churning	**Analytical modeling ... 2-phase/2-species CFD** ⇦

As we aggressively prosecute a variety of air-oil seal problems, we welcome collaborations and strategic partnerships with qualified entities outside AlliedSignal. Here is a tentative list of air-oil seal and sump related R&D programs that we plan to work next year. Some are continuation of work already launched, while some are new program that we're considering. Again, due to lack of time here, I am not going to talk about each of these. If any one of these interests you, please contact me, and we can talk offline.

However, I am going to briefly touch on one of the new programs we're contemplating … Sump and Gearbox Churning, a program we may engage in the near future, may be even next year.

CHART #12

SUMP & GEARBOX CHURNING —— GENERIC PROBLEM



PROBLEM: DEVELOP ANALYTICAL TOOLS TO MODEL AIR-OIL FLOW BEHAVIOR IN GENERIC SUMP AND GEARBOX. PROBLEM DOMAIN INDICATES TYPICAL BOUNDARY CONDITIONS.

<u>**Sump and Gearbox Air-oil flow and Churning**</u>. After the oil performs it's service to seals, gears, bearings in a gearbox, we need to move the oil out in the most efficient manner, so that churning is avoided. Currently, gearbox designs largely rely on past experience and rules of thumb. We use test rigs to improve performance, but that can be very expensive, time consuming, and not guarantee optimal solution. Analytical design tools are needed, <u>that will work in parallel</u> with experimental tools.

The generic problem statement involves analytically modeling the 3-dimensional space of a gearbox. The work can start out as a 2D problem, but the aim is to move towards 3D when possible. This figure shows the schematic of the generic problem domain with typical boundary conditions.

The boundaries of the gearbox/sump domain includes

- a liquid oil supply (such as oil jet, or splash, etc.),
- an air-oil scavenge (or drain),
- any number of air vents,
- static structures in the sump (such as baffles, turning vanes, etc.),
- rotating bodies that impart angular momentum to the air-oil fluid, such as seals, gears, bearing, and shafting
- gravity,
- etc.

Gearbox/sump volume and shape can be independent variables.

We would like to analytically predict the air-oil flow pattern/behavior in such a gearbox. Additionally, we would like to estimate churning heat generation. People with CFD expertise, especially involving 2 species (air & oil) and 2 phase flow may find this problem fascinating.

Thank you for your attention.