ACTIVE THERMAL SESSION TOPICS

Active Thermal Paper Session I (Monday 8:00AM to 12:00PM)

Time	ID	Title	Author(s)	Affiliation	Email
8:00AM	TFAWS2012-AT-01	Variable Conductance Heat Pipes for Variable Thermal Links	William G. Anderson Michael C. Ellis John R. Hartenstine Christopher J. Peters Calin Tarau Kara L. Walker	Advanced Cooling Technologies, Inc.	Bill.Anderson@1-act.com
8:30AM	TFAWS2012-AT-02	Loop Heat Pipe with Thermal Control Valve for Variable Thermal Conductance	Kara L. Walker John R. Hartenstine Andrew Slippey Calin Tarau William G. Anderson	Advanced Cooling Technologies, Inc.	
9:00AM	TFAWS2012-AT-03	High Accuracy Liquid Propellant Slosh Predictions Using an Integrated CFD and Controls Analysis Interface	Brandon Marsell David Griffin Dr. Paul Schallhorn Jacob Roth	QinetiQ NASA KSC	brandon.marsell@nasa.gov
9:30AM	TFAWS2012-AT-04	Numerical Investigation of Aerodynamical Performance of Damaged Low-Reynolds Airfoils for UAV Application	Ali Doosttalab Mohammad Mohammadi Ali Ashrafizadeh Mehdi Doosttalab	K.N.Toosi University of Technology, Nordex GmbH	adoosttalab@asme.org
10:30AM	TFAWS2012-AT-05	Active Solar Array Thermal Control System for the Solar Probe Plus Spacecraft	Carl Ercol Greg Guyette Wei-Lin Cho	Johns Hopkins University Applied Physics Laboratory, Hamilton Sundstrand	carl.ercol@jhuapl.edu
11:00AM	TFAWS2012-AT-06	Mechanically Pumped Fluid Loops: Components and Systems for Space Application	Michael Brown	Pacific Design Technologies, Inc.	m.brown@pd-tech.com
11:30AM	TFAWS2012-AT-07	Environmental Control and Life Support System on Spacecraft	Divya Krishnamoorthy	Mailam Engineering College	Mynasa.cool@gmail.com

Active Thermal Paper Session II (Thursday 7:30AM to 11:30AM)

Time	ID	Title	Author(s)	Affiliation	Email
7:30AM	TFAWS2012-AT-08	Performance of Nanofluids in Microchannel Heat Exchangers	Debendra Das Ravikanth S. Vajjha	University of Alaska Fairbanks	dkdas@alaska.edu
8:00AM	TFAWS2012-AT-09	Efficient Thermally Conductive Strap Design for Cryogenic Propellant Tank Supports and Plumbing	Justin Elchert	NASA GRC	justin.p.elchert@nasa.gov
8:30AM	TFAWS2012-AT-10	The Transport of Mass, Energy, and Entropy in Cryogenic Support Struts for Engineering Design	Justin Elchert	NASA GRC	justin.p.elchert@nasa.gov
9:00AM	TFAWS2012-AT-11	A Re-Entry Vehicle Reaction Control System Thermo-Fluidic Analysis Approach	Lorenzo Andrioli Savino De Palo	Thales Alenia Space	lorenzo.andrioli@thalesaleniaspace.com
10:00AM	TFAWS2012-AT-12	IV & V of Orion Active Thermal Control System (ATCS) Dynamic Models	Xiao-Yen Wang	NASA GRC	xiao-yen.j.wang@nasa.gov
10:30AM	TFAWS2012-AT-13	A Scaling Tool For Modeling Single Stage Reverse Turbo-Brayton Cycle Cryocoolers with a Broad Area Cooling System for Cryogenic Propellant Tanks	Monica Guzik Thomas M. Tomsik	NASA GRC	monica.c.guzik@nasa.gov
11:00AM	TFAWS2012-AT-14	Overview of OCT's Game Changing Solicitation for Variable Heat Rejection Technologies	Rubik Sheth	NASA JSC	rubik.sheth-1@nasa.gov

VARIABLE CONDUCTANCE HEAT PIPES FOR VARIABLE THERMAL LINKS

William G. Anderson, Advanced Cooling Technologies, Inc.
Michael C. Ellis, Advanced Cooling Technologies, Inc.
John R. Hartenstine, Advanced Cooling Technologies, Inc.
Christopher J. Peters, Advanced Cooling Technologies, Inc.
Calin Tarau, Advanced Cooling Technologies, Inc.
Kara L. Walker, Advanced Cooling Technologies, Inc.

ABSTRACT

A typical Variable Conductance Heat Pipe, shown in Figure 1, has an evaporator, a single condenser, and an electrically heated reservoir at the end of the condenser. This system is commonly used in spacecraft thermal control to provide ±1-2°C temperature control over widely varying powers and condenser temperatures.

This paper will discuss VCHP applications where a variable thermal link is desired, not tight temperature control. In most of these applications, liquid in the condenser can freeze. VCHPs or gas-loaded heat pipes simplify start-up with a frozen condenser.

LOOP HEAT PIPE WITH THERMAL CONTROL VALVE FOR VARIABLE THERMAL CONDUCTANCE

Kara L. Walker, Advanced Cooling Technologies, Inc.
John R. Hartenstine, Advanced Cooling Technologies, Inc.
Andrew Slippey, Advanced Cooling Technologies, Inc.
Calin Tarau, Advanced Cooling Technologies, Inc.
William G. Anderson, Advanced Cooling Technologies, Inc.

ABSTRACT

It is often desirable to partially or completely shut down a Loop Heat Pipe (LHP), for example, to maintain the temperature of electronics connected to the LHP on a satellite during an eclipse. The standard way to control the LHP is apply electric power to heat the compensation chamber, as required. The amount of electrical power to shut down an LHP during an eclipse on orbit is generally reasonable.

On the other hand, for LHPs on Lunar and Martian Landers and Rovers, the electrical power requirements can be excessive. For example, the Anchor Node Mission for the International Lunar Network (ILN) has a Warm Electronics Box (WEB) and a battery, both of which must be maintained in a fairly narrow temperature range using a variable thermal conductance link. During the Lunar day, heat must be transferred from the WEB to a radiator as efficiently as possible; see Figure 1. During the night, heat transfer from the WEB must be minimized to keep the electronics and batteries warm with minimal power, even with a very low (100 K) heat sink; see Figure 2. A mini-LHP has the highest Technology Readiness Level, but requires electrical power to shut-down during the 14-day Lunar night, with a significant penalty in battery mass: 1 watt of electrical power translates into 5kg of battery mass.

TFAWS2012-AT-03

HIGH ACCURACY LIQUID PROPELLANT SLOSH PREDICTIONS USING AN INTEGRATED CFD AND CONTROLS ANALYSIS INTERFACE

Brandon Marsell, QinetiQ North America
David Griffin, QinetiQ North America
Dr. Paul Schallhorn, NASA Kennedy Space Center
Jacob Roth, NASA Kennedy Space Center

ABSTRACT

Coupling computational fluid dynamics (CFD) with a controls analysis tool elegantly allows for high accuracy predictions of the interaction between sloshing liquid propellants and the control system of a launch vehicle. Instead of relying on mechanical analogs which are not valid during all stages of flight, this method allows for a direct link between the vehicle dynamic environments calculated by the solver in the controls analysis tool to the fluid flow equations solved by the CFD code. This paper describes such a coupling methodology, presents the results of a series of test cases, and compares said results against equivalent results from extensively validated tools. The coupling methodology, described herein, has proven to be highly accurate in a variety of different cases.

NUMERICAL INVESTIGATION OF AERODYNAMICAL PERFORMANCE OF DAMAGED LOW-REYNOLDS AIRFOILS FOR UAV APPLICATION

Ali Doosttalab, K.N.Toosi University of Technology
Mohammad Mohammadi, K.N.Toosi University of Technology
Ali Ashrafizadeh, Associate Professor, K.N.Toosi University of Technology
Mehdi Doosttalab, R&D Engineer, Nordex GmbH

ABSTRACT

This paper presents two-dimensional numerical investigations and comparison of aerodynamical characteristics at low Reynolds number flow between undamaged and a diversity of different damaged low-Reynolds and high-lift UAV airfoils. Damages are in form of bullet impact holes in different areas along the chord (at 0.25c, 0.5c and 0.75c) and at three different bullet incident angles (+30, 0 and -30 degrees) at mid-chord. Extensive Numerical simulations have been done, utilizing the RANS model through solving the Navier-Stokes equations at low Reynolds number of 2× . The SST-transitional model has been used in the prediction and comparison of the unique flow phenomena prior and after the damages occurred. The obtained numerical results for undamaged airfoils are compared with the data based on experiments, within less than 5% of error. Numerical simulation processes were performed, using FLUENT environment, in order to obtain the aerodynamic performances of the proposed model. The results show the significant decrease in aerodynamic performance of the airfoil due to damages done by bullet impact and this degradation in performance is dependent to the damage chord position and impact angle. The CFD calculation results showed that lift coefficient loss increases as the damage location along the chord line moves toward the leading edge especially at higher angle of attacks. The numerical simulations also showed that increasing the damage angle leads to more loss of aerodynamical performances of the airfoil. This is the first time that damage investigations are performed on High-Lift Low-Reynolds UAV airfoils.

ACTIVE SOLAR ARRAY THERMAL CONTROL SYSTEM FOR THE SOLAR PROBE PLUS SPACECRAFT

Carl J. Ercol, Johns Hopkins University
Greg Guyette, Hamilton Sundstrand
Wei-Lin Cho, Hamilton Sundstrand

ABSTRACT

The Solar Probe Plus (SPP) spacecraft will orbit the Sun closer than any other previous probe. As dictated by the current mission design, the spacecraft will achieve many perihelia as close as 9.5 RS from the Sun. During those passes, it will encounter a solar flux of ~500 suns, or 70 W/cm2. This flux is more than 50 times
larger than the solar heating seen by any previous spacecraft. During the entire mission, the spacecraft and science instruments will be protected by a Thermal Protection System (TPS), and electrical power is produced by using somewhat conventional photovoltaic technology. Because of the high solar load, an active cooling system is required to remove the waste heat from the solar cell and transport it to a remote radiator system for rejection to deep space. As part of the SPP Phase A study, a specific effort focused on the manufacturing and testing of a breadboard cooling system to address the basic feasibility and operation of the system. This paper will describe the performance results of the breadboard cooling system and the path needed to bring that system to a Technology Readiness Level (TRL) of 6 on the schedule needed for the flight project.

MECHANICALLY PUMPED FLUID LOOPS: COMPONENTS AND SYSTEMS FOR SPACE APPLICATIONS

Michael Brown, Pacific Design Technologies, Inc.

ABSTRACT

The paper presents an overview of components in a typical mechanically pumped fluid heat transfer loop, system considerations, testing protocol and means to quantify performance. A brief discussion of systems used in past missions and future trends is also included. The fundamental system design and sizing considerations addressed include operating temperature, heat transfer rate, mass, power and volume limitations. A discussion of fluid selection criteria, materials compatibility, pump types and power sources is included. The paper also provides a description of several systems that have been used for on orbit and deep space missions. The paper will also draw comparisons to active thermal control systems used in conventional airborne vehicles. The systems and missions addressed include:

Past Missions: Mars Pathfinder, Mars Exploration Rovers, Mars Science Laboratory,
Alpha Magnetic Spectrometer II

Future Missions: Solar Probe Plus

Airborne Systems: Various manned and un-manned Intelligence, Surveillance and
Reconnaissance (ISR) platforms

Special considerations for space missions will be addressed, such as system design, reliability, cleanliness and filtration.
A discussion of typical testing methods will be provided; this will include thermal and thermal-vacuum, vibration/shock, EMI and endurance testing. Standard methods to assess the performance of pumped fluid systems through measurement of flow, pressure drop and temperature will be briefly described.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM ON SPACECRAFT

Divya Krishnamoorthy, Mailam Engineering College

ABSTRACT

The environmental control and life support system on a spacecraft maintains a safe and comfortable environment in which the crew can live and work by supplying oxygen and water and by removing carbon dioxide, water vapour, and trace contaminants from cabin air. Although open-loop systems have been used successfully in the past for short duration missions, the economics of current and future long-duration missions in space will make nearly complete recycling of air and water imperative. A variety of operations will be necessary to achieve the goal of nearly complete recycling. These include separation and reduction of carbon dioxide, removal of trace gas-phase contaminants, recovery and purification of humidity condensate, purification and polishing of wastewater streams, and others. Several of these can be performed totally or in part by adsorption processes. These processes are good candidates to perform separations and purifications in space due to their gravity independence, high reliability, relatively high energy efficiency, design flexibility, technological maturity, and regenerative nature. For these reasons, adsorption has historically played a key role in life support on U.S. and Russian piloted spacecraft. Among the life support applications that can be achieved through use of adsorption technology are removal of trace contaminants and carbon dioxide from cabin air and recovery of potable water from waste streams. In each of these cases, adsorption technology has been selected for use onboard the International Space Station. The requirements, science, and hardware for these applications are discussed. Human space exploration may eventually lead to construction of planetary habitats. These habitats may provide additional opportunities for use of adsorption.

PERFORMANCE OF NANOFLUIDS IN MICROCHANNEL HEAT EXCHANGERS

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Ravikanth S. Vajjha, University of Alaska Fairbanks

ABSTRACT

Efficient heat transfer to maintain a comfortable temperature in the crew cabin in a space craft, in the space lab and within the enclosure of the space suit is absolutely essential for safe and successful operation of humans in NASA missions. Furthermore, maintaining temperatures of critical electrical and mechanical hardwares in the spacecraft at a lower limit prevents thermal failure and extends the life span of the components. Therefore, superior heat transfer characteristic of a coolant is an essential consideration while designing the thermal control systems of spacecrafts. Nanofluids, which are suspensions of nanometer size particles in the conventional heat transfer fluids, have recently evolved as a superior heat transfer medium. They can reduce the size and weight of heat transfer systems, while requiring less pumping power to transfer the same amount of heat. Additionally, research in recent years implementing microchannels in heat exchangers endowed with highly increased surface area has proven that the miniaturization of heat exchangers are possible, which will reduce the size and weight. Both nanofluids and microchannels would ensure lowering the cost per kilogram to launch and to orbit and should increase the payload carrying capacity. These benefits have motivated us to perform research on comparing the performance of nanofluids flowing in a microchannel heat exchanger. We have considered three different nanofluids; containing aluminum oxide, copper oxide and silicon dioxide nanoparticles dispersed in the same type of base fluid. We have compared their performances with the pure base fluid. Experimental correlations developed for the thermophysical properties, e.g. viscosity, thermal conductivity, specific heat and density of these nanofluids would be presented. Convective heat transfer correlations developed for nanofluids from experiments would also be summarized. Several correlations of Nusselt number and friction factor developed by recent researchers in microchannel flow for single phase liquids and nanofluids will be presented. Using these correlations, we have analyzed the three nanofluids of particle volumetric concentration varying from 1 to 6%. Our results demonstrate the following conclusions. Compared to the base fluid, all three nanofluids exhibit higher convective heat transfer coefficient on the basis of equal Reynolds number. The heat transfer coefficient increases with an increase in particle

volumetric concentration, which should lead to the reduction in surface area and the subsequent size reduction, for dissipating the same amount of heat. However, with an increase in particle volumetric concentration, the pressure loss increases due to an increase in viscosity. This effect requires higher pumping power. The enhancement in heat transfer of some nanofluids at lower particle concentration is proportionately more than the enhancement of pumping power. The analyses indicate that, there exists a preferred type of nanoparticle, aluminum oxide, of an optimum percentage of dilute volumetric concentration, possibly around 2 % that can be determined by a careful optimization study. We will also show that the heat transfer and friction factor correlations of microchannel flow are limited in the existing literature, and some show wide variations, dictating the need for further research.

EFFICIENT THERMALLY CONDUCTIVE STRAP DESIGN FOR CRYOGENIC PROPELLANT TANK SUPPORTS AND PLUMBING

J.P. Elchert, NASA Glenn Research Center

ABSTRACT

After evaluating NASA space architecture goals, the Office of Chief Technologist identified the need for developing enabling technology for long term loiters in space with cryogenic fluids. Heat interception theory, design, and fabrication are critical parts of the solution to this challenging problem. In the case of the cryogenic boil-off reduction system test at the NASA Glenn Research Center, thermally conductive links were an effective compromise between performance and manufacturability. The design methodology for both locating the heat intercept and predicting the reduction in boil-off heat leak is discussed in detail. Results from the chosen design are presented. It was found that contact resistance resulting from different mechanical attachment techniques played a significant role in the form and functionality of a successful design.

TFAWS2012-AT-10

THE TRANSPORT OF MASS, ENERGY, AND ENTROPY IN CRYOGENIC SUPPORT STRUTS FOR ENGINEERING DESIGN

J.P. Elchert, NASA Glenn Research Center

ABSTRACT

Engineers working to understand and reduce cryogen boil-off must solve a variety of transport problems. A barrier to the proliferation of cryogenic technology is the lack of comprehensive references for practicing engineers. One important class of nonlinear problems involves the thermal and mechanical design of cryogenic struts. A review of the literature and theory is presented in this essay along with commentary on the interplay between engineering design approach and simplifying assumptions for theoretical models. Specifically, thermal radiation and conduction combined mode solutions with a discussion on insulation, optimum emissivity, and geometrical phenomenon are presented herein. Solutions to cooling and heat interception problems are also presented, including a discussion of the entropy generation effect. And the literature on the combined mechanical and thermal design of cryogenic support struts is reviewed with a brief introduction to the associated numerical methods.

A RE-ENTRY VEHICLE REACTION CONTROL SYSTEM THERMO-FLUIDIC ANALYSIS APPROACH

Lorenzo Andrioli, Thales Alenia Space
Savino De Palo, Thales Alenia Space

ABSTRACT

A general analysis methodological approach defined and implemented in the frame of a Reaction Control System (RCS) thermo-fluidic analysis campaign is presented. The developed approach is being refined to be adopted for the ESA IXV re-entry vehicle RCS design assessment activity. The modeled RCS is basically a tubing network connecting a spherical elastomeric diaphragm propellant tank to the thruster units. Considering a common propellant such as hydrazine, thus liable of self-ignition above 75°C (167°F), the main objective is to give a comprehensive evaluation of the fuel behavior through all the mission phases. The variety of the analysis cases performed lets achieve the secondary objective of the study. The latter is to give an estimation of the maximum and minimum temperature reached by the items and devices constituting the RCS, such as valves, filters, etc. To achieve such a result, a robust and reliable approach has been developed, to give both an acceptable run time and a precise solution focused to the temperature calculation especially into the network dead ends and stagnating branches. The environment the RCS copes with is a set of boundary conditions extrapolated from the System Level Thermal Mathematical Model (IOTMM) simulating the whole vehicle thermal behavior. As a result a set of three SindaFluint models has been built to assess the worst operating conditions through which the hydrazine loop shall go during the whole mission duration. Moreover, the critical phase of purging operated by the pressurant discharge has been modeled, thus giving a clear description of the gas behavior while flowing through the piping. The results obtained through the analysis campaign are a key point of an RCS design assessment. Thanks to the adopted modeling techniques propellant temperature criticalities are easily spotted. Further improvements from the items and devices thermal modeling standpoint are foreseen, for the actual configuration is mainly focused on the fluidic aspect.

IV & V OF ORION ACTIVE THERMAL CONTROL SYSTEM (ATCS) DYNAMIC MODELS

Xiao-Yen J. Wang, NASA Glenn Research Center

ABSTRACT

This paper presents independent verification and validation efforts at NASA Glenn Research Center (GRC) for the crew exploration vehicle (Orion) active thermal control system (ATCS) dynamic models. An independent ATCS model was built at GRC using Simulink/Matlab to validate the Orion ATCS performance for both ISS and Lunar missions. The current ATCS Simulink model includes major components in ATCS, such as heat exchangers and radiator panels, and the control algorithms. The ATCS performance for the ISS mission is verified with a SINDA/FLUINT ATCS model built by Hamilton Sundstrand (HS). The sublimated water during different attitudes occurring in the mission timeline, such as Tail Nadir, Tail forward, Tail to sun, Nose forward, and ISS docked, are computed and compared with the results generated by SINDA/FLUINT model as shown in Fig. 1. The total water usage for ISS mission, (171 lbm without safe heaven, DAC-3 data) was also verified. The details of the model and comparison will be presented in the final paper.

TFAWS2012-AT-13

SCALING TOOL FOR MODELING SINGLE STAGE REVERSE TURBO-BRAYTON CYCLE CRYOCOOLERS WITH A BROAD AREA COOLING SYSTEM FOR CRYOGENIC PROPELLANT TANKS

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Thomas M. Tomsik, NASA Glenn Research Center

ABSTRACT

In the pursuit of long-duration space exploration, a growing need has arisen for the development of active cooling systems for cryogenic propellant storage tanks in order to reduce or eliminate the mass loss of the cryogenic fuel that is caused by boil-off. One method of actively cooling a cryogenic storage tank involves the use of cryocoolers with a distributed Broad Area Cooling (BAC) system. However, current cryocooler technology has been oriented towards heat removal at very small heat loads when operating at temperatures near those required for liquid hydrogenstorage. As focus shifts to larger tanks and longer missions, the heat load requirements on the cooling system increase dramatically. It has been theorized that the Reverse Turbo-Brayton Cycle (RTBC) cryocooler is currently the most capable technology for efficiently managing these large heat loads. This paper illustrates a method for scaling an active cooling system consisting of a single stage RTBC cryocooler and integrated BAC network from the low capacity designs currently in use to the large heat loads associated with future missions. The described method utilizes fundamental thermodynamic and fluid relationships and turbomachinery scaling laws to perform a comprehensive component-level analysis of the cooling system for a wide range of tank sizes and applications. Preliminary validation efforts include comparison with a previously published low-capacity model, as well as proposed scaling results generated by an inhouse extensibility study. Forward work will include further validation with experimental results generated during testing performed at NASA Glenn Research Center's Small Multi-PurposeResearch Facility (SMiRF) during the upcoming year.

TFAWS2012-AT-14

OVERVIEW OF OCT'S GAME CHANGING SOLICITATION FOR VARIABLE HEAT REJECTION TECHNOLOGIES

Rubik Sheth, NASA Johnson Space Center

ABSTRACT

Abstract not available at time of publication.