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Effect of Elevation and Altitude on Heat Exchange Process on Fighter Aircrafts Engine and Optimization of Heat Transfer Rate by Using Sodium- Potassium Alloy

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Abstract:
In the fighter aircrafts it is very important to have minimum heat transfer rate across the periphery of the aircrafts so that the amount of thrust produced by the engine do not diminished by the phenomenon known as heat transfer across the body of fighter jets. The cited article is thought towards providing a efficient and advance for minimizing the heat lost across the different sections of fighter air jets so the fighter air jets do not compromise its velocity and Mach due the temperature lost gradients. The modern aircrafts come with the advance engine cooling technology, but due the design consideration and other macroscopic factors the amount of heat lost has not been minimized yet, thus the supersonic speed of fighter air jets somewhat gets decline value. In this cited article the main focus is directed towards providing a optimum solution for the problem that is being encountered in the present fighter jets, so that the reduction in the supersonic speed due the phenomenon of heat transfer can be fixed in order to get desired sonic and supersonic speed

Keywords: *Sodium- Potassium Alloy, Mach Speed, Radiation Losses, Heat Exchangers*

I. INTRODUCTION

The fighter aircrafts needs very minute design consideration while designing the various components of fighter air jets in order to have the desire speed and acceleration, due to operation of fighter aircrafts at very high altitude the surrounding environment encountered by air jets is critical one and due to this there is sudden change in the phenomenon of heat transfer and there is enormous chances of malfunctions of the engines[1], In order to compensate these losses the concepts of suitable cooling system in the fighter air jets is very much essential for normal functioning of jets engines even at very high altitude and drastic surrounding temperatures. The major problem which is being encountered with the conventional cooling system is that they have tendency to deviate from its desired nature of cooling at very critical temperature and environment [2], so it is very much essential to look for modern cooling system in aircraft's so that it can meet even supercritical conditions and provide proper thrust to the jets without compensating with its performance [3]. The present article will discuss the major implication on the performance of aircraft's by implementing the sodium-potassium alloy cooling system and try to plot a critical comparison between the conventional cooling system and the present sodium-potassium alloys cooling system, so that the demand of efficient cooling system in the 5th generation aircrafts may be fulfilled at efficient cost.

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II. LITERATURE REVIEW

There is not much research happened in the field of optimizing the heat transfer rate across the periphery of fighter air jets there are some articles which discuss the phenomenon of heat transfer in the supersonic fighter air jets, In this contextA.C.Bhaskar,R. Sathyanarayanan& S. Paul Vizhian in their article discussed the factors which must be meet in order to make an heat exchanger for aircrafts[4]. J.L.G oliveria, CassianoTecchio and other in their article ‘passive aircrafts cooling system for variable thermal conditions’, discussed the effects of variable thermal conditions from temperature ranging from - 30-50 degreeCelsius for the natural and forced convection process due to which there was significant effect on the cooling rate[5]. In the article published by A V Chichindaev, he focused on the cooling compressed by the negative temperature that exists between heat exchanger and turbines[6]. In the article published by YasinOzdemir, MuammerOzgoren, IlkerGoktepeli they focused on the case of energy analysis for the air conditioning effect in the AIRBUS A330 and tried to investigate all those phenomena that will affect the health of crew members as well as passengers by the effect of air conditioning at very high altitude[7]. In the article published by Joseph Palmer, EssamShehab they tried to focus on Demonstrating of cryogenic cooling framework plan ideas for superconducting flying machine impetus and thus study is only compacted to particular case and that is cryogenic engines[8]. In the article published by G. Romeo; E. Cestino; F. Borello; and G. Correa they tried to concentrate their study on Building Method for Air-Cooling Design of Two-Seat Propeller-Driven Aircraft Powered by Fuel Cells and obtained a specific result that will suit in the particular case[9]. Apart from these there are many articles from online as well offline sources that has been consulted to make the study very intensive so that the problem which is being encountered presently may be minimized.

Properties of Sodium-Potassium Alloy:

Properties	**Numerical Value**
Density	• 0.866 g/cm^3,20°C • 0.855 g/cm^3,100°C • 0.749 g/cm^3,550°C
Thermal Properties	
Melting temperature (T_m)	−12.6 °C
Thermal conductivity (k) at 100 °C	0.224 W/cm
Specific heat capacity (c)	982 J/ kg·K

Table:1: Properties of Na-K alloy

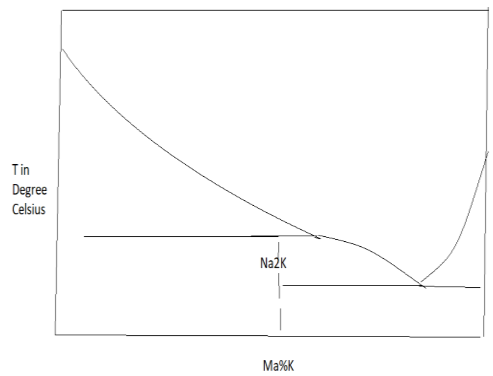

Fig:1: Properties curve for Na-K alloy.

Na-K has been utilized as the coolant in test quick neutron atomic reactors. In contrast to economic commercial plants, these are now significantly used and defueled. Utilization of lead or unadulterated sodium, different materials utilized in pragmatic reactors, would require ceaseless warming to keep up the coolant as a fluid. Utilization of Na-K conquers this[10]. In achieving the desired target for which this article is cited the eutectic mixture of sodium-potassium alloy may be very beneficial for maintaining the required thrust by compacting the heat through the wall of aircrafts engine prevent the heat loss due to its significant properties(table:1) by

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either conduction, convection or radiation[11]. The synthesis of Na-K alloy is usually done by the process known as reactive distillation and in most of the cases it find its application in heavy nuclear reactor[12]. the purpose of using the eutectic mixture of Na-k is to enhance the thrust of the fighter jet propulsion by minimizing heat lost by various mode that usually happens in conventional fighter aircrafts and the enhance properties of Na-K alloy is mainly due to is eutectic mixture composition and chemical synergy as shown by the Fig:1 [13].

Performance of Fighter Aircrafts with conventional cooling systems:

In the conventional fighter aircrafts the concept of natural and forced convection currents are applied for studying the heat lost without considering much about the effect of radiation heat lost in designing the heat exchanger for the aircrafts[14], in designing the heat exchanger for aircrafts there are numbers of test which the heat exchanger must qualify in order to work as per requirement and can be listed as, Proof Pressure Test ,Thermal Shock, Pressure Cycling Test,Burst Pressure Test,Vibration Test,Acceleration Test,Mechanical Shock Test,Humidity Test,Combined Pressure and Temperature & Flow Rate (CPTF) Cycling Test[15]. Fig:3 shows how Various Heat Transfer Process Across the different section of Fighter Jet, through which the transfer of heat and mass occurs in the aircrafts while its operation.The major disadvantage of the conventional of conventional heat exchanger that are designed while considering the above design parameters is that the effect of heat lost at very high velocity and very high altitude is studied without inserting the effect of radiation heat losses due to which the effect on the Mach speed of aircrafts reduces at the greater extent[16].

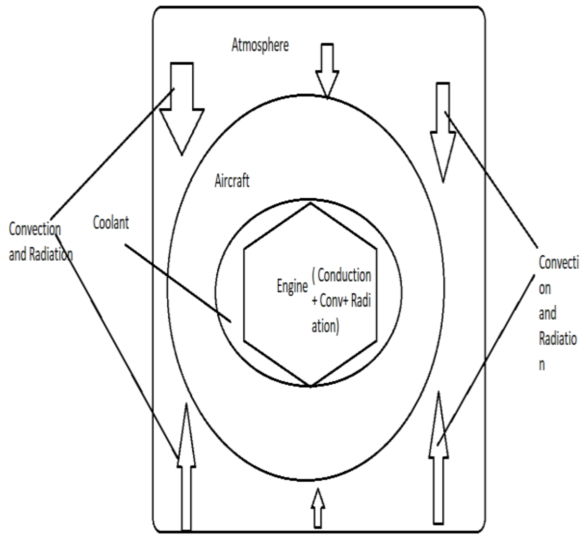

Fig:3: Various Heat Transfer Process Across the different section of Fighter Jet.

Due to mainly dependent upon the forced and natural convection current in cooling system there is huge lagging in the turboshaft speed and the turbine heat exchanges rate somewhat disturbed[17], due to which the convection current takes away the heavy amount of thrust generating current and the required thrust rate is not obtained[18].

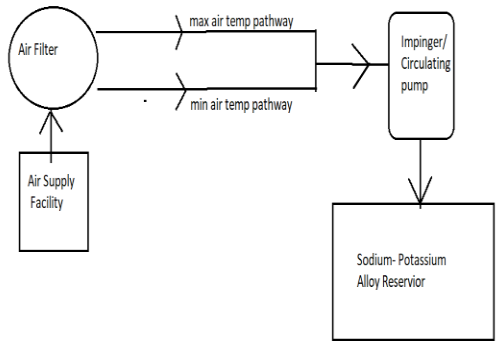

Fig:4:Mechanism of Cooling inside Engine of jet.

Cooling Requirements:

The most essential external aerodynamic effect which the consideration and relevant to the utilize the thermal environmentin heating of the fluid or air in the boundaryor periphery layer that envelops the aircraft which causes the effect arises from conversion of kinetic energy to stored molecular or

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internal energy[19], and from viscous resistance which is being offered to the aircrafts body at supersonic Mach speed and relatively very high altitude and low surrounding temperature[20]. In all the effect of conversion the adiabatic heat exchange process is assumed so to have the minimum losses of energy to the surrounding[21]. Effect of Radiation Heat Transfer Coefficient with temp is clearly be predicted by the graph as shown in fig:6, which is the crucial aspects in designing the heat exchanger of fighter air jets.

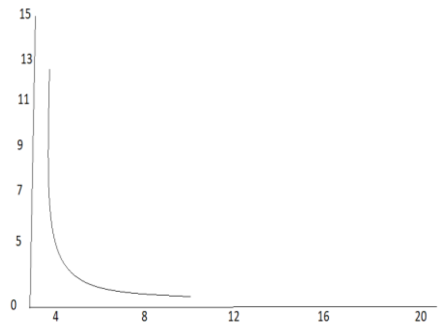

Fig:5: Effect of Convection Heat Transfer Coefficient with temp. (T on Y axis and h_a on X axis)

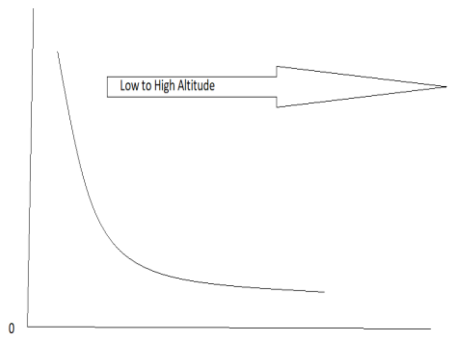

Fig:6: Effect of Radiation Heat Transfer Coefficient with temp. (T on Y axis and Radiation Heat transfer Coefficient on X axis)

Streamlined warming is touchy to the Mach-elevation flight envelope of the airplane and the outer air temperatures[22].Radiation heat losses and transfer is generally being ignored in the warm examination of the encompassing cooled hardware[23]. Besides, airplane producers' details for flying heat structure ordinarily necessitate that the heat plan of the surrounding cooled flight gear depend just on normal convection to carry out the responsibility[24]. In this postulation, nonetheless, the impacts of the radiative heat transfer on the warm exhibition of the surrounding cooling as an element of elevation are demonstrated to be significant[25].

Equations:

General Equationfor convection heat transfer.

Nu=C(Gr*Pr)^n=CRa^n--------------------(1)

$\frac{h*l}{k}$ = C($\rho g_c \beta C_P \Delta T L$^3\\$\mu$^2 $*$ $\mu \backslash c_p k$)^n-(2)

Q=hAΔT------------------------------------(3)

Where c_p= specific heat constant pressure,

g_c= gravitational acceleration

Gr= Grashof Number

h= Heat transfer coefficient

k= Thermal conductivity of air.

L= length of plate.

Nu= nusselt number

Pr= Prandlt number

Ra= Rayleigh Number

T1= Temp of ambient air

T2= Temp of heated surface.

ΔT= Temp difference

B= Coefficient of thermal expansion of air

ρ&μ= density and dynamic viscosity of air.

For radiation losses

$$\delta E(\text{MeV}) = 8.85 \times 10^{-2} \frac{[E(\text{GeV})]^4}{\rho(\text{meters})}. \qquad (1656)$$

In which all the terms have usual meanings

Performance by Na-K alloy as a coolant:

When the Eutectic mixture of sodium and potassium alloy is used as the coolant in the heat sink of the fighter aircrafts then the numbers of parameters is may be obtained and thus the significant results is differentiated from typical conventional heat exchangers used in fighter air jets(fig:8). When the volume of sodium and potassium alloy as coolant is stored with the forced circulation pump being installed to supply the Na-K mixture in every section of the engine periphery then it may constitute that the obtained results far differ from the conventional one in major aspects(fig:9). It can also be constituted that how the Propagation of Temperatures across the different section of Fighter Aircraft and how much its numerical value vary to obtain significant result(fig:7)

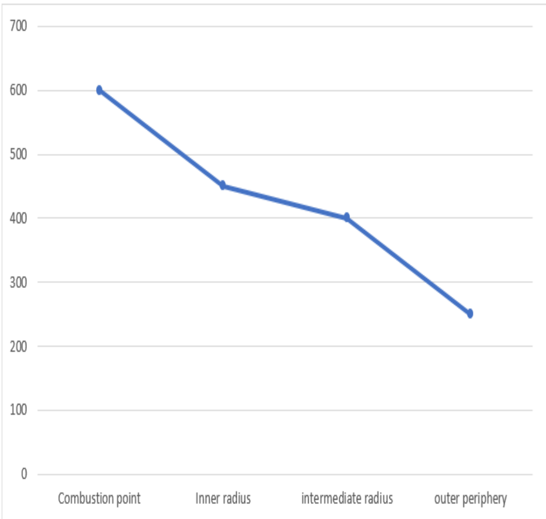

Fig:7: Propagation of Temperatures across the different section of Fighter Aircraft

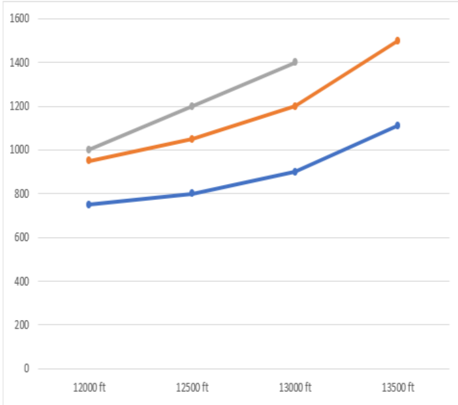

Fig:8: Heat loss in watt with the elevation and Mach Speed of Fighter jet

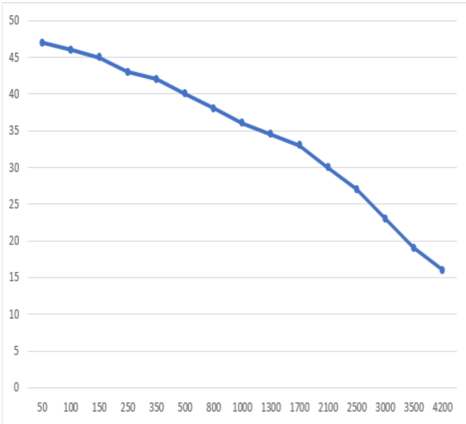

Fig:9: Variation of Temperatures With Elevation

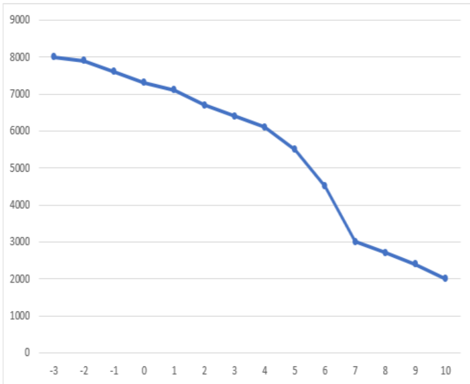

Fig:10:Realtion between Pressure Exerted and Elevation on Fighter Jet.

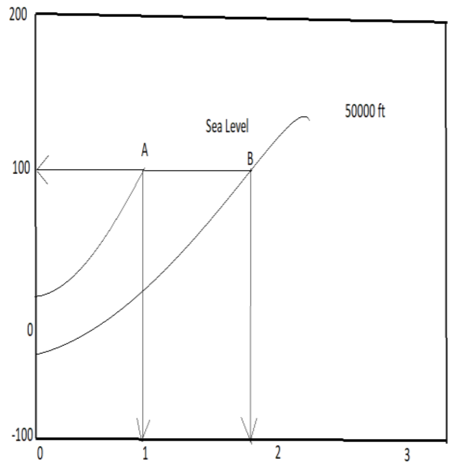

Fig:11: Isentropic Air temperature at the Periphery of Fighter Jets Vs Mach Speed and Elevation

III. RESULTS AND DISCUSSION:

With the use of proper eutectic mixture of sodium and potassium alloy there is significant results which are obtained and enhanced(fig:10).which may be noted and when they compared with the conventional heat exchanger results there is sharp corner for their differentiated results(fig:10). Due to the enormous potential of sodium and potassium alloy and remarkable proprieties(fig:11), they may find its suitability in the most advance fighter air jets which is presently being in the developmental phase. The scope of research regarding this article is not limited to this obtained result but it can be extended to large optimized results

References:

[1].Dieckmann, R., Kofeld, Otto, and Jenkins, Larry C. Increased Avionics Cooling Capacity for F-15 Aircraft. SAE Sixteenth ICES, San Diego, 1986.

[2].Feldmanis, C. J. Cooling Techniques and Thermal Analysis of Circuit Board Mounted Electronic Equipment. The Winter Annual Meeting of ASME, Washington D.C. , 1981.

[3].Personal communication with Jerry E. Hall. Technical Specialist in Enginnering Technology, Propulsion and Thermodynamics. McDonnell Douglas Corporation, 1989.

[4]. A.C. Bhaskar,R. Sathyanarayanan& S. Paul Vizhian,Qualification of an aircraft compact heat exchanger.

[5]. J.L.G oliveria, CassianoTecchioPassive Heat Exchange System for Aircraft Equipment Cooling Applications.

[6]. A V Chichindaev, Research on Heat Exchange Process in Aircraft Air Conditioning System.

[7].YasinOzdemir, MuammerOzgoren, IlkerGoktepel ,ENERGY ANALYSIS FOR AN AIR-CONDITIONING SYSTEM OF A COMMERCIAL AIRCRAFT: CASE STUDY FOR AIRBUS A330.

[8].Joseph Palmer, EssamShehabModelling of cryogenic cooling system design concepts for superconducting aircraft propulsion.

[9].G. Romeo; E. Cestino; F. Borello; and G. Correa, Engineering Method for Air-Cooling Design of Two-Seat Propeller-Driven Aircraft Powered by Fuel Cells

[10].Howells, I. Aircraft Cooling Techniques. AGARD Conference proceedings No. 196 on : AVIONIC COOLING AND POWER SUPPLIES FOR ADVANCED AIRCRAFT, November, 1976.

[11].Personal communication with Charles T. Leonard. Research & Development Environmental Controls. Boeing Commercial Company, 1989.

[12].Nordwall, Bruce D. Boeing Studies Passive Cooling for Next-Generation Avionics. Aviation Week & Space Technology, January 4, 1988.

[13].Steinberg, Dave S. Cooling Techniques for Electronic Equipment. John Wiley & Sons, New York, 1980.

[14].Military Standard. MIL-STD-810C : Environmental Test Methods. U.S. Dept. of Defense, 1975.

[15].Jackson, S. Keith Jr. The Effect of Avionics System Characteristics on Fighter Aircraft Size, Cooling, and Electrical Power

ISSN: 0193-4120 Page No. 15955 - 15961

Subsystems. AGARD Conference proceedings No. 196 on : AVIONIC COOLING AND POWER SUPPLIES FOR ADVANCED AIRCRAFT, November, 1976.

[16].Kraus, Allan D. Cooling Electronic Equipment. Prentice-Hall, Inc. Englewood Cliffs, N.J., 1965.

[17].Herald Schonenborn, Prurkhard Simon, Ernst Ebert, Paul Storm, “Thermo-mechanical Design of heat exchanger for a recuperative aero engine”, Proceedings of ASME Turbo Expo 2004; Power for Land, Sea and Air, Vienna, Austria, June 14-17, 2004.

[18].Pellischek. G, “Compact heat exchanger technology for Aero Engine”, Proceedings of International Symposium on Air breathing engines, P 203-208, 1991.

[19].PS 68-870. F-15 -Procurement Specification for Avionics. McDonnell Douglas Corporation, 1984.

[20].Allison, D.L., "Multidisciplinary Analysis and Design Optimization of an Efficient Supersonic Air Vehicle". 2013, Virginia Polytechnic Institute and State University.

[21].Https://eic.rsc.org/2000056.Article/Sodium-Potassium Alloy.

[22].Bodie, M., et al., Thermal analysis of an integrated aircraft model. AIAA Paper, 2010. 20: p. 0-288.

[23].Shah, R.K. and D.P. Sekulic, Fundamentals of heat exchanger design. 2003: John Wiley & Sons.

[24].Williams, M., et al., "Advanced heat exchanger technology for aerospace applications". 2008, SAE Technical Paper. 64

[25].Warren M. Rohsenow, J.P.H., E.N. Ganic, Handbook of heat transfer applications. 1985, McGraw-Hill, New York.