J58 (JT11D-20) Preliminary Design and Analysis

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**As part of the INME 4707 course offered at the Department of Mechanical Engineering, University of Puerto Rico at Mayaguez, we are required to model and analyze the thermal performance of a J58 Turbojet engine.**

1. **Nomenclature**

*A* = amplitude of oscillation

*a* = cylinder diameter

*Cp*= pressure coefficient

*Cx* = force coefficient in the *x* direction

*Cy* = force coefficient in the *y* direction

c = chord

d*t* = time step

*Fx* = *X* component of the resultant pressure force acting on the vehicle

*Fy* = *Y* component of the resultant pressure force acting on the vehicle

*f, g* = generic functions

*h* = height

*i* = time index during navigation

*j* = waypoint index

*K* = trailing-edge (TE) nondimensional angular deflection rate

1. **Introduction**

INSERT INITIAL INTRODUCTION

## Problem Statement

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## Background Information



Figure 1: Standard J11D-20 Station Nomenclature [1]

Table 1: Maximum Operating Temperatures [1] [2]

|  |  |  |
| --- | --- | --- |
| COMPONENT/STAGE | TEMP (ºF) | TEMP (ºC) |
| Inlet T1 | 800+ | 426+ |
| COMPRESSOR Inlet T2 | 800+ | 426+ |
| COMPRESSOR 4th Stage TD | 1050 | 565.56 |
| COMBUSTOR Inlet T3 | 1300 | 704.44 |
| TURBINE Inlet T4 | 2000 | 1093.33 |
| TURBINE Exit T5 | 1450 | 787.78 |
| AB T6 | 3200 | 1760 |
| Exhaust NOZZLE T8 | 1500 | 815.15 |

The JT11D-20 variant of the P&W J58 engine has several components that merit some explanation. For instance, Figure 1 depicts a Bypass Air and Secondary Air Flow; the engine behaved as a traditional afterburning turbojet from subsonic to Mach 2.2, but transitioned to a turboramjet at Mach 2.2 . Above Mach 2.2, 6 valves bypass air from the fourth compressor stage (Station D) to the afterburner thereby combining a turbojet with a compressor assisted ramjet. However, this report will limit the analysis to conditions below Mach 2.2 in order to consider the turbojet nature of the JT11D-20. The secondary airflow depicted in Figure 1 allows “descent at low airflow, low power, without unstarting the inlet.“ [3] (It is also shared with the cowl shock trap bleed as per [3].)

The JT11D-20 was designed for a wide range of operational requirements which included sub- and supersonic flight conditions and a wide range of altitudes. This versatility requires the designed to be evaluated at several conditions which are listed in

Table 2: Engine Specs

|  |  |  |
| --- | --- | --- |
| SPECIFICATION | VALUE RANGE [EN] | VALUE RANGE [SI] |
| **Altitude** [4] | **25K-90K ft** | **7.62 – 27.43 km** |
| **Speed** [5] | **Mach 0.75 – 3.2** | |
| **Dry TSFC @ Max Thrust** [6] | **0.8 lb/lbf hr** | **81.6 kg/kN hr** |
| **Wet TSFC @ Max Thrust** [6] | **1.9 lb/lbf hr** | **164 kg/kN hr** |
| **Fuel** [7] | **JP-7** | |
| **Fuel Storage** [8] | **80,285 lb** | **36,416 kg** |
| **Fuel Lower Heating Value** [9] | **5.48 kWh/lb** | **43,682 kJ/kg** |
| **Thrust** [7] | **32,500 lbf** | **144,567 N** |
| **Air Volume Flow @ Cruise** [10] | **100K ft3/s** | **2831.68 m3/s** |
| **Compression Ratio < Mach 2.2** [8] | **8.8:1** | |
| **Compressor** [11] | **8-Stage Axial** | |
| **Turbine** [11] | **2-Stage** | |
| **Weight** [11] | **6,500 lb** | **2,948 kg** |
| **Air Mass Flow** [8] | **326-450 lb/s** | **147 – 204 kg/s** |
| **Dry Fuel Mass Flow @ Max** | **5.55 lb/s** | **2.52 kg/s** |
| **Wet Fuel Mass Flow @ Max** | **17.94 lb/s** | **8.14 kg/s** |
| **Dry Fuel to Air Ratio** | **0.012-0.017** | |
| **Wet Fuel to Air Ratio** | **0.0398-0.055** | |
|  |  |  |

Table : Validation Flight Conditions

|  |  |  |
| --- | --- | --- |
| Condition ID | Altitude [ft] | Mach |
| Takeoff [2] | 0 | 0.3542 |
| Refueling/Buddy Mission [2] | 25000 | 0.75 |
| Climbing [2] | 30000 | 1.25 |
| Concorde [12] | 60000 | 2.00 |
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# References

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| --- | --- |
| [1] | P. Law, *SR-71 Propulsion System P&W J58 Engine (JT11D-20),* 2013. |
| [2] | *SR-71 Flight Manual,* Norton, CA: Norton, AFB, 1986. |
| [3] | J. T. Anderson, "How Supersonic Inlets Work: Details of the Geometry and Operation of the SR-71 Mixed Compression Inlet," Lockheed Martin Corporation, 2013. |
| [4] | C. L. Johnson, "Development of the Lockheed SR-71 Blackbird," *Lockheed Horizons,* 1982. |
| [5] | T. R. Conners, "Predicted Performance of a Thrust- Enhanced SR-71 Aircraft with an External Payload," *NASA Technical Memorandum 104330,* 1997. |
| [6] | Jet Engine Specification Database, "Military Turbojet/Turbofan Specifications," [Online]. Available: http://www.jet-engine.net/miltfspec.html. [Accessed 11 04 2018]. |
| [7] | Atomic Toaster, "A Look at the Pratt & Whitney J-58JT11D-20," 22 August 2012. [Online]. Available: http://atomictoasters.com/2012/08/a-look-at-the-pratt-whitney-j-58jt11d-20/. [Accessed 17 03 2018]. |
| [8] | R. H. Graham, SR-71 Revealed: The Untold Story, Osceola, WI: Zenith Imprint, 1996. |
| [9] | Coordinating Research Council, Inc., "Handbook of Aviation Fuel Properties (CRC Report No. 530)," Society of Automotive Engineers, Inc., Warrendale, PA, 1983. |
| [10] | P. W. Merlin, "Design and Development of the Blackbird: Challenges and Lessons Learned," in *47th AIAA Aerospace Sciences Meeting Including The New Horizons Forum and Aerospace Exposition*, Orlando, FL, 2009. |
| [11] | National Air and Space Museum, "Pratt & Whitney J58 (JT11D-20) Turbojet Engine," [Online]. Available: https://airandspace.si.edu/collection-objects/pratt-whitney-j58-jt11d-20-turbojet-engine. [Accessed 17 03 2018]. |
| [12] | U. K. Saha, *Jet Propulsion: The Concorde Aircraft,* Guwahiti, India: Indian Institute of Technology Guwahiti. |
| [13] | T. R. Conners, "Predicted Performance of a Thrust-Enhanced SR-71 Aircraft With an External Payload," , 1995. [Online]. Available: https://ntrs.nasa.gov/search.jsp?r=19970019923. [Accessed 24 3 2018]. |

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