Flow Characteristics of Manufacturing Defects on Lip Skins and the Effect on Specific Fuel Consumption

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Introduction

Problem Statement
Analysis shows that inlet lip skins with manufacturing defects could increase SFC. GKN Aerospace wants to understand that relationship.

Motivation/Background
Waviness Defect
- GKN Aerospace provided tolerance guidelines for waviness
- Analyzing outside the tolerance is expected to provide the defect’s impact on SFC if the tolerance was loosened
- Products within the tolerance are assumed to have negligible effects on SFC

Environmental Consideration: Providing our findings would help decrease fuel consumption for customers

Waviness Guidelines
L: wavelength
N: nominal contour
D: wavelength min/max depth

Waviness Guidelines

Detail Design

GKN provided a generic lip skin model (Left, cross section).
Modified lip skin model with constant thickness, taken from the thickest cross section of the provided lip skin. This will simplify simulations, and most of changes will occur where most of the defects are present, i.e. the thickest cross section (Right, cross section).

Axisymmetric simulations will be used to separate cells into two regions: Laminar Region and Turbulent Region.
- Spalart Allmaras turbulent model

Validation – NACA 0012
Since the defects are too small to model physically, the validation process involves creating a planar 2D simulation of NACA 0012 and comparing with experimental data, then creating a planar 2D simulation of our nacelle and comparing with the NACA 0012 since the shape of the nacelle is similar to the shape of an airfoil. The methods used to accomplish these simulations will be the same methods used for axisymmetric flow. The results compared are similar with a drag count of 3.

With this, we are able to apply axisymmetric flow to our nacelle with confidence that our method is valid.

Design Process

Customer Specifications

Laminar Flow Surface (LFS)
- Tolerance = 0.0020 D/L
  - For wavelengths (L) exceeding 2" Tolerance = 0.0025 D/L

Critical Flow Surface (CFS)
- For wavelengths (L) exceeding 2"

Hilite Flow Surface (HFS)
- Tolerance = 0.0050 D/L
  - For wavelengths (L) exceeding 2"

Environmental Consideration: Providing our findings would help decrease fuel consumption for customers

Results

The nine models are varied in waviness, and the coefficient of drag is compared to the ideal model (no defects). The goal is to determine how the waviness affects specific fuel consumption.

\[ SFC = \frac{\text{Fuel mass flow rate}}{\text{Net Thrust}} \]

Re= 1,213,357

<table>
<thead>
<tr>
<th>Model</th>
<th>( \Delta C_D ) From Ideal</th>
<th>% Difference</th>
<th>SFC (inc or dec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>0.0112e-03</td>
<td>0.327</td>
<td>Increase</td>
</tr>
<tr>
<td>Model 2</td>
<td>-0.0186e-03</td>
<td>0.264</td>
<td>Decrease</td>
</tr>
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<td>Model 5</td>
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<td>0.110</td>
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<td>Model 6</td>
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<td>0.440</td>
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<td>0.324</td>
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<td>Model 8</td>
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<td>0.093</td>
<td>Decrease</td>
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<tr>
<td>Model 9</td>
<td>0.0146e-03</td>
<td>0.423</td>
<td>Increase</td>
</tr>
</tbody>
</table>

If the coefficient of drag increases from ideal, then net thrust decreases, and SFC increases, and vice versa. Ideally, SFC should be decreased.

Analysis

Each surface will exceed their tolerances at the same percentage

- 9.5 in. greater than W1 (6.5 in. max, HFS 2.5 in.)
- 6.5 in. greater than W2 (5.5 in. max, HFS 2.5 in.)

Project Analysis Components: Knowledge and analysis of fluid mechanics and flight mechanics are the main components of engineering analysis.

Tools: Using a basic CAD file of a lip skin provided by GKN, we used 2D computational fluid dynamics (CFD, Ansys) to analyze flow and drag characteristics of various defects.

References
2. “2DN00: 2D NACA 0012 Airfoil Validation Case.” NASA, NASA, 11 Apr. 2018

Acknowledgments
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