LEWICE3D/GlennHT Particle Analysis of the Honeywell Al502 Low Pressure Compressor

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Analysis of AL502 Engine Only PSL Configuration

- A new grid was developed which modeled the region from the exit of the PSL bell mouth to the exit of the transition duct between the low and high pressure compressors.
- A coarse grid and a refined grid was developed for this configuration. The coarse grid model was used for this analysis.
- Flow solutions were generated for a rollback condition (DP0443) and a non-rollback condition (DP0226).
- Particle computations were made using a 5 micron ice particle and a 7 bin 24 micron MVD ice particle distribution subject to phase change.
- A fully sticky impact model was chosen for the 5 microns ice particle analysis.
- The 24 micron model employed an SLD splash model to emulate particle breakup. This model probably generates more impingement on the surfaces than an ice particle impact model due to the stickier nature of liquid water versus ice.

Analysis of AL502 Engine Only PSL Configuration, cont.

- Modifications were made to the LEWICE3D code to update the relative humidity at each mixing plane. Previously the input free stream relative humidity was used to initialize the parcels at each mixing plane. This had the effect of generating more evaporation of the particles because the relative humidity decreases with the increase in flow temperatures. The evaporation was more pronounced at the smaller particles sizes.
- To resolve the particle parcel parameters (beta, temperature, melt fractions) along the duct walls sufficiently the capability to refine certain patches to a higher level was added to the code. Typically the default setting for convergence (beta +/-.01) did not resolve areas with small beta very well (beta less than .02). Decreasing the convergence tolerance generated better results but at the cost of a very large number of parcels (50 million) in the rest of the region where the convergence was reasonable at the default convergence setting. Targeting the low beta duct walls with the new patch refinement capability generated a more reasonable increase in the amount of trajectory work (10-50%).

Analysis of AL502 Engine Only PSL Configuration, cont.

- Modified mass averaging of temperature and melt fraction to be enthalpy based rather than on the values themselves. For some cases which involved the averaging of parcels with fully melted and partially melted parcels the resulting temperature was higher than freezing while the melt fraction was between 0 and 1 which was not correct for perfect mixing.

Analysis of AL502 Engine Only PSL Configuration, cont.

- In-flow Conditions for PSL case DP0443 (rollback):

  Airspeed, 145 m/s

  Static Pressure, 33,373 Pa

  Static Temperature, 253.3 K

  LWC, 2 g/m^3

  Relative Humidity, 100%

- In-flow Conditions for PSL case DP0256 (non-rollback):

  Airspeed, 153 m/s

  Static Pressure, 34,252 Pa

  Static Temperature, 260.1 K

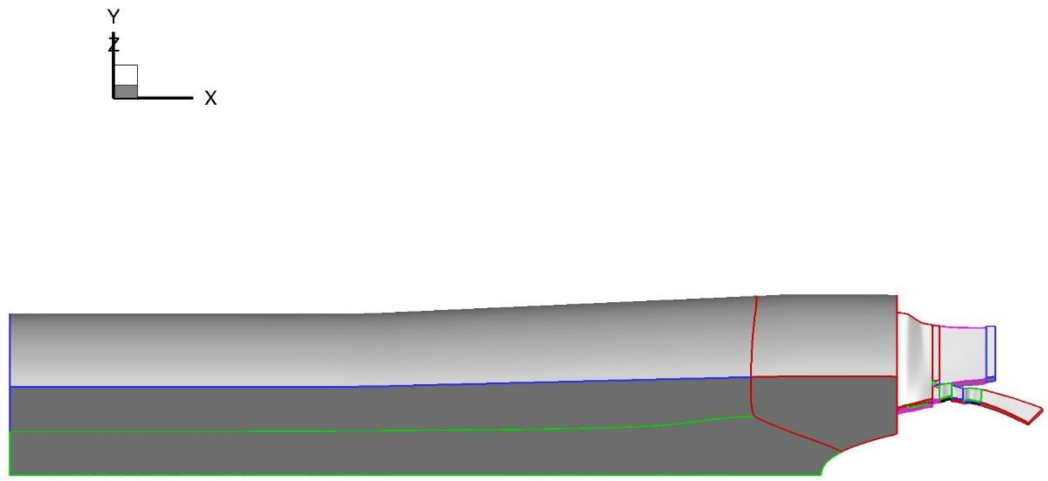
  LWC, 1 g/m^3

  Relative Humidity, 100%

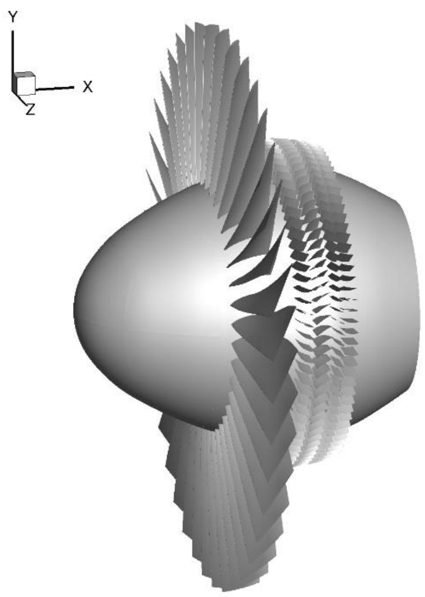
AL502 Low Pressure Compressor

- The particle analysis, which considered sublimation, evaporation and phase change, was generated for a 5 micron ice particle with a sticky impact model and for a 24 micron, 7 bin ice particle distribution with an SLD splash model used to simulate ice particle breakup.
- An SLD splash model was chosen for the 24 micron distribution case to simulate the ice particle breakup because a model was not available and it was thought that the breakup characteristics of an ice particle were similar to that of a similarly sized water droplet. Although the SLD splash model generates more impingement on a surface than an ice particle impact model due to the stickier nature of liquid water versus ice it is useful because it can give an indication of the location and state of the impacting particles which is useful for assessing regions which are at risk for icing.
- The particle concentration was 2 g/m^3 for case DP0443 and 1 g/m^3 for case DP0256.
- The particles were released at station -120 in a fully frozen state at the static temperature of the surrounding flow.

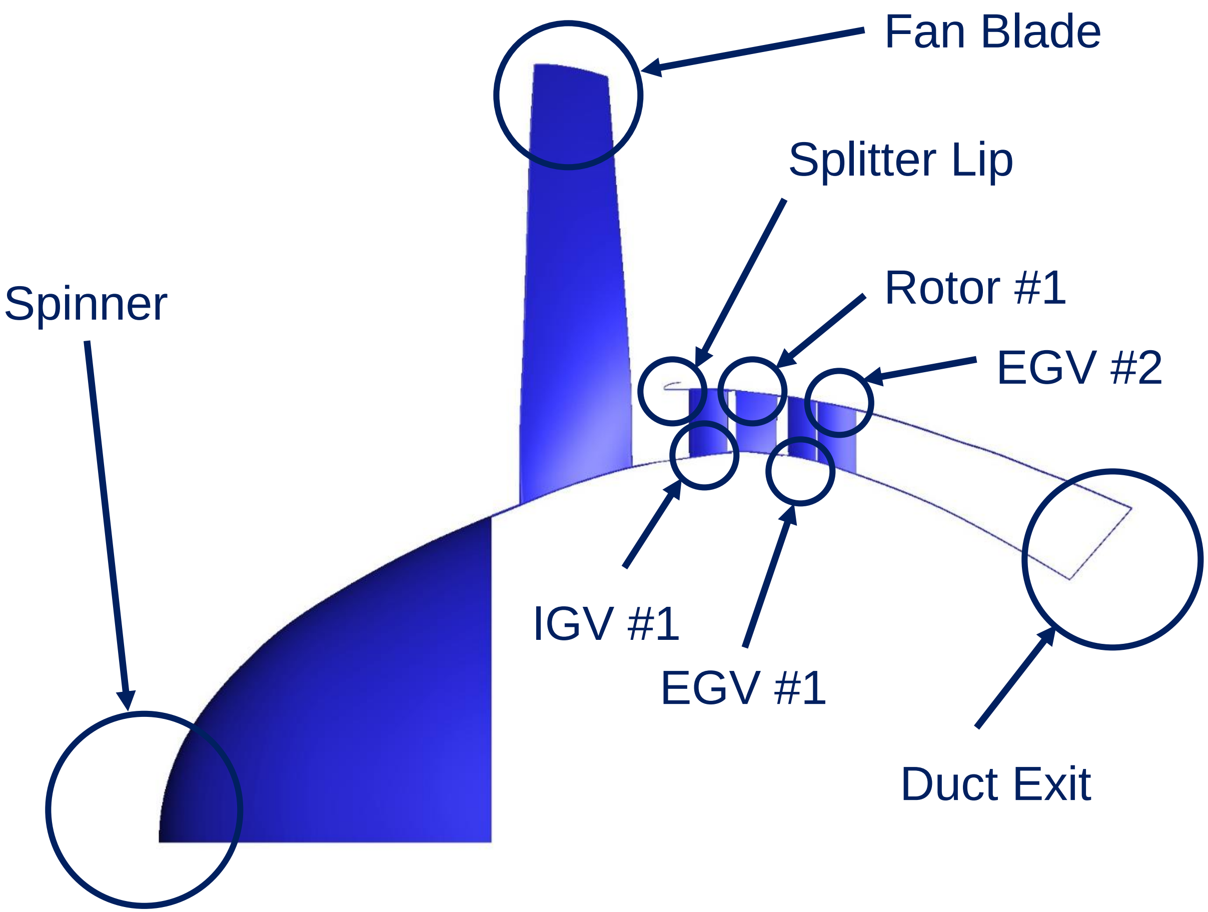
AL502 Grid Model



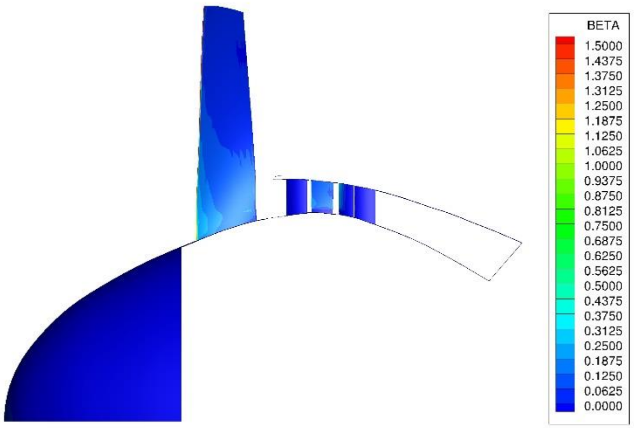
Grid Block Structure



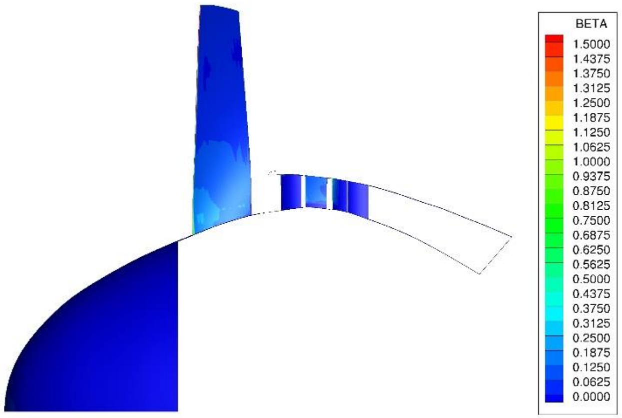
Surface Model


Fan Blade
Splitter Lip
Rotor #1
EGV #2
Spinner
IGV #1
EGV #1
Duct Exit

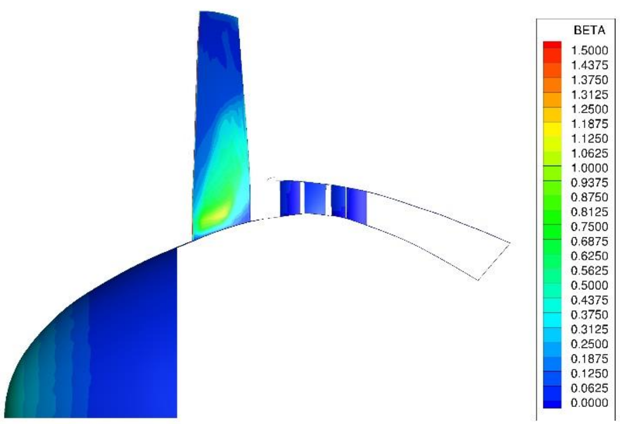
Collection Efficiency for AL502 Low Pressure Compressor



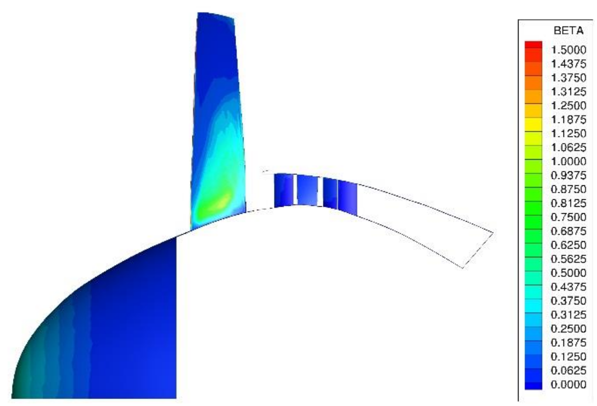
D5, DP0443 (rollback)



D5, DP0256 (non-rollback)

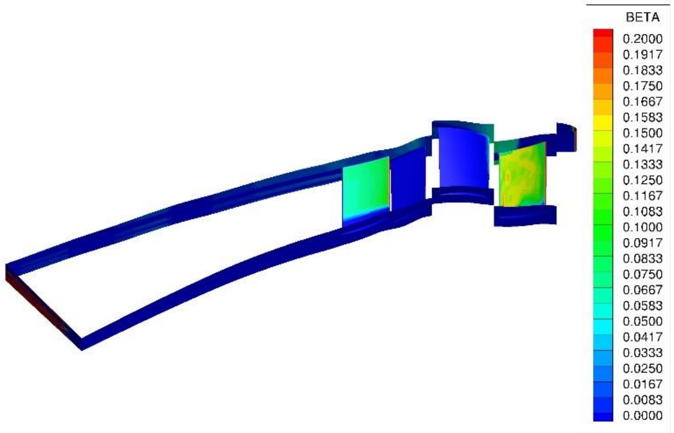


D24, 7-bin IRT, SLD, DP0443 (rollback)

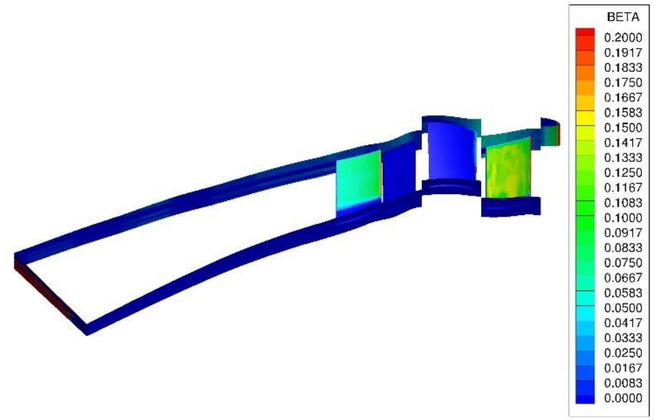


D24, 7-bin IRT, SLD, DP0256 (non-rollback)

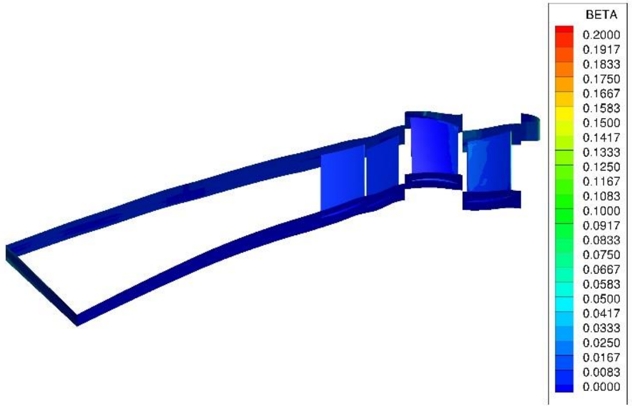
Collection Efficiency for AL502 Low Pressure Compressor



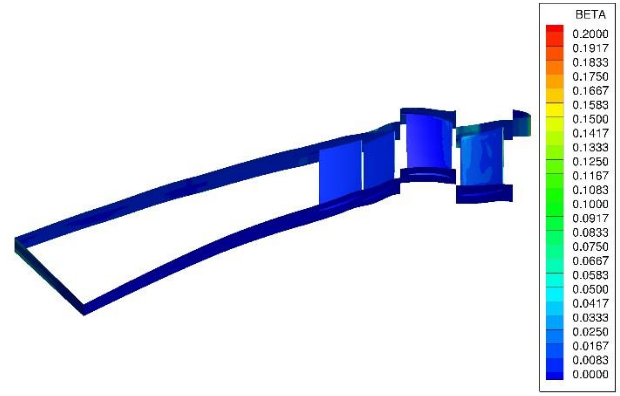
D5, DP0443 (rollback)



D5, DP0256 (non-rollback)

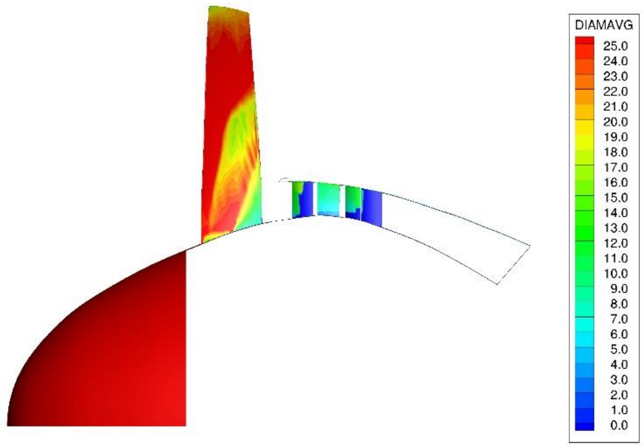


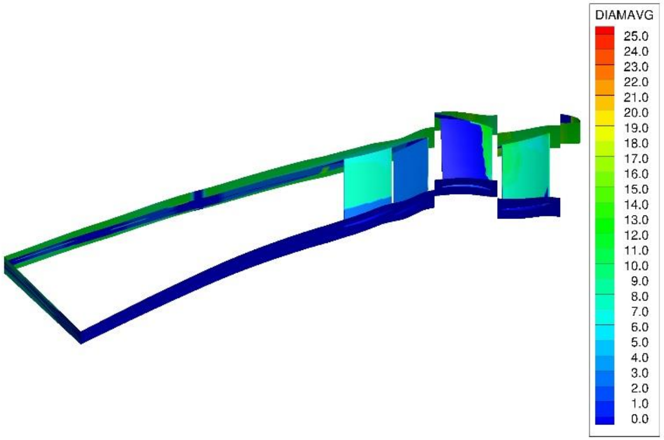
D24, 7-bin IRT, SLD, DP0443 (rollback)



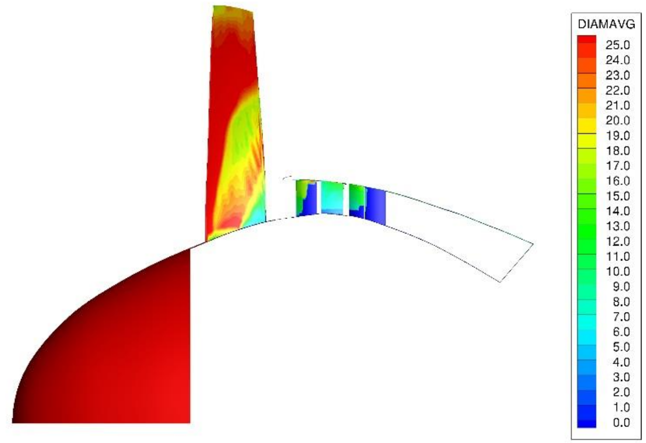
D24, 7-bin IRT, SLD, DP0256 (non-rollback)

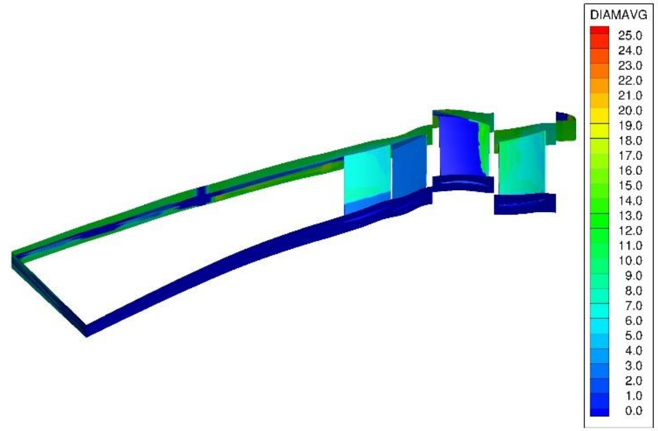
Particle Size for AL502 Low Pressure Compressor





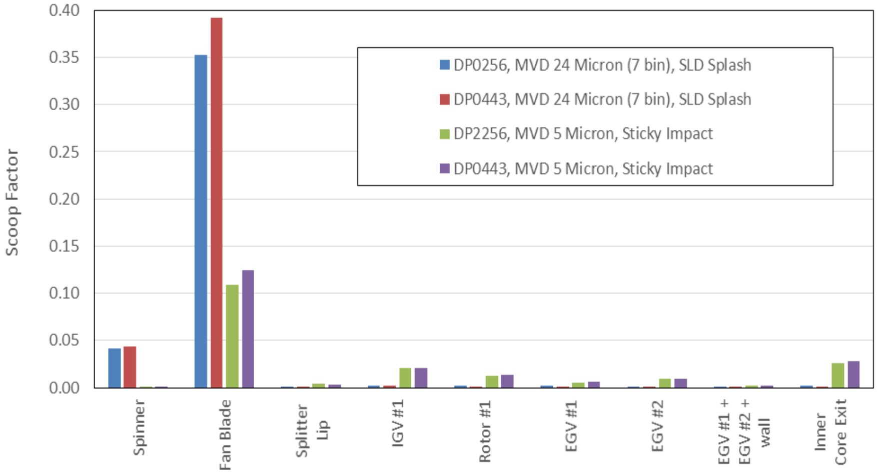
D24, 7-bin IRT, SLD, DP0443 (rollback)

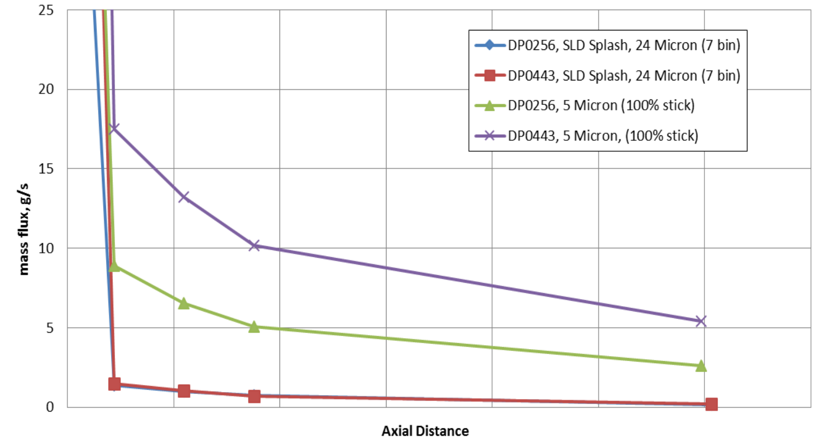


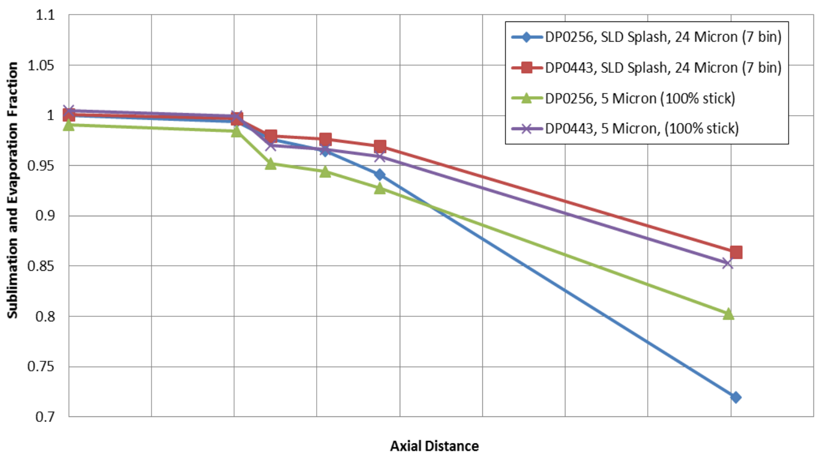


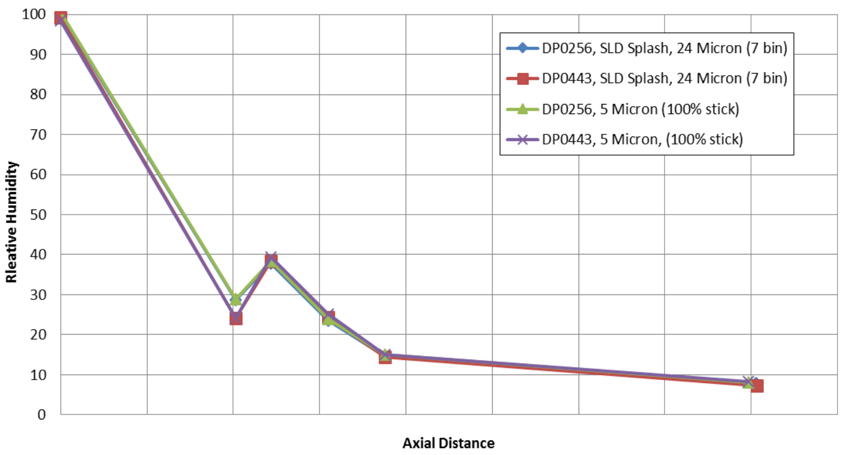
D24, 7-bin IRT, SLD, DP0256 (non-rollback)

Mass Transport Statistics for AL502 Low Pressure Compressor

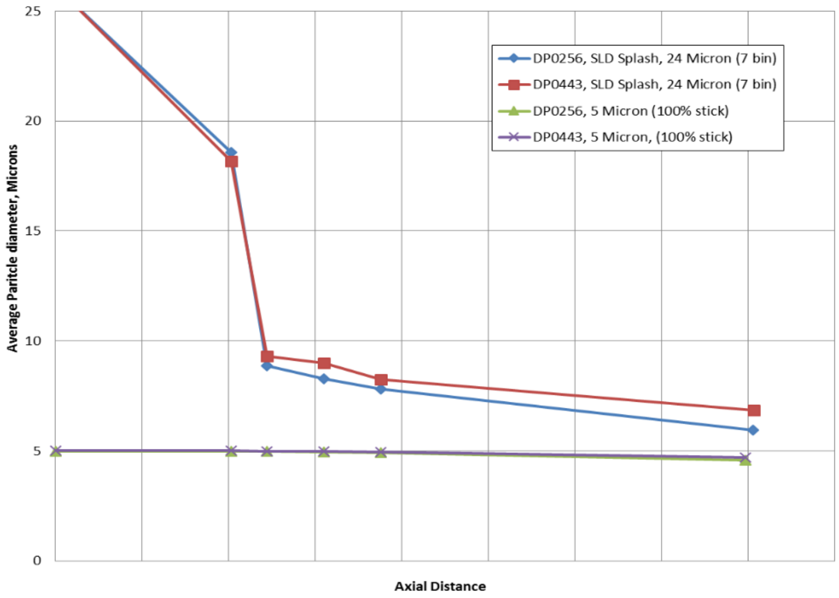


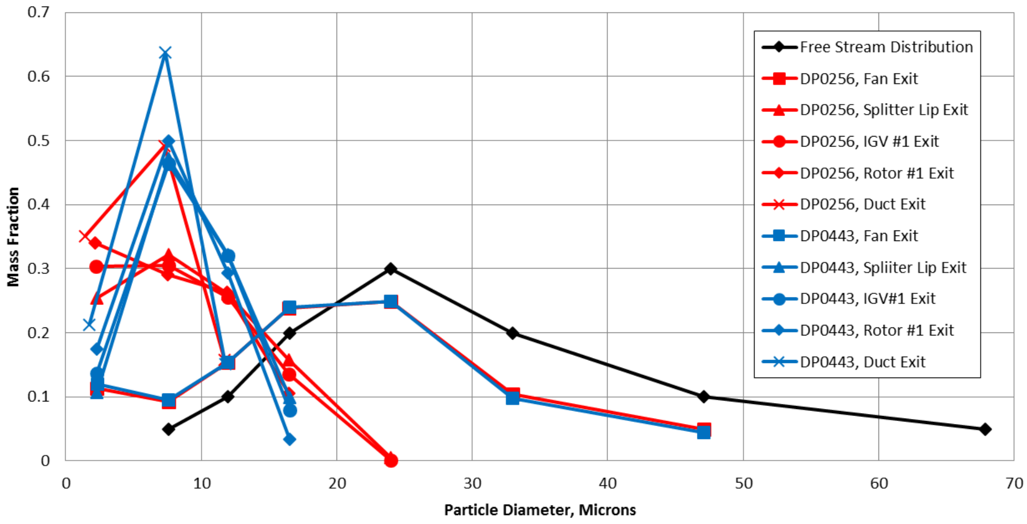




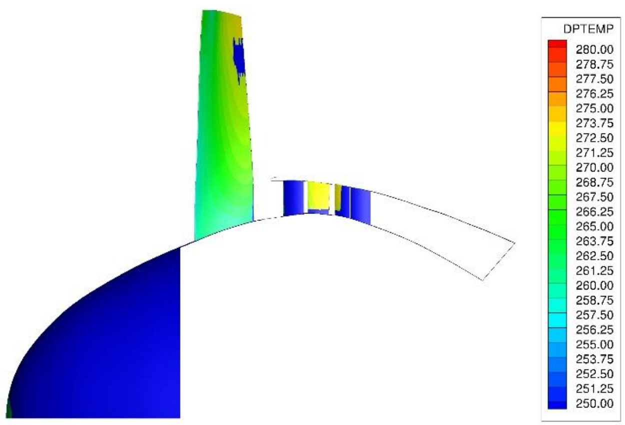


Particle Size for AL502 Low Pressure Compressor

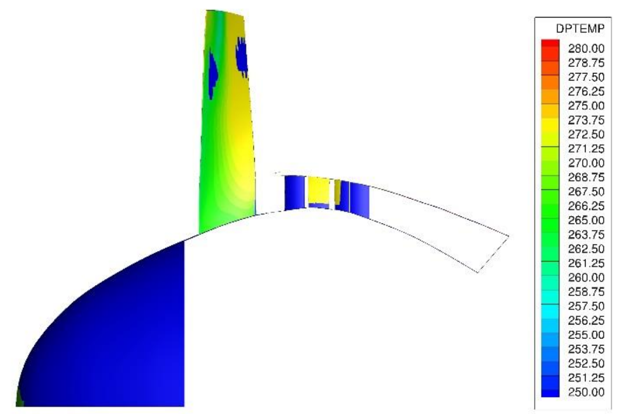




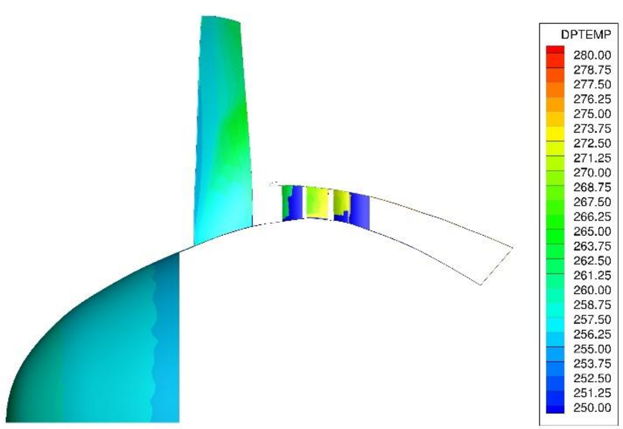
Particle Temperature for AL502 Low Pressure Compressor



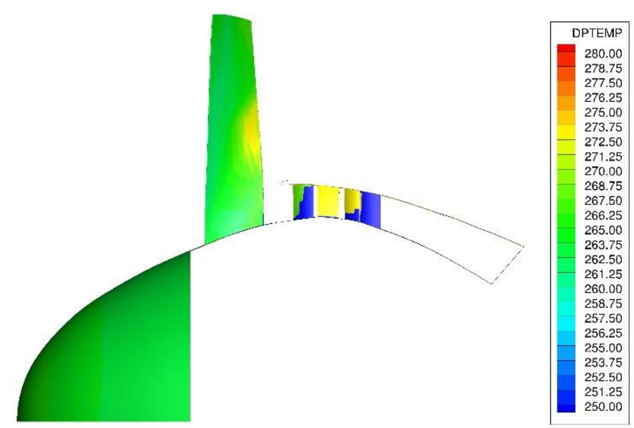
D5, DP0443 (rollback)



D5, DP0256 (non-rollback)

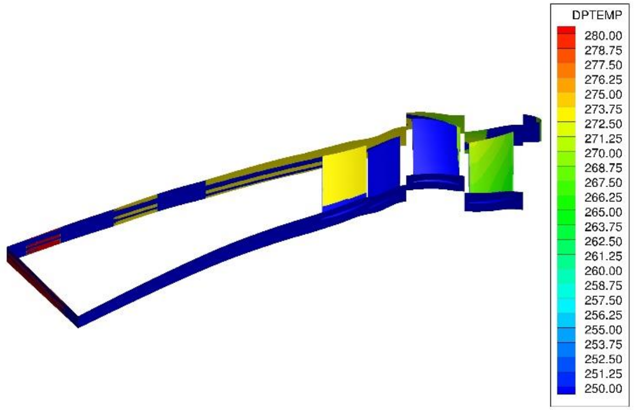


D24, 7-bin IRT, SLD, DP0443 (rollback)

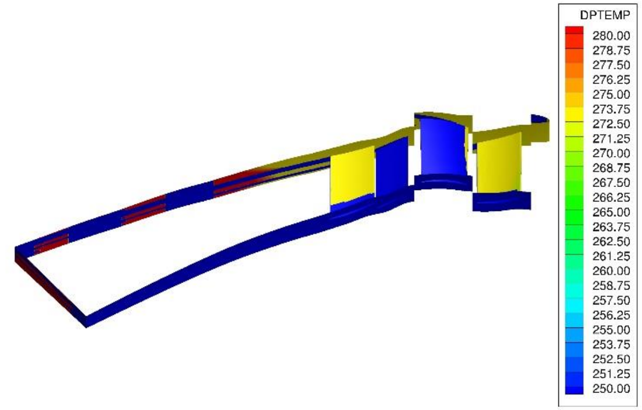


D24, 7-bin IRT, SLD, DP0256 (non-rollback)

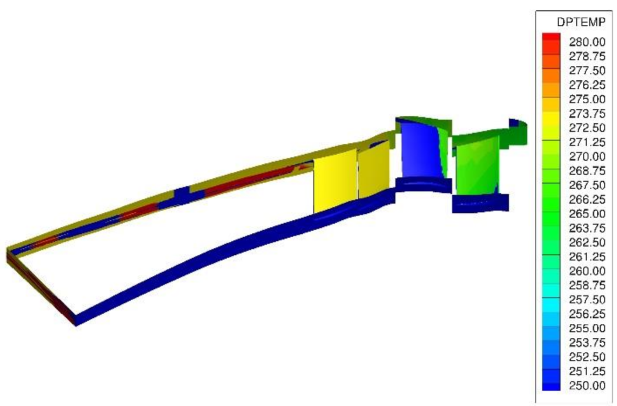
Particle Temperature for AL502 Low Pressure Compressor



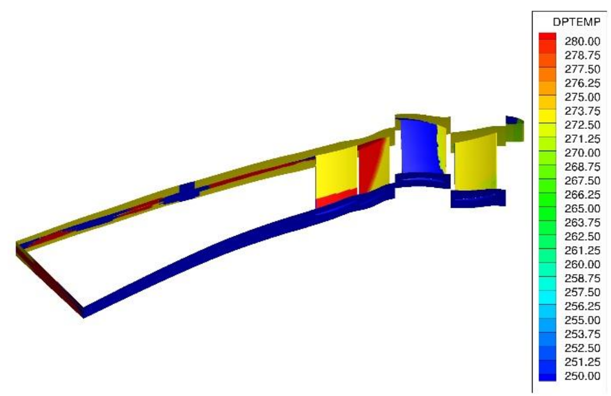
D5, DP0443 (rollback)



D5, DP0256 (non-rollback)

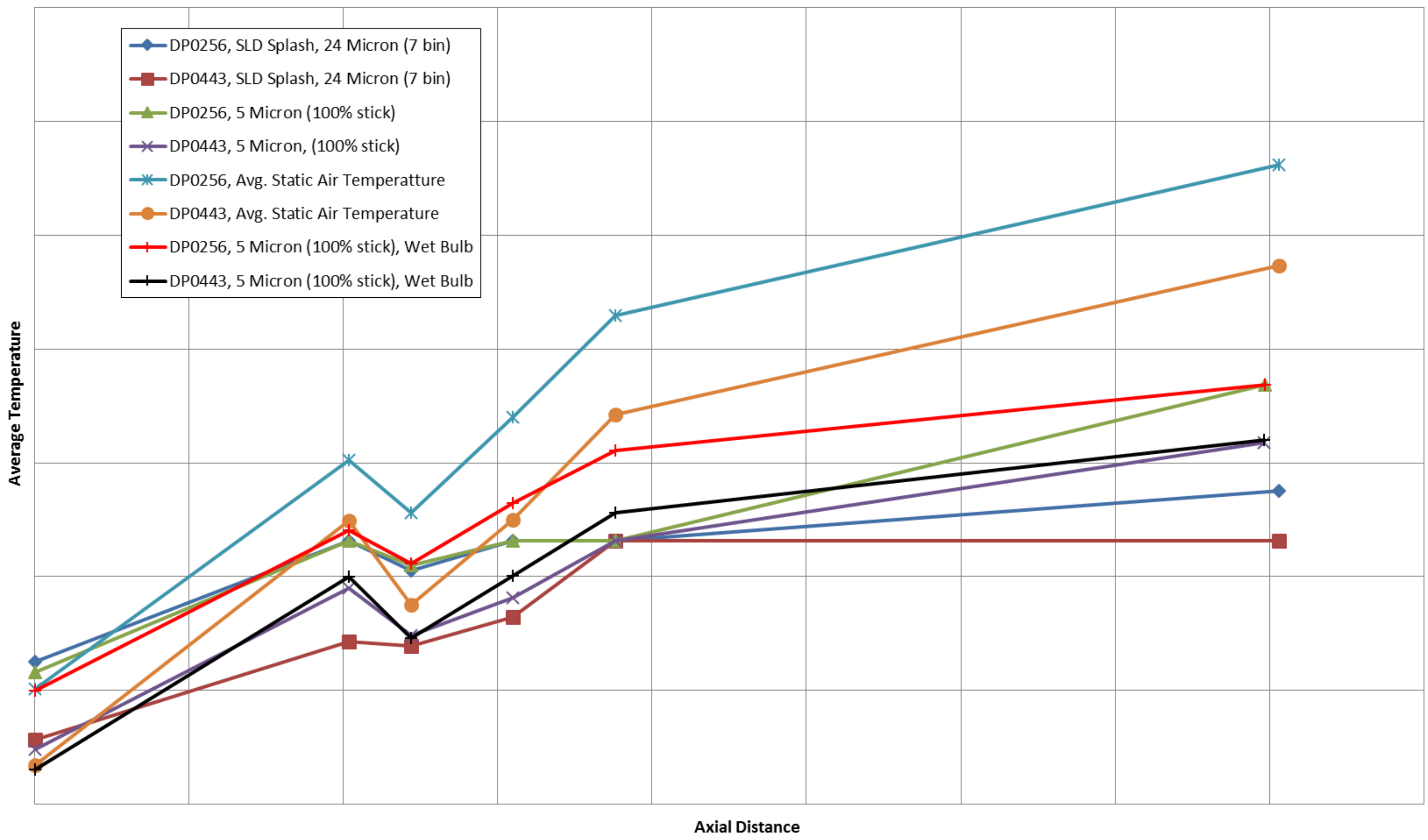


D24, 7-bin IRT, SLD, DP0443 (rollback)

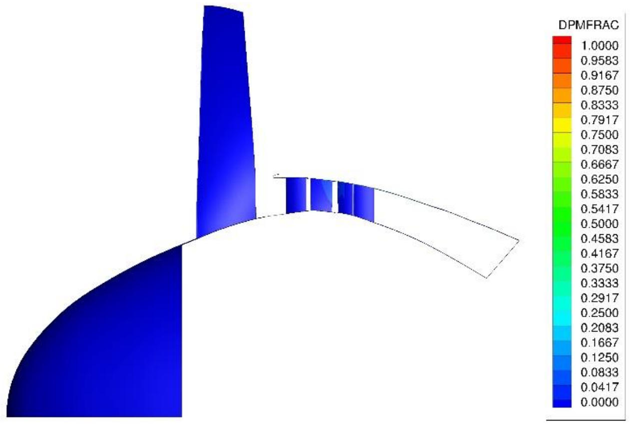


D24, 7-bin IRT, SLD, DP0256 (non-rollback)

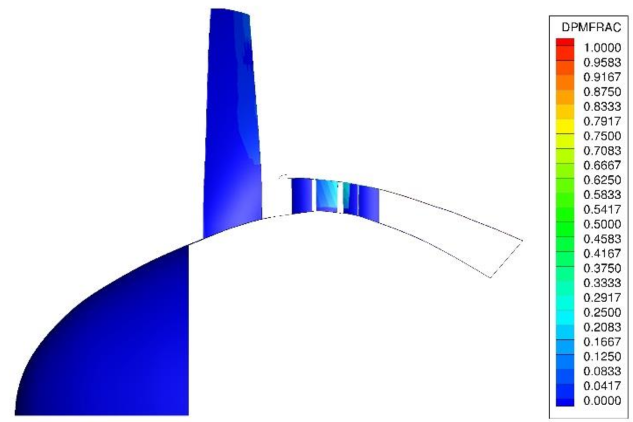
Axial Temperature Distributions for AL502 Low Pressure Compressor



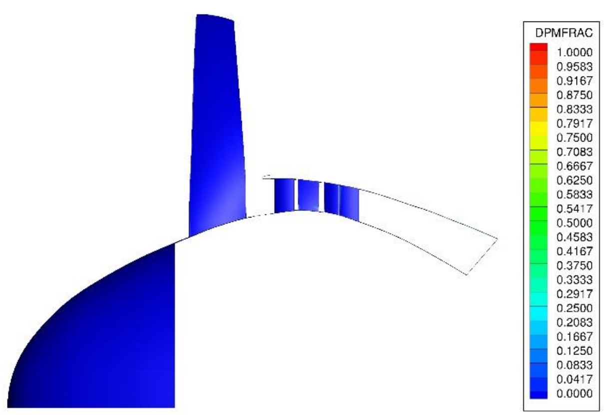
Particle Melt Fraction for AL502 Low Pressure Compressor



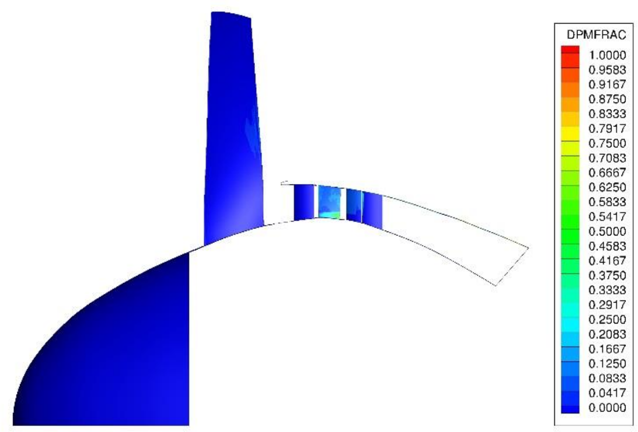
D5, DP0443 (rollback)



D5, DP0256 (non-rollback)

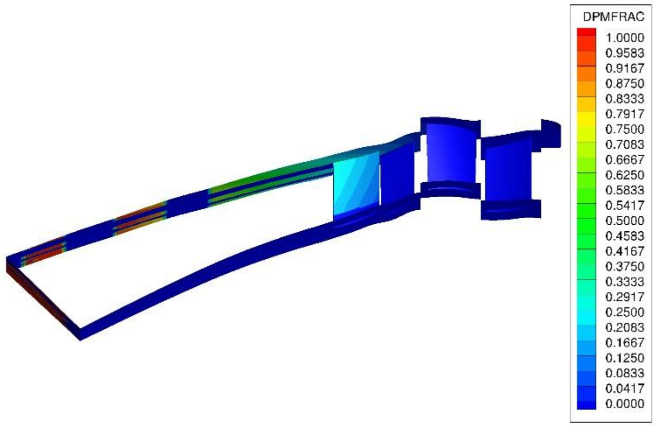


D24, 7-bin IRT, SLD, DP0443 (rollback)

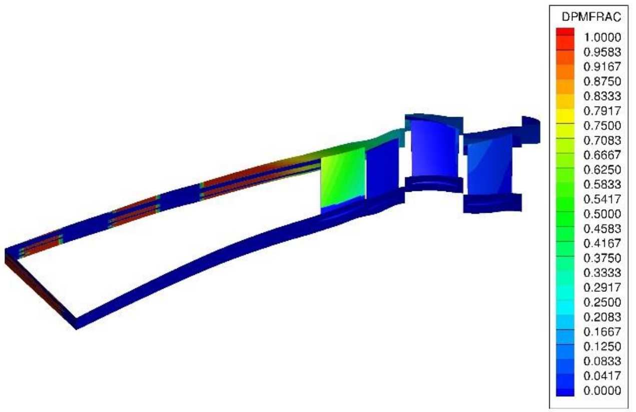


D24, 7-bin IRT, SLD, DP0256 (non-rollback)

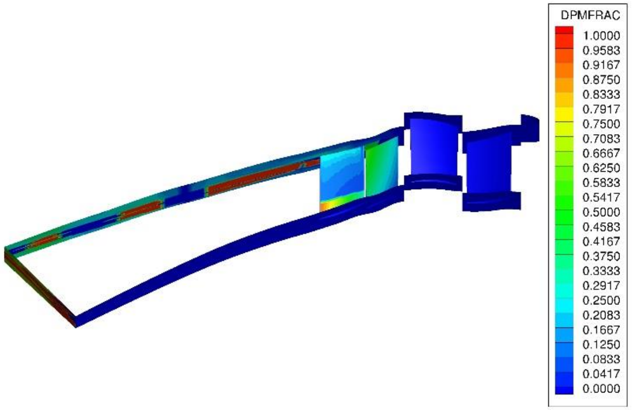
Particle Melt Fraction for AL502 Low Pressure Compressor



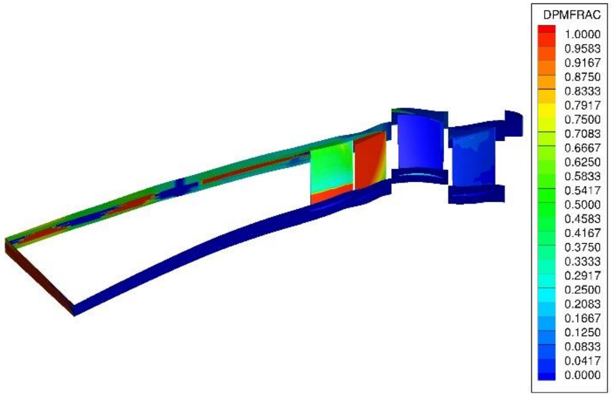
D5, DP0443 (rollback)



D5, DP0256 (non-rollback)

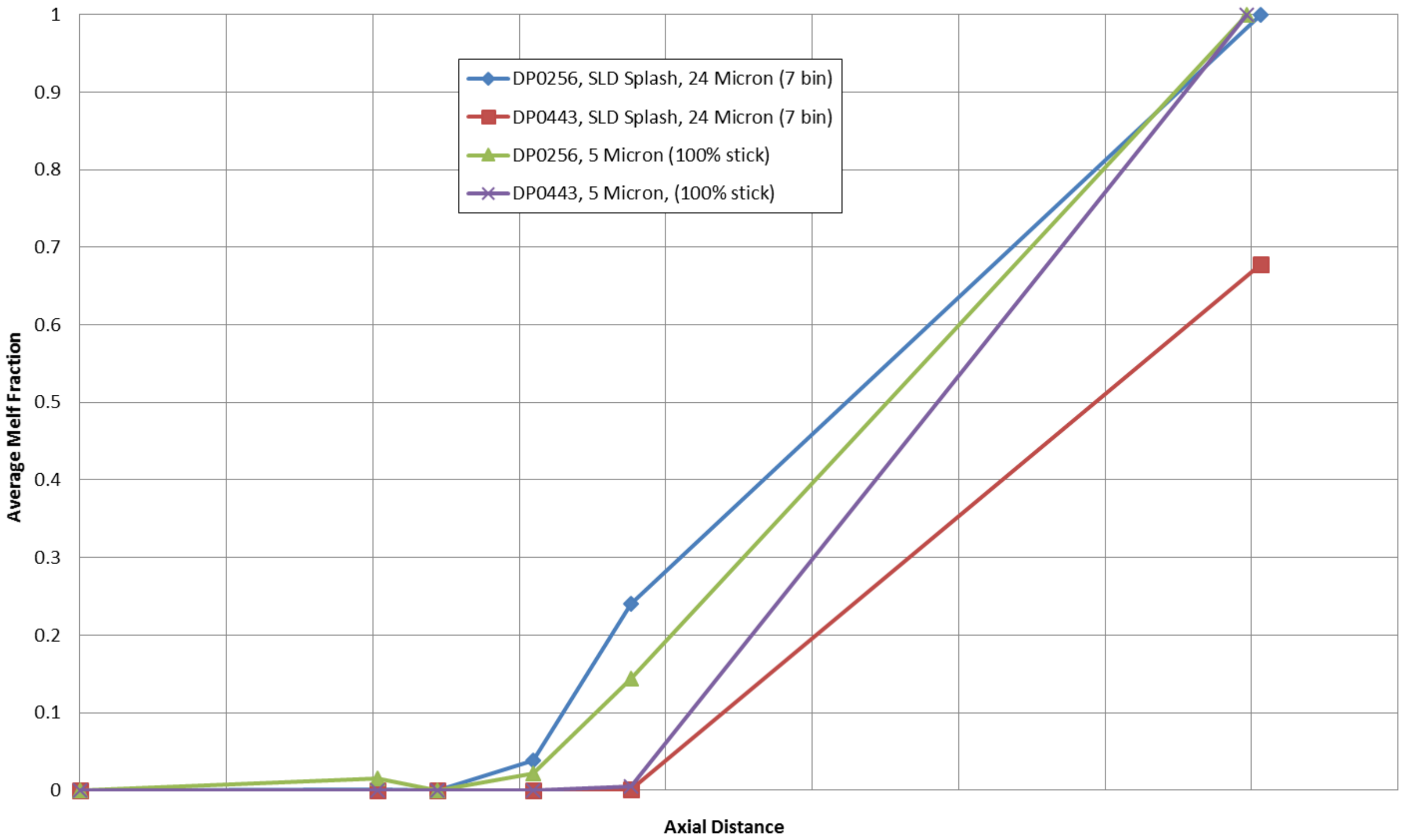


D24, 7-bin IRT, SLD, DP0443 (rollback)

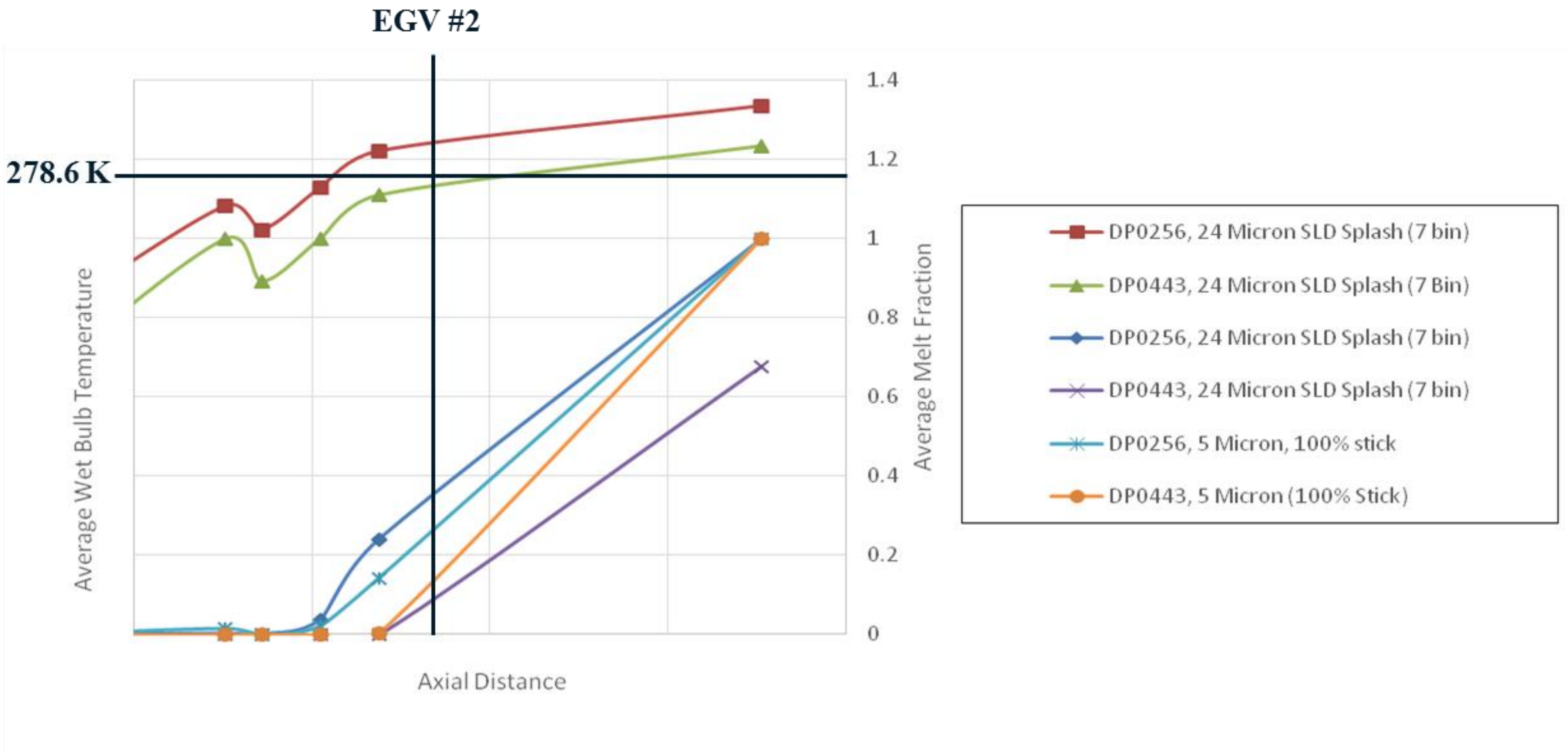


D24, 7-bin IRT, SLD, DP0256 (non-rollback)

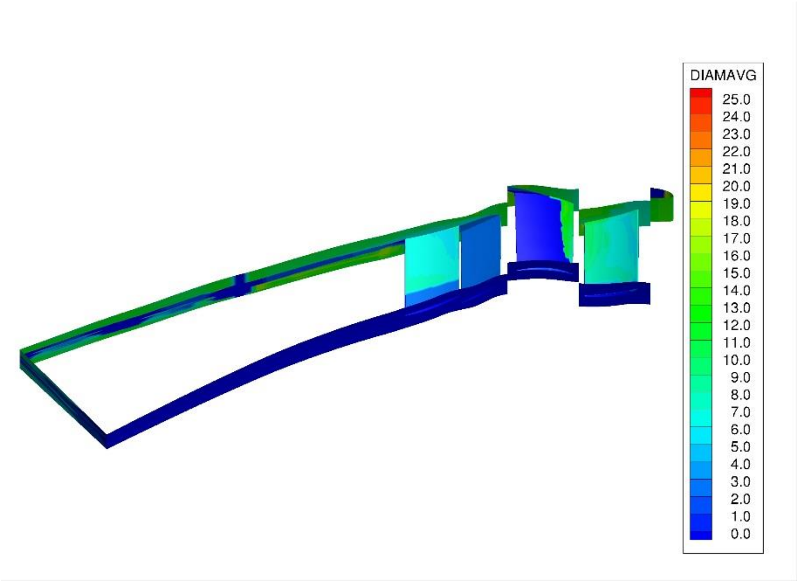
Axial Particle Melt Fraction for AL502 Low Pressure Compressor

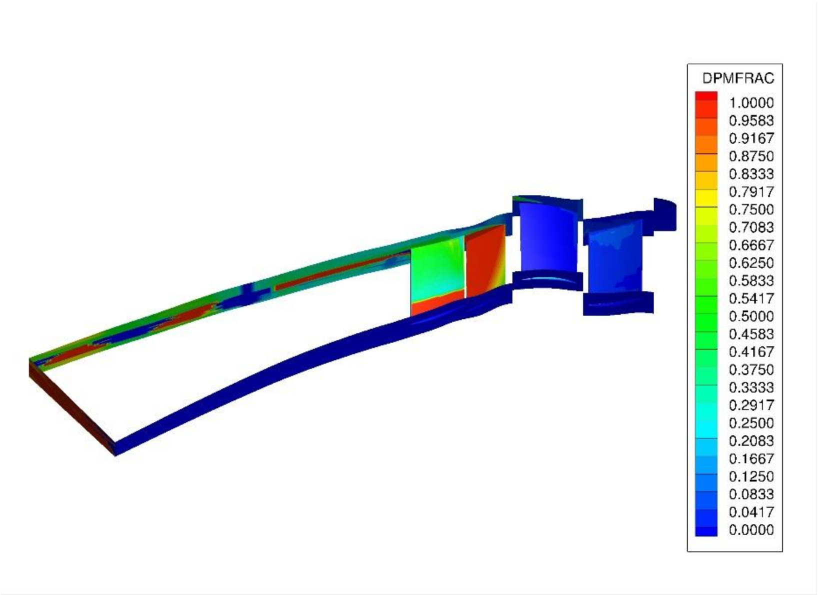


Wet Bulb Temperature and Melt Fraction for AL502 Low Pressure Compressor



Particle Size and Melt Fraction for AL502 Low Pressure Compressor





D24, 7-bin IRT, SLD, DP0256 (non-rollback)

Conclusions

- The amount of impingement for the components were similar for the same particle impact model and size distribution for the DP0443 (rollback) and DP0256 (non-rollback) flow conditions.
- The particle temperature and melt fraction were higher at the same location for the DP0256 (non-rollback) than for the DP0443 case (rollback) due to the higher incoming inlet temperature for the DP0256 case.
- The 24 micron ice particle distribution case produced higher impact temperatures and lower melt fractions on the components downstream of the fan than the 5 micron case because the particles generated by the breakup model were smaller than 5 microns allowing them to warm and melt more readily.
- The larger DP0256 SLD splash case produced more mass loss than the 5 micron DP0256 particle case because it produced a large amount of smaller particles during impact (< 5 microns) which were more susceptible to sublimation and evaporation.

Conclusions,cont.

- The icing risk criterion developed during the NRC tests for melt fraction (0.05 > melt fraction < .32) and wet bulb temperatures (< 5.5^{o}C) was useful in predicting the icing risk for the ALF502 low pressure compressor for the two test points selected for this analysis. The criterion showed that the icing event case (DP0443) was susceptible to icing in the EGV #2-outer duct intersection region and that the particle melt fractions and temperatures were too high to generate icing for the warmer non-icing event (DP0226).
- These results show that the GlennHT/LEWICE3D steady, mixing plane approach can be useful for predicting icing risk in turbomachinery.
- The development of an ice particle impact model which includes the effects of particle breakup, phase change, and surface state is necessary to further improve the utility of these tools in the prediction of ice particle transport with phase change through turbomachinery.