Minority Report on
Turbomachinery Aerodynamics

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If you hate being an audience, build your own stage. Don't criticize how people play their roles, but play yours well.

Be passionate and enthusiastic about what you are interested in, even addicted to.

As an Aquarius, I stay curious and ever young at heart.

Insanity is doing the same thing over and over again and expecting different results.

Hello, everyone!

For a long time, I've been scheduling to present the turbine aerodynamics documents and training materials for you guys, from the beginning of TFE1042 program through the Small turbofan engine (SW engine) project.

Please visit https://reedjoe.com whenever needed, from where you are able to find the reports related to turbine aerodynamic design for TFE1042.

I'm not intending to offer you turbine design reference or useful tools, but the concept, even reality, throughout the turbine design practices.

You might probably doubt what if you had never had the chance to touch these reports. To tell the truth, nothing will happen, and there is nothing to do with your ability of turbine aerodynamic design.

What You Should Have Known

However, you should have known any details in the reports, which were originally acquired from Garrett turbine aero people's experience or long term ability established based on turbine design principles.

To fully understand the details in reports is an attitude and a methodology to studying or research on some field of science as well.

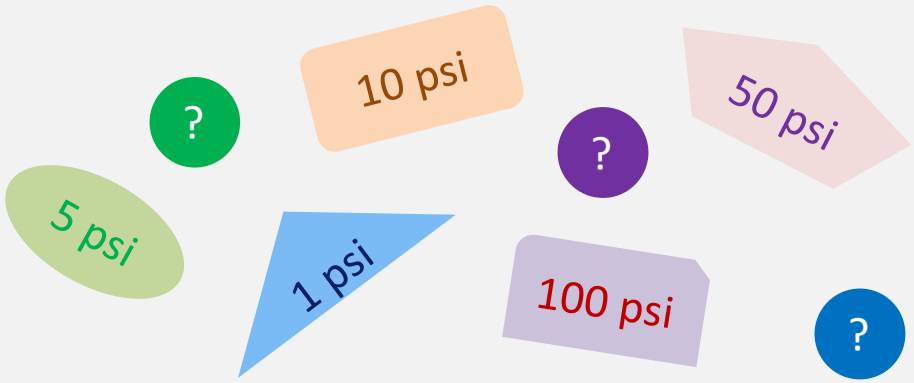
Applying the equivalent attitude and spirit to every disciplines, you will have a great level jump of competence significantly different from others.

If every researcher of a country is doing the same way as you are, then the accumulated competence of them in the aerospace will be enough to explore the space.

What's the pressure difference of pressure and suction surfaces of an aircraft wing?

If you have no idea, you can calculate it based on the following facts.

Given a 747-400 airplane with 416 seats, it features taking off weight 396,891 kg, wing area 560 m^2, fuel weight 213,187 kg, total load weight 63,503 kg, including 416 passengers, packages, water, food, etc.



What about turbine blade surfaces of fighter engines ?
And turbine blade surfaces of the space shuttle main engine?
Hint: The turbine blade chord length=1 cm

Preliminary design and through flow analysis

1.In the phase of turbine preliminary design, the LP turbine exit radius should be determined first for the flow path configuration. What parameters are related to MCD group and needed to do trade-offs with?

2. What's the primary purpose of turbine preliminary design? What plays the role?

3. How to distinguish blade channels between those for compressors and for turbines from the geometric point of view? That is, please explain why the channel is convergent for the turbine, but divergent for the compressor along the flow direction perpendicular to channel cross sections.

Hint:

1)What is parallel defined?

2)Is each turbine blade or compressor blade parallel to each other?

3)What's the difference between blade space and channel width?

4)Please sketch a cascade for compressor and turbine separately, and notice how you distinguish between them.

4.What needs to be determined in the S_2, meridional plane, through flow analysis of turbine? What's the criteria in consideration of aerodynamics and mechanics respectively?

Blading design

5.What does blading mean? What's the design criteria for optimal blading design?

Hint:

1)What is blade design?
2)What is blade-to-blade analysis?
3)What's the design criteria for blade geometry and blade loading?

6.Generally speaking, does the vane stacking of turbine differ from that of blade stacking, say for TFE1042, and what's the criteria for determining the stacking axis? Explain for what and how we do the blade tilt and lean?

7.What's the criteria for the optimal design of eye and impeller diameters of a centrifugal compressor?

8. How was the wide chord fan design initiated and used on the turbomachinery aerodynamics? Is it due to computing technology enhancement, like the capacity of computer systems, being more powerful for 3D analysis or the continuously accumulated capabilities and experiences of engineers?

Performance analysis and rig testing

9. How to calculate and simulate the rig test conditions?

10. How to simulate the LPT inlet flow distribution following HPT for the LPT rig test?

11. How to measure the turbine exit temperature, for which what is assumed and needs to be done?

12. How to measure the rotor exit flow angle distribution in the rig test?

13. What's the difference between rig parts and engine parts?

14. What's the pre-twisting angle for turbine rotor, and what that for?

15. How to modify the turbine performance map curves for efficiency and flow, which are obtained from the performance analysis outputs?

Extensive discussion

16. An inspection of F-35 revealed a crack on a turbine blade in the Pratt-built jet engine of an F-35 jet on a test plane in Florida on February 19, 2013. The Pentagon announced the grounding of all F-35 warplanes on February 22, 2013. Pentagon reviewed the Pratt recommendation to resume F-35 flights on February 28, 2013. The company's engineers said that the crack with the turbine was not caused by high-cycle fatigue, but a "creep rupture" which was caused by the fact that the engine on that particular test plane had been run particularly hard at hot temperatures since it was used for after-burner testing.

1) Why the Pratt said the problem was not caused by high cycle fatigue, but creep rupture?

2) What, how and when are we supposed to do about the turbine blade design or performance analysis to prevent kind of problems to happen during testing?

17. Some engineers said that they already have a powerful full 3D turbo-machinery aerodynamic design codes, and it is no difficulty to accomplish the turbine blade design right after inputting the cycle analysis data. It seems that we will have the same design capability as, say, NASA does if we have the same design tools as those of NASA, doesn't it? If so, do we still need the mean line analysis, the streamline analysis, and quasi-3D blading other than the 3D analysis for the turbine design? If yes, what the roles do they play?

18. The comparison between analysis and test data is not the end of aerodynamic design, but the beginning. As such, what if there is mismatch between analysis and test data? In the LPT rig test of TFE1042, it's found that the choking flow and efficiency was 5% and 2% lower than expected respectively, what will you plan to do for that?

19. There was a flutter problem with LPT rotor blade of TFE1042 at some operation points. How will you tackle with that?

20. When do we use the corrected data and physical data? How can we interpret the corrected concept in a few words to let related persons quickly understand?

Hint:

Given turbine efficiency η, it's a function of $(N, W, P_{t,in}, P_{t,ex}, P_{amb}, T_{amb})$, where N is physical rotation speed, $P_{t,in}$ turbine inlet pressure, W flow rate, $P_{t,in}$ turbine inlet total pressure, $P_{t,ex}$ turbine exit total pressure, T_{amb} ambient temperature, P_{amb} ambient pressure.

Please prove that turbine efficiency η, and flow rate $\frac{W\sqrt{\theta}}{\delta}$ is a function of $(\frac{N}{\sqrt{\theta}}, PR)$, where $PR=P_{t,in}/P_{t,ex}, \theta = T_{amb}/519^{o}R, \delta = P_{amb}/14.7psi.$

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For the details

Culture is the habit of being pleased with the best and knowing why.