

Compressor flow : NASA Rotor 37

The NASA rotor 37 is an isolated transonic axial compressor rotor with 36 blades. This case was initially included in a wider research program that intent to cover a range of design parameters typical of aircraft turbine engine high-pressure compressor inlet stage. The test case is detailed in reference 1 and is used for CFD validation.

All the data available for this case were measured with NASA rotor 37 operating at the equivalent design rotational speed of 17188.7 rpm. To establish reference points for detailed flow field measurements, overall performance was determined at equivalent mass flow rates from the choke mass flow to a minimum slightly above the rotor stall flow. The experimental choke mass flow as determined by NASA was $m_{\text{choke}} = 20.93$ kg/s whereas the near stall flow rate was experimentally determined to be $m = 0.925 m_{\text{choke}} = 19.36$ kg/s. A total of 13 sets of overall performance data were measured over this range. Overall performance includes average total pressure ratio and adiabatic efficiency. Laser anemometer velocity data were acquired in four hub-to-tip measuring planes but only at mass flow rates of $0.98 m_{\text{choke}}$ and $0.925 m_{\text{choke}}$ (i.e., at near stall flow rate).

Inlet boundary conditions could be inferred from experimental data available at a first measurement plane located 4.19 cm upstream of the blade leading edge. Radial distributions of the total pressure and the total temperature are available at this entrance station denoted station 1 in [1].

List and description of the uncertainty parameters

The fluid is air treated as perfect gas with the following properties:

- specific heat C_p : 1004.5 J/Kg.K
- adiabatic coefficient: 1.4
- Prandtl number: 0.708
- kinematic viscosity following the Sutherland Law.

Physical model : RANS Computation with turbulence models
(typically based on $k\epsilon$, $k\omega$, $k\omega$ -sst or Spalart Allmaras)

One of the following uncertainties must be considered:

Option	Uncertainty parameter	The most likely value (m)	Minimum value (a)	Maximum value (b)	PDF-type
1	Inlet total pressure (p_t)	Standard input profiles at station 1	95% m	105% m	Symmetric beta pdf
2	Static outlet pressure	$m_P = \text{see table 1}$	98% m_P	102% m_P	Symmetric beta pdf
3	Tip clearance	$m_H = 0.356$ mm	50% m_H	150% m_H	Symmetric beta pdf

For each analysed option the contributor has to prepare a detailed description of the employed non-deterministic methodology and its computational efficiency. The computational efficiency should be reported as the ratio between the computational times of the non-deterministic and deterministic analyses.

Option 1:

The most likely value represented by the radial distribution of the inlet total pressure is considered that from station 1 in [1]. The velocity is assumed axial.

The probability density function (pdf) is a symmetric beta pdf:

The beta pdf of random variable x is given by (see [2]):

$$f(x) = \frac{1}{B(p, q)} \cdot \frac{(x-a)^{p-1} (b-x)^{q-1}}{(b-a)^{p+q-1}}, \quad x \in [a, b] \quad (1)$$

a, b being the minimum and maximum values of the random variable and B the beta function. The shape parameters are $p=4$ and $q=4$.

Requested output:

- non-deterministic compressor map: pressure ratio ($=p_{t,OUT}/p_{t,IN}$) versus mass flow rate
- non-deterministic compressor map: efficiency versus mass flow rate

The subscripts "IN" and "OUT" corresponds to the inlet and outlet planes of the compressor stage.

The running points on the non-deterministic compressor maps are those fixed by the mean values while the error bars must cover the range $[-\sigma/2, \sigma/2]$, where σ is the standard deviation.

The contributors are requested to run at least five running points given in table 1

<i>Running point</i>	<i>Outlet static pressure (Pa)</i>
1	99215
2	110000
3	114074
4	119035
5	121033
6	123008
7	124027

Six files each of them containing the values of the mean and standard deviation of the pressure ratio, efficiency and the mass flow rate computed for each running point have to be sent to organizers.

The files will be named as follow:

NameContributor_MEAN_PRES_option1.dat, NameContributor_STDEV_PRES_option1.dat
NameContributor_MEAN_EFF_option1.dat, NameContributor_STDEV_EFF_option1.dat
NameContributor_MEAN_MASS_option1.dat, NameContributor_STDEV_MASS_option1.dat

Each file will contain two columns: the first one indicating the running point and the second one the computed value.

Option 2:

The experimental radial distributions of the total pressure and the total temperature available at station 1 in [1] will be set at inlet section of the compressor stage. The velocity is assumed axial.

The probability density function (pdf) is a symmetric beta pdf defined by (1).

Requested output:

- non-deterministic compressor map: pressure ratio ($=p_{t,OUT}/p_{t,IN}$) versus mass flow rate
- non-deterministic compressor map: efficiency versus mass flow rate

The subscripts "IN" and "OUT" corresponds to the inlet and outlet planes of the compressor stage.

The running points on the non-deterministic compressor maps are those fixed by the mean values while the error bars must cover the range $[-\sigma/2, \sigma/2]$, where σ is the standard deviation.

The contributors are requested to run at least five running points given in table 1

Six files each of them containing the values of the mean and standard deviation of the pressure ratio, efficiency and the mass flow rate computed for each running point have to be sent to organizers.

The files will be named as follow:

NameContributor_MEAN_PRES_option2.dat, NameContributor_STDEV_PRES_option2.dat
NameContributor_MEAN_EFF_option2.dat, NameContributor_STDEV_EFF_option2.dat
NameContributor_MEAN_MASS_option2.dat, NameContributor_STDEV_MASS_option2.dat

Each file will contain two columns: the first one indicating the running point and the second one the computed value.

Option 3:

The experimental radial distributions of the total pressure and the total temperature available at station 1 in [1] will be set at inlet section of the compressor stage. The velocity is assumed axial.

The probability density function (pdf) is a symmetric beta pdf defined by (1).

Requested output:

- non-deterministic compressor map: pressure ratio ($=p_{t,OUT}/p_{t,IN}$) versus mass flow rate
- non-deterministic compressor map: efficiency versus mass flow rate

The subscripts "IN" and "OUT" corresponds to the inlet and outlet planes of the compressor stage.

The running points on the non-deterministic compressor maps are those fixed by the mean values while the error bars must cover the range $[-\sigma, \sigma]$, where σ is the standard deviation.

The contributors are requested to run at least five running points given in table 1.

Six files each of them containing the values of the mean and standard deviation of the pressure ratio, efficiency and the mass flow rate computed for each running point have to be sent to organizers.

The files will be named as follow:

NameContributor_MEAN_PRES_option3.dat, NameContributor_STDEV_PRES_option3.dat
NameContributor_MEAN_EFF_option3.dat, NameContributor_STDEV_EFF_option3.dat
NameContributor_MEAN_MASS_option3.dat, NameContributor_STDEV_MASS_option3.dat

Each file will contain two columns: the first one indicating the running point and the second one the computed value.

References

[1] AGARD-AR-355 (1998), "CFD validation for propulsion system components". (<http://www.rta.nato.int/Pubs/RDP.asp?RDP=AGARD-AR-355>)

[2] Johnson, N. L., Kotz, S., *Continuous Univariate Distributions*, vol.2, chapter 24, Boston, Houghton Mifflin, 1970.