Comparison of the exact VINK geometry and the geometric fit

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This report presents a comparison of the first stage in the VINK compressor, here denoted R1S1, and the geometric fit using an airfoil profiling tool denoted R1S1A. The approximated first stage rotor by itself will be denoted R1A, and the approximated first stage stator will be denoted S1A.

Comparison of R1 and R1A

The geometry of the first rotor (R1) of the VINK compressor generated using the software AxCent^{TM} is based on a multiple circular arc (MCA) definition and was approximated using an airfoil profiling tool, resulting in the blade R1A which was subsequently used for a structural analysis and an aerodynamic performance evaluation [1]. For a comparison of the two rotor geometries, the blade is cut at 5 sections of constant Y-coordinate listed in Table 1. The airfoil geometries are compared as if comparing a manufactured blade with a prescribed blade geometry.

The positions of constant Y-coordinate that are compared with respect to airfoil deviations are highlighted in Fig. 1 and correspond to the approximate 10%, 30%, 50%, 70% and 90% spanwise positions. The maximum local airfoil deviations for the rotor at these five positions are listed in Table 2 and is shown to be below 0.08 mm. This variation is within the tolerance band for manufacturing ±0.1 mm shown for a compressor blade in [2]. The maximum deviation on a global scale is, from evaluating these sections without considering a best fit, below 0.3 mm. Airfoil profiles from the two geometries are shown at three spanwise locations in Fig. 2. To highlight the locations of maximum deviation, the leading and trailing edge of the blades at all the compared sections are shown in Fig. 3 with a black circle placed on the original R1 geometry with a radius of 0.1 mm.

Table 1: ROTOR LOCATIONS FOR COMPARISON

Y-coordinate [mm]	Approx. spanwise position [%]
495	10
523	30
551	50
580	70
608	90

Table 2: MAXIMUM LOCAL ROTOR AIRFOIL DEVIATIONS

Y-coordinate [mm]	Maximum local deviation [mm]
495	0.049
523	0.074
551	0.043
580	0.039
608	0.055

The main difference between the designs is shown to be the leading and trailing edge curves, connecting the suction and pressure side. There are different approaches that can be used to connect the suction and pressure surface of MCA blades as the MCA definition refers to the specification of the suction and pressure sides.

Comparison of S1 and S1A

The geometry of the first rotor (S1) of the VINK compressor generated using the software AxCent^{TM} is based on an MCA definition and was approximated using an airfoil profiling tool, resulting in the blade S1A which was subsequently used for an evaluation of the aerodynamic performance [1]. For a comparison of the two stator geometries, the stator is cut at 5 sections of constant Y-coordinate listed in Table 3. The airfoil sections are compared as if comparing a manufactured blade with a prescribed blade geometry.

The positions of constant Y-coordinate that are compared with respect to airfoil deviations are highlighted in Fig. 4. The positions correspond to the approximate 10%, 30%, 50%, 70% and 90% spanwise positions. The maximum local airfoil deviations for the stator at these five positions are listed in Table 4 and shown to be at or below 0.07 mm. This variation is within the tolerance band for manufacturing ±0.1 mm shown for a compressor blade in [2]. The maximum deviation on a global scale is, from evaluating these sections without considering a best fit, below 0.3 mm. Airfoil profiles from the two geometries are shown at three spanwise locations in Fig. 5. To highlight the locations of maximum deviation, the leading and trailing edge of the blades at the compared sections are shown in Fig. 6 with a black circle placed on the original S1 geometry with a radius of 0.1 mm. The main difference between the designs is shown to be the curve connecting the suction and pressure side, same as for the rotor. There are different approaches that can be used to connect the suction and pressure surface of a multicircular arc (MCA) blades as the MCA definition refers to the specification of the suction and pressure sides.

References

[1] Lejon, M., Grönstedt, T., Glodic, N., Petrie-Repar, P., Genrup, M., and Mann, A., 2017. "Multidisciplinary Design of a Three Stage High Speed Booster". In Proceedings of ASME Turbo Expo 2017, no. GT2017-64466.

[2] Schnell, R., Lengyel-Kampmann, T., and Nicke, E., 2014. "On the Impact of Geometric Variability on Fan Aerodynamic Performance, Unsteady Blade Row Interaction, and Its Mechanical Characteristics". *Journal of Turbomachinery,* ***139***(9), p. 091005.

Table 3: STATOR LOCATIONS FOR COMPARISON

Y-coordinate [mm]	Approx. spanwise position [%]
503	10
526	30
550	50
573	70
596	90

Table 4: MAXIMUM LOCAL STATOR AIRFOIL DEVIATIONS

Y-coordinate [mm]	Maximum local deviation [mm]
503	0.056
526	0.053
550	0.042
573	0.058
596	0.070

Appendix

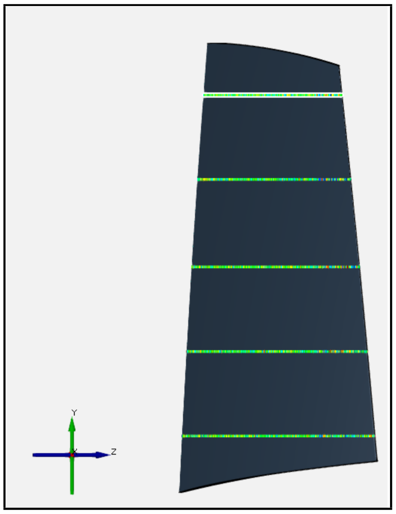


Figure 1: ROTOR WITH ANALYZED AIRFOIL SECTIONS HIGHLIGHTED

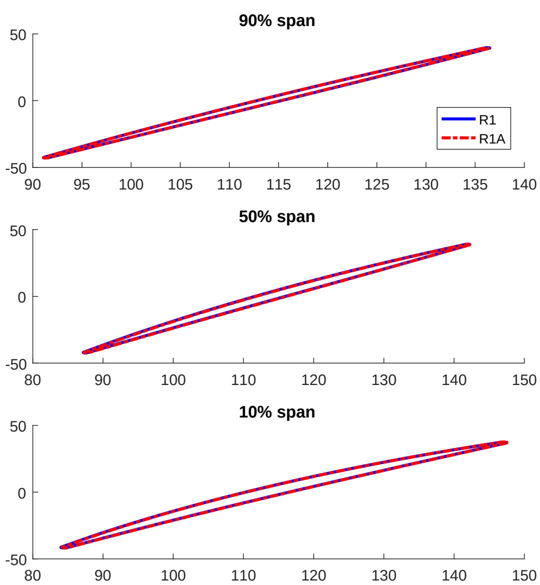
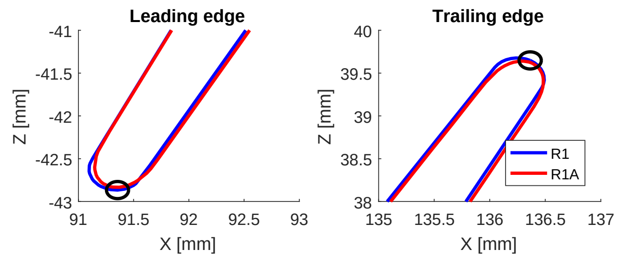
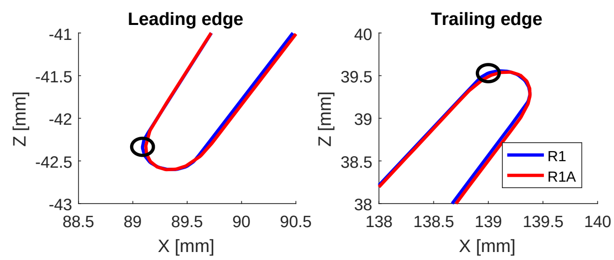


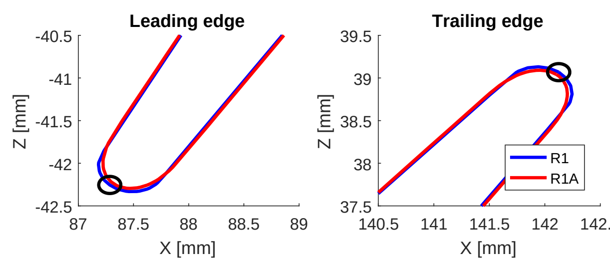
Figure 2: R1 AND R1A AT THREE SPANWISE POSITIONS



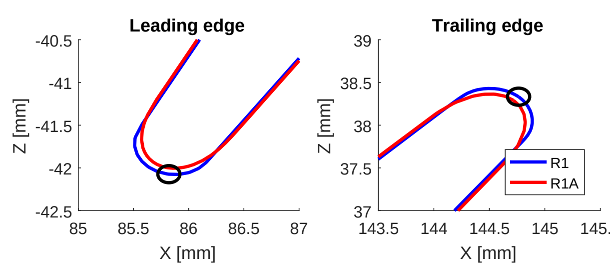
(a) 90% span



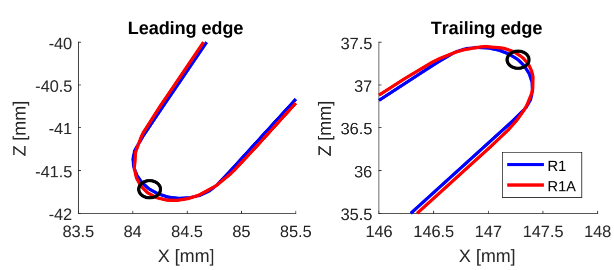
(b) 70% span



(c) 50% span



(d) 30% span



(e) 10% span

Figure 3: LOCAL ROTOR AIRFOIL DEVIATIONS

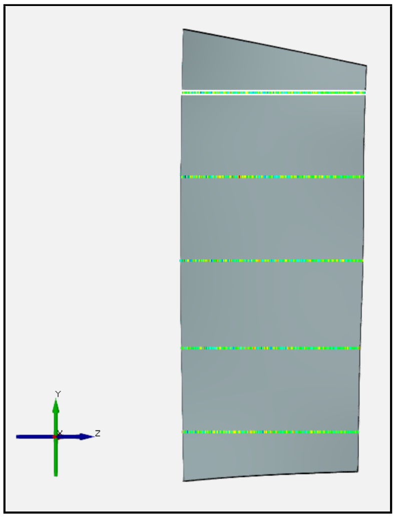


Figure 4: STATOR WITH ANALYZED AIRFOIL SECTIONS HIGHLIGHTED

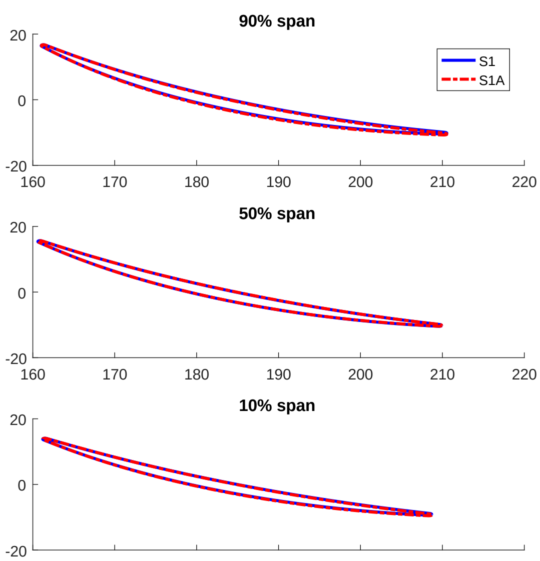
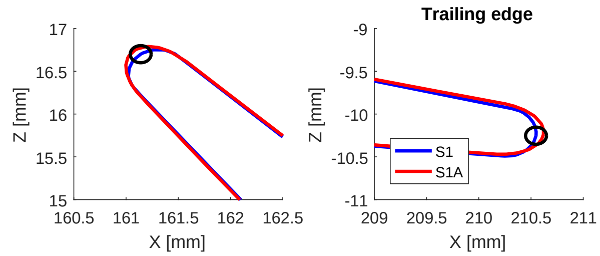
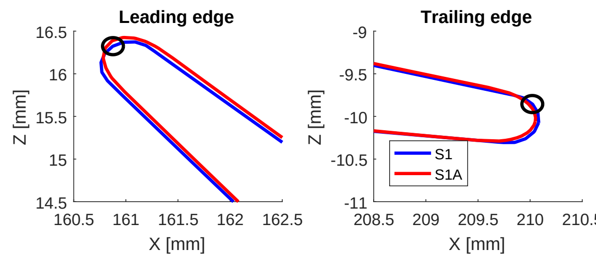


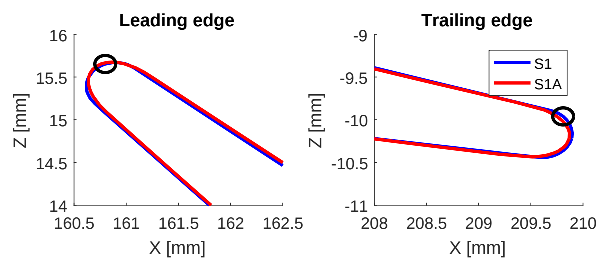
Figure 5: S1 AND S1A AT THREE SPANWISE POSITIONS



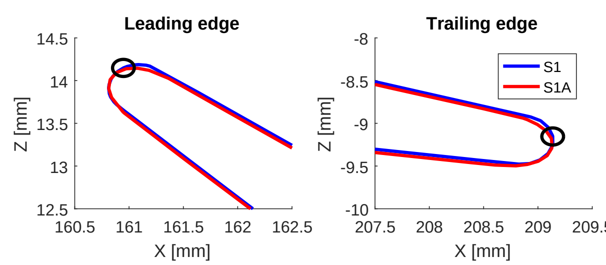
(a) 90% span



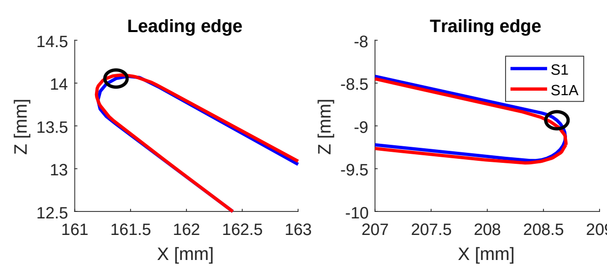
(b) 70% span



(c) 50% span



(d) 30% span



(e) 10% span

Figure 6: LOCAL STATOR AIRFOIL DEVIATIONS