Radial Turbine Performance Measurement Under Extreme Off-Design Conditions

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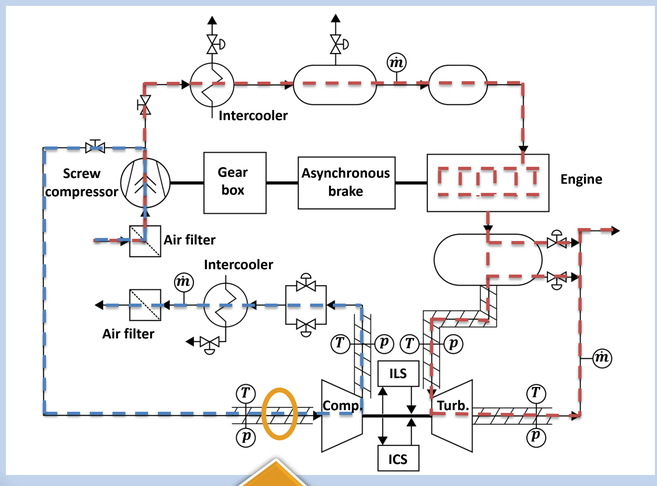
motores térmicos

Abstract

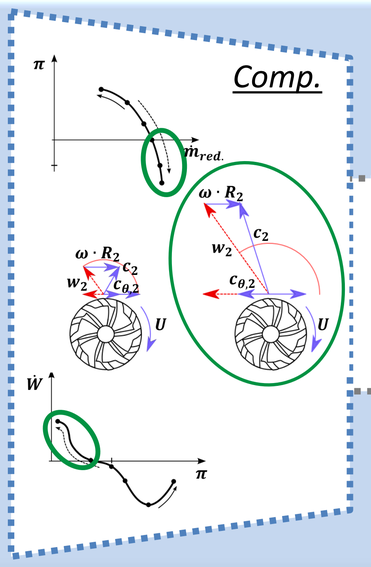
During automotive urban driving conditions and future homologation cycles, automotive radial turbochargers experience transient conditions, where the turbine produces very low power outputs. Under these conditions, the turbine power output might be not enough to feed the mechanical power needs of the compressor, which complicates the measurements under steady state. In this work a method is presented that uses the turbocharger compressor as a centrifugal turbine enabling turbine performance measurements from points of very high expansion ratio up to very low pressure ratios with low power outputs. The results allow to characterize the turbine in a broad range.

Experimental facility



- Screw compressor
- Truck engine
- Asynchronous brake
- 2 separate air cycles
- Turbo thermally insulated
- Valves for mass flow regulation

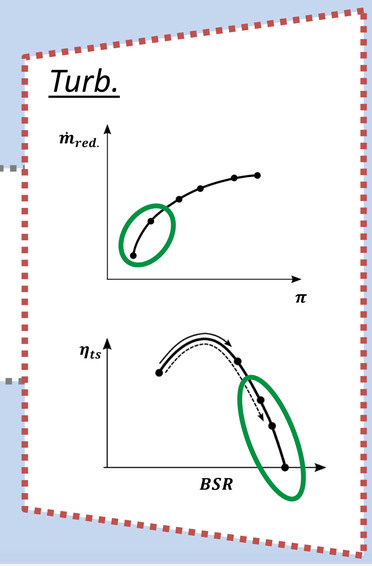
Theory



$$\sum \dot{Q} + \dot{W}_{turb.} + \dot{W}_{comp.} + \dot{W}_{fric.}(f(\omega)) = 0$$

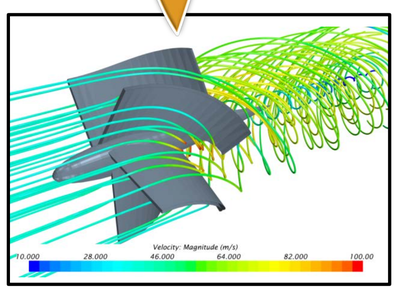
Euler's turbomachinery equation:

$$\dot{W} = \dot{m} \cdot \omega \cdot (R_1 \cdot c_{\theta,1} - R_2 \cdot c_{\theta,2})$$

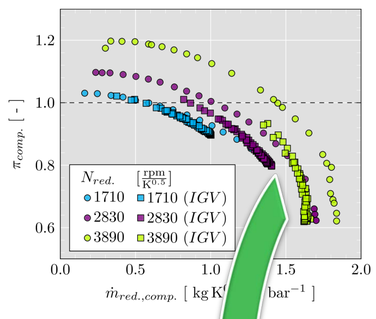


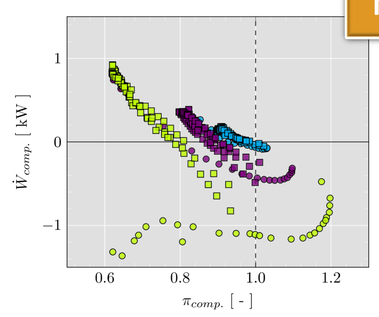
Compressor Setups & Turbine Results

$1710 - 3890 \frac{rpm}{K^{0.5}}$

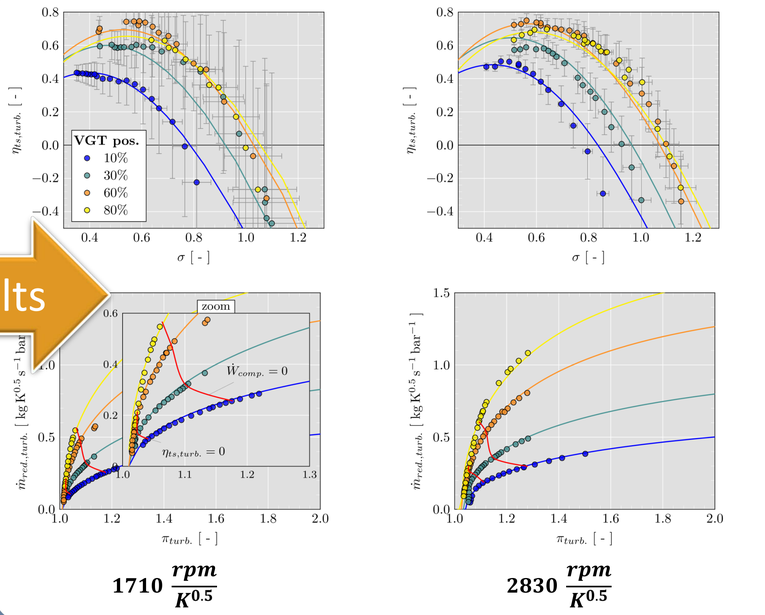


The power output has been risen significantly by introducing the IGV. Thus the measurement of low efficiencies at the turbine side at moderate rotational speeds has been possible.





Results



$1710 \frac{rpm}{K^{0.5}}$ $2830 \frac{rpm}{K^{0.5}}$ $3890 \frac{rpm}{K^{0.5}}$

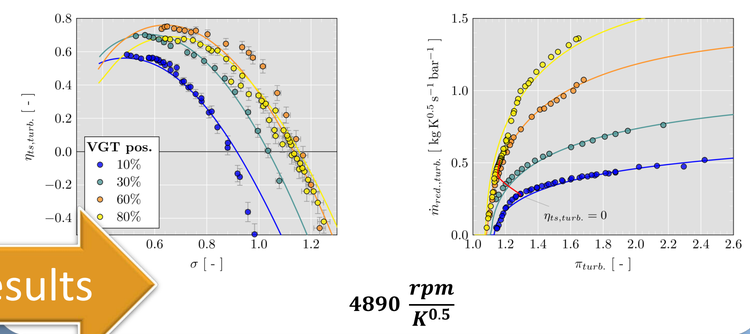
Limitation:

Rising the rotational speed, choking inside of the compressor volute and diffuser has taken place. Further setup modifications have been needed to measure at higher speeds.

$4890 \frac{rpm}{K^{0.5}}$

The choking appears inside of the volute and diffuser since the area ratios are not designed for the existing pressure ratios. Hence, this limitation can be overcome by milling the compressor casing as shown on the left.

Results



$4890 \frac{rpm}{K^{0.5}}$

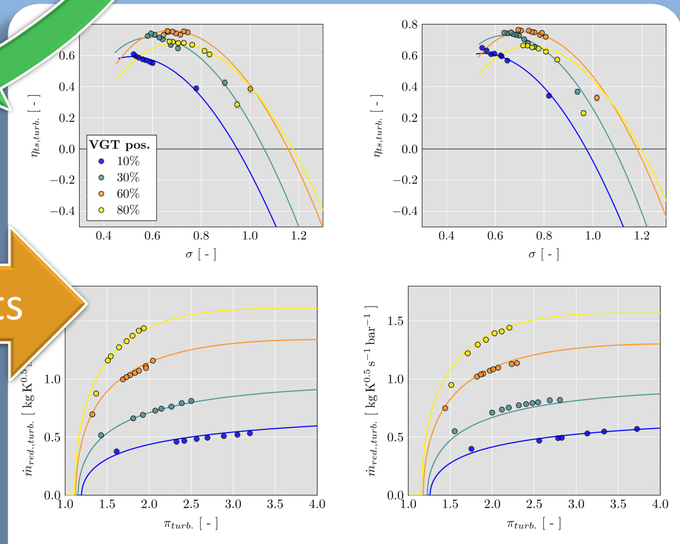
Limitation:

Rising the rotational speed, the lubrication film has broken down while expanding to the ambient pressure. At this condition a huge amount of oil is sucked though the compressor to the surrounding and metal to metal contact occurs, destructing the turbocharger.

$5830 \& 6715 \frac{rpm}{K^{0.5}}$

To gain beneficial results for two remaining speeds the point close to zero mechanical efficiency has been measured ($\dot{W}_{comp.} = 0$). The compressor wheel and its casing have been detached.

Results



$5830 \frac{rpm}{K^{0.5}}$ $6715 \frac{rpm}{K^{0.5}}$

Conclusion

In this project, a procedure for measuring radial turbine performance at extreme low efficiencies has been developed. By means of an upstream IGV the turbocharger compressor acts not only as a braking unit but also as a power supplier for the turbine. This procedure is limited towards higher rotational speeds since choking appears inside of the compressor volute by expanding the air even more instead of compressing it. Further results have been obtained by milling the compressor volute and later detaching the compressor wheel