# On the impact of non-isothermal and pulsating flow on turbocharger turbine performance

KTH CCGEX

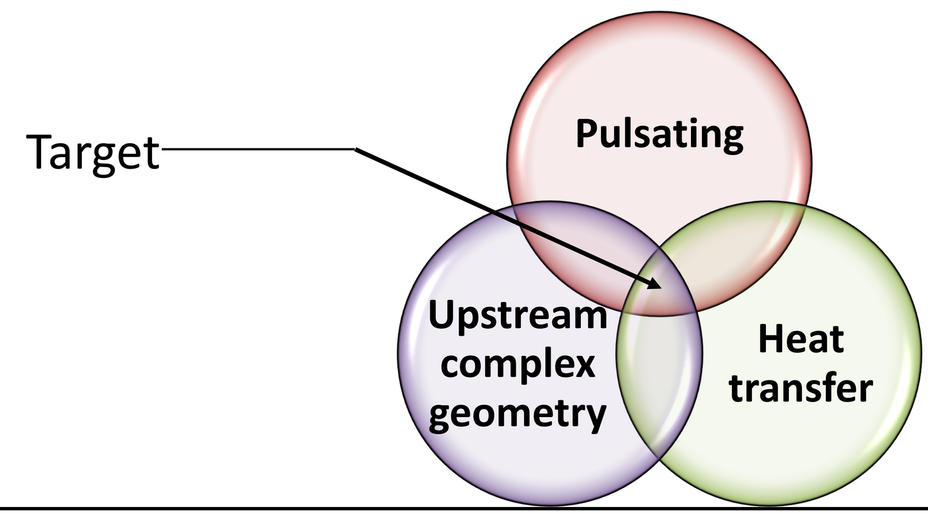
*Shyang Maw Lim*

*smlim@kth.se*

The aim of this study is to investigate the impact of upstream exhaust manifold on the performance, heat transfer and the associated flow physics of a turbocharger radial turbine operating under engine-like flow conditions. We integrate the exhaust manifold to the turbine, and compare its results to the commonly employed model without the exhaust manifold. Based on the three-dimensional (3D) and unsteady flow field predicted by using Detached Eddy Simulation (DES), the exergy budget for each turbine component is computed to quantify the aerothermodynamic losses, heat loss and turbine power. Furthermore, the impact of secondary flow due to the presence of upstream exhaust manifold is assessed. The incident angle of the flow at the rotor inlet is quantified to understand the effect of flow non-uniformities in the rotor on the turbine performance.

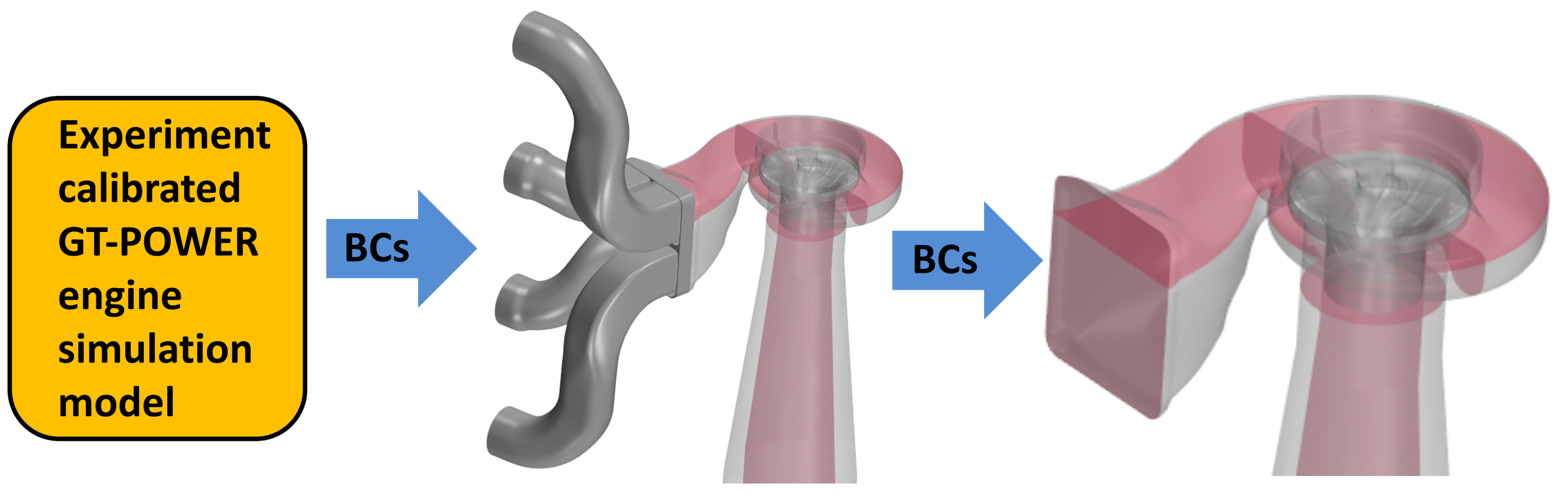
## Introduction and Motivation:

A turbocharger turbine for automotive engine application is subjected to unsteady hot and pulsatile flow, with significant heat loss. The upstream exhaust complex manifold further disturbs the flow into the turbine. Despite the aforementioned operational characteristics, most of the experiments and numerical studies ignore the presence of the exhaust manifold and assume adiabatic conditions. The impact of the secondary flow and flow non-uniformities on turbine performance and heat transfer is unknown. The exergy-based approach is used to quantify turbine's performance and the heat transfer associated losses.




## Setup:

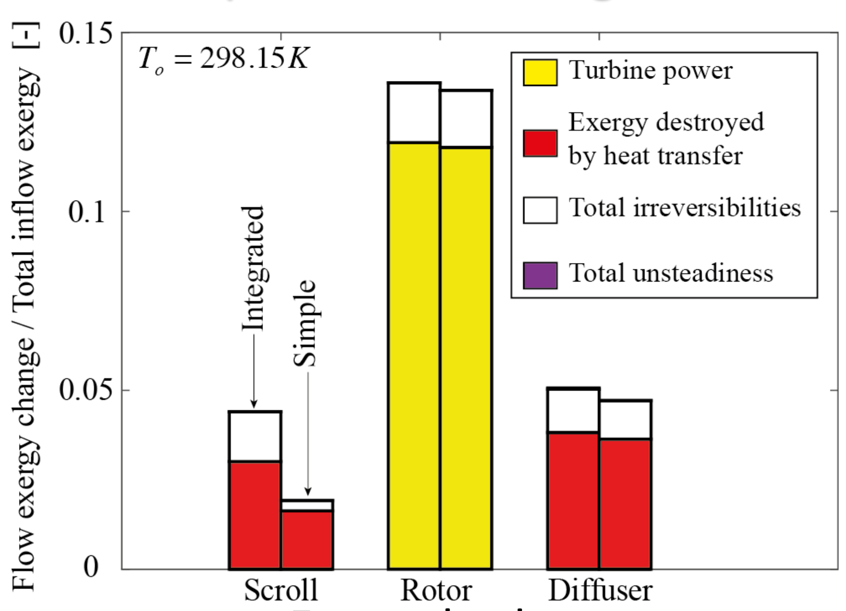
A turbocharger turbine operating at low engine speed of 1500 rpm is considered. Time-varying boundary conditions (e.g. inlet mass flow rate, total temperature, outlet pressure) and wall temperatures predicted by an experimentally calibrated GT-POWER engine simulation model are imposed on the integrated model. Then, the time-varying flow variables at the exhaust manifold-scroll interface predicted by the integrated model is imposed on the simple model, with ignorance of secondary flow.



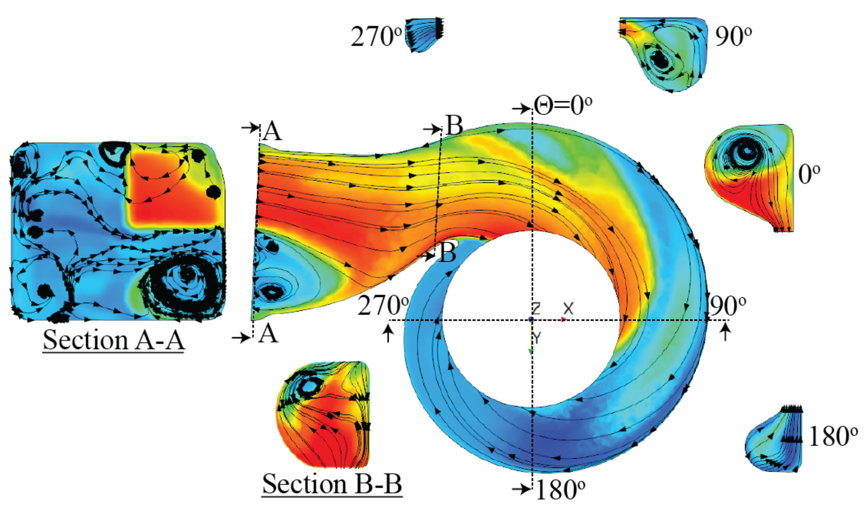

Full model Simple model

## Results:

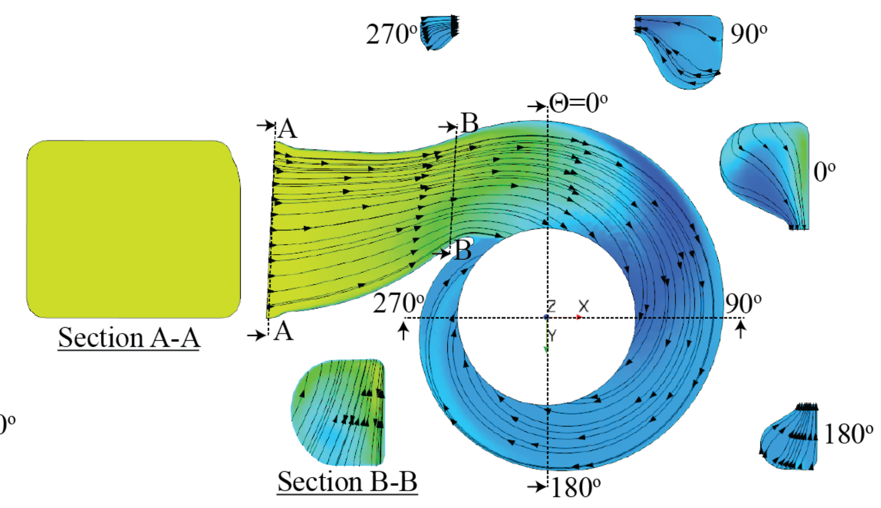
1. Exergy budget shows that upstream exhaust manifold enhances the heat loss and total irreversibilities in the scroll. Nevertheless, the impacts of exhaust manifold on the exergy budget of the downstream component (i.e. rotor, diffuser ) are insignificant.
2. Total enthalpy distribution superimposed on flow streamlines shows that while the flow for the simple model is generally undisturbed, strong secondary flow exists in the scroll due to the presence of exhaust manifold. The flow physics between the integrated and simple models are different.
3. Significant differences in the rotor inlet flow incidence angle are observed between the two configurations at the instance of the initial blow-down pulse of exhaust gas .




Exergy budget

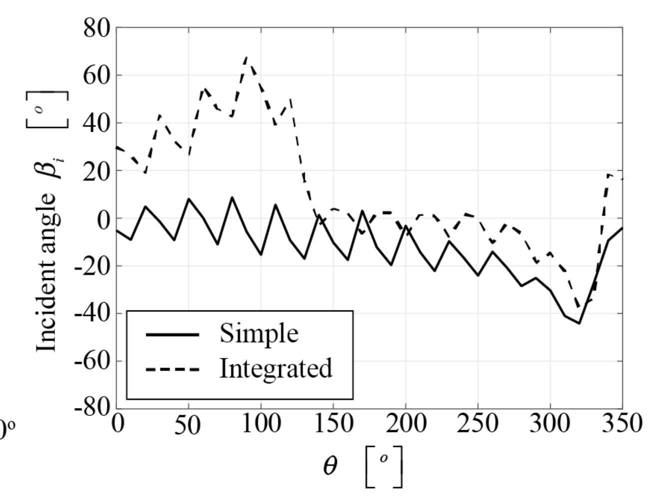



Full model




Simple model

Total enthalpy and streamlines (initial blow down instance)




Incident angle (initial blow down instance)

## Summary and Conclusion:

Results show that upstream exhaust geometry can generate secondary flow and circumferential non-uniformities, with significant impact on heat transfer and total irreversibilities. Although there is significant difference in the rotor inlet flow incidence angle circumferentially, as comparing between the two geometrical models, this does not affect the average turbine power significantly. The outcomes of this study show that integration of the exhaust manifold to the turbine is necessary to understand both the flow physics and the associated global performance correctly.

## Acknowledgements:

Advisors: Mihai Mihaescu, Anders Dahlkild

VOLVO BorgWarner Energimyndigheten SCANIA VOLVO