A NEW COMPUTER MODELLING FOR VARIABLE NOZZLE ON AN ADVANCED SUPERCHARGING ENGINE

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Abstract

Advanced research work has lead to the development of a new simulation program. The thermodynamic parameters at engine admission and exhaust of an engine-mounted variable-geometry turbine can thus be evaluated. A detailed study of losses is conducted experimentally and numerically within the scroll, the vaned channel and the rotor in relation to nozzle opening angles. Simulation results made on the variable geometry turbine are analysed in relation to main flow entry parameters and are compared systematically with experimental data gathered on turbocharger test bench and on Diesel engine.

The development of a new computer modelling aims to establish the thermodynamics parameters at the admission and exhaust of a supercharged engine. Special attention must be put on modelling of losses which constitute a sensible problem in energy conversion. Indeed, the turbocharger is of very reduced size and functions over a wide range rotating speed (25000 to 250000 rpm) and flow rates (0.05 to 0.5 kg/s).

Modelling machine

The machine is divided into characteristic sub-blocks and resolution of thermomechanical flow equations is carried out using the necessary geometrical parameters. The gas is assumed perfect, the flow compressible, viscous and turbulent, steady on average. Potential energy is ignored and a two-dimensional approach is conducted within each turbine sub-blocks for a detailed study of the losses.

Modelling of irreversibilities

The complex nature of the flow within the scroll results in losses in quantity of movement and angular momentum. But, these dissipative phenomena and a new correlation between total pressure loss and loss in angular momentum is proposed.

A 2.5D simulation within the rotor aims to establish first of all the flow description in the meridian and circumferential planes of the machine following the concept established by Wu (1951).

Global turbine validation

Calculated results are compared to the complete experimental variable geometry turbine performance map. The analysis is firstly conducted over the $60000 < N_t(\text{rpm}) < 80000$ rotor speed range. For the 60000 rpm rotor speed, the error in efficiency values is approximately 5% for expansion ratios in the range $1.25 < \tau < 1.4$.

The analysis is conducted for a specific experimental rotor speed line, 2769 (77000) which falls between the simulated lines 2734 (76000) and 2877 (80000) for an 80% open distributor position. The error is evaluated first by comparing the efficiency curves as a function of expansion ratio. The 2734 (76000) model speed profile is very similar to the experimental 2769 (77000) profile. Simulation results cover a widened expansion ratio envelope $1.2<\tau<1.9$ compared to experimental values, for $1.4<\tau<1.65$.

The average difference remains less than 3%, whilst the maximum difference is around 6%. One notes, unsurprisingly a small translation of the efficiency curve for the 2877 (80000) curve, as a function of expansion ratio. One also notes however a deviation of specific mass flow rate, the simulation giving values 6% higher with respect to the considered point.

Conclusion

The description of energy transformation and associated losses within each sub-block of a variable geometry turbine is presented and systematic verifications have been made. The simulation enables one to establish all parameters and the complete performance at inlet and exit of the machine. Simulation results are compared with experimental results and show an average error of between 4 and 6% for turbine efficiency as a function of expansion ratio. Incidence losses at rotor inlet are the main source of losses. This is quite understandable since the flow angle varies over 100° following the running point considered.

It would be of great use now to make further tests, particularly around the maximum torque engine running point as well as for part loads. The simulation also requires completion with a model of heat losses in order to take into account the real non-adiabatic environment of the turbine, of particular importance at part load and low running speeds, which is often the case during urban driving.

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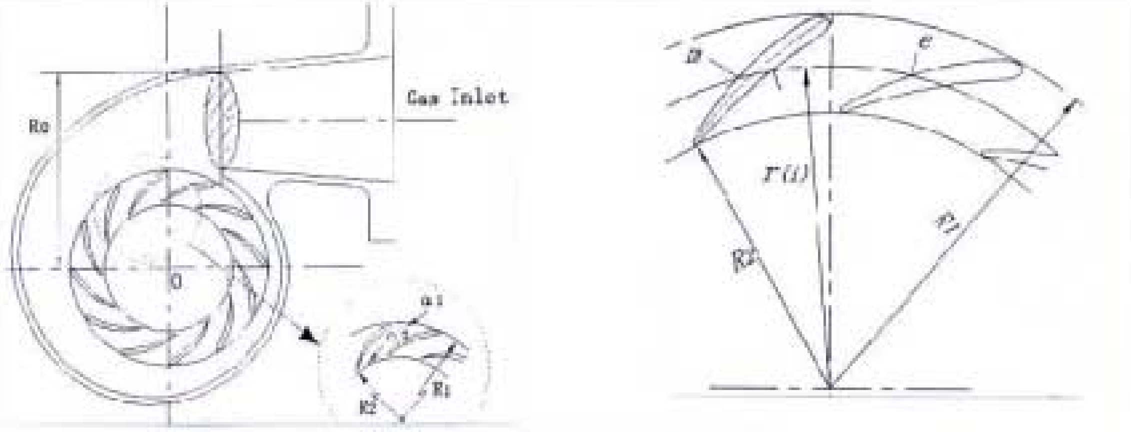

Figure 1 Variable geometry turbine

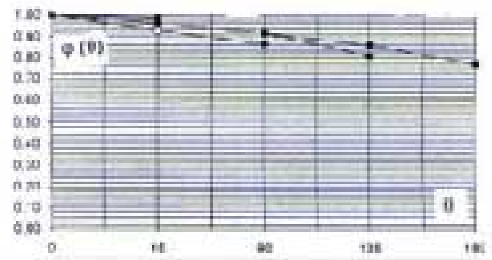

Figure 2 Velocity deceleration

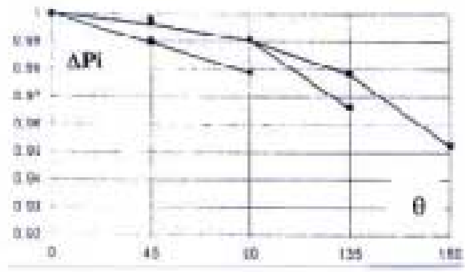

Figure 3 Total pressure loss

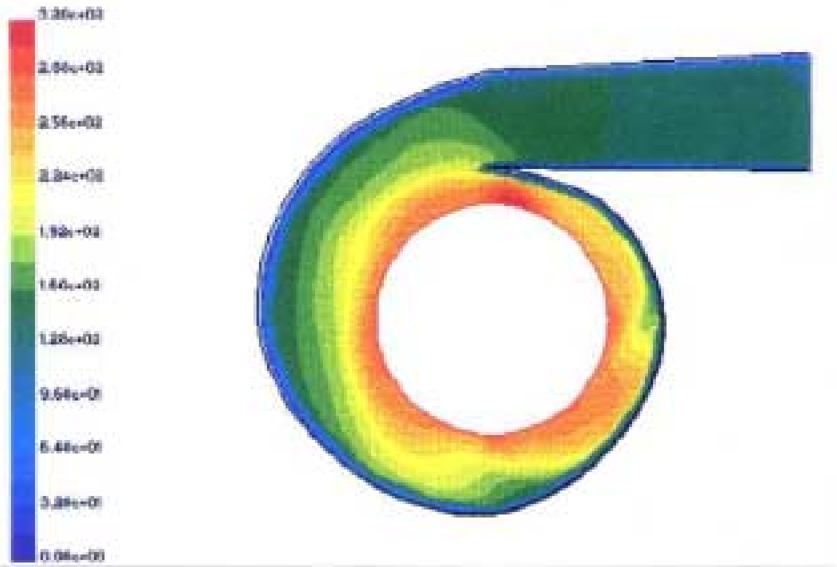

Figure 4 Profiles of velocity magnitude within the scroll

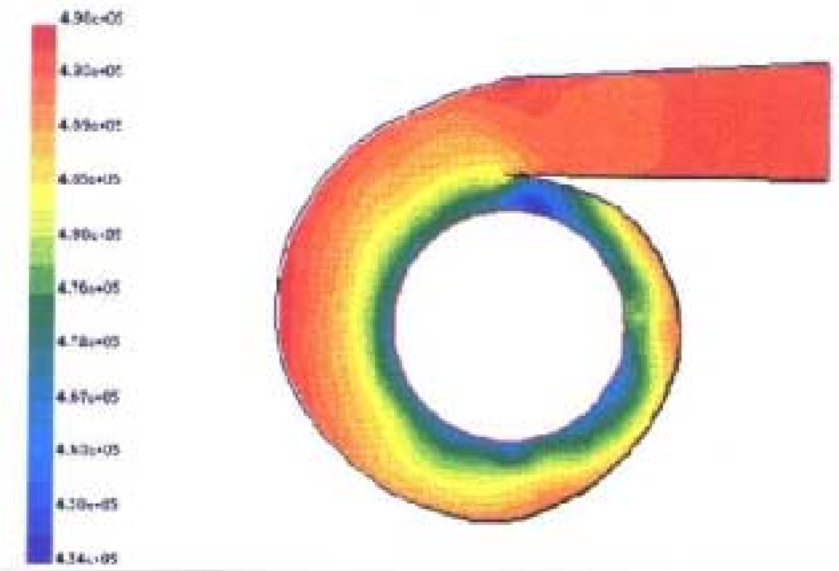

Figure 5 Profiles of static enthalpy within the scroll

RATIO PRESSURE 2.25 :1

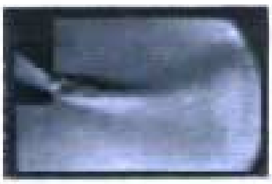

Figure 6 Strioscopic vizualisation of supersonic jet channel exiting

RATIO PRESSURE 2.25 :1

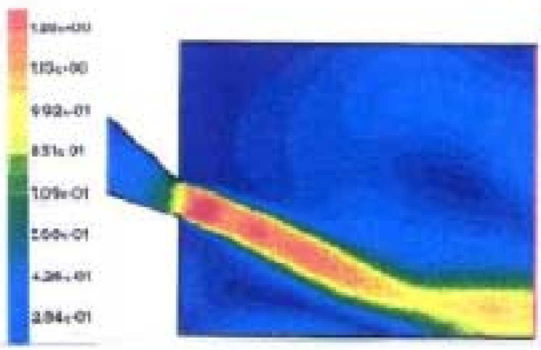

Figure 7 Modelling supersonic jet channel exiting

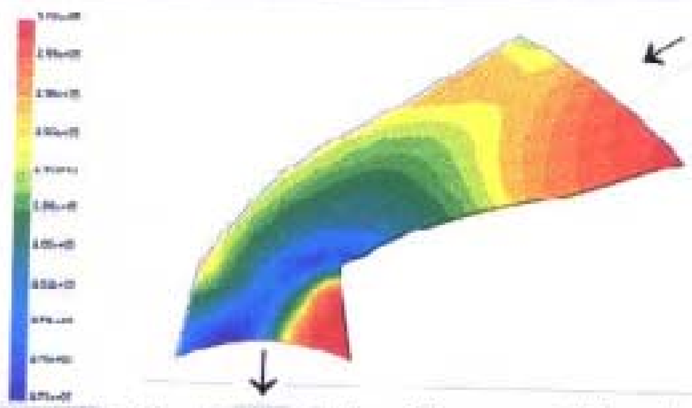

Figure 8 Profiles of static enthalpy within a curvated channel

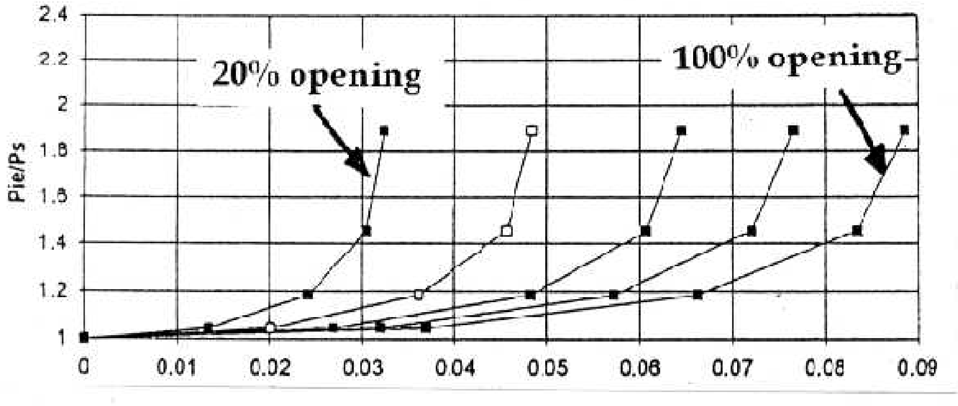

Figure 9 Distributor permeability as a function of its opening position

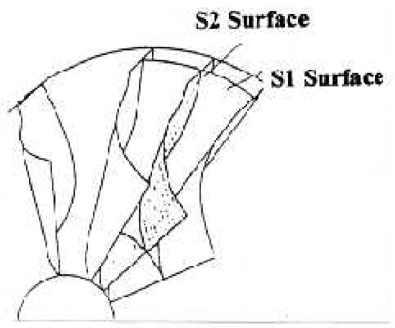

Figure 10 (S1) and (S2) surfaces within the rotor

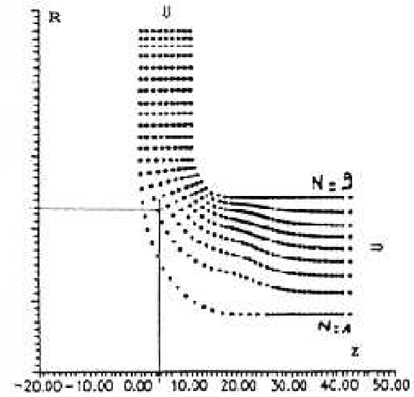

Figure 11 Meridian streamlines

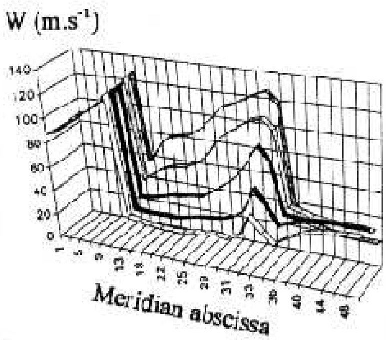

Figure 12 Profiles of relative velocities within the rotor

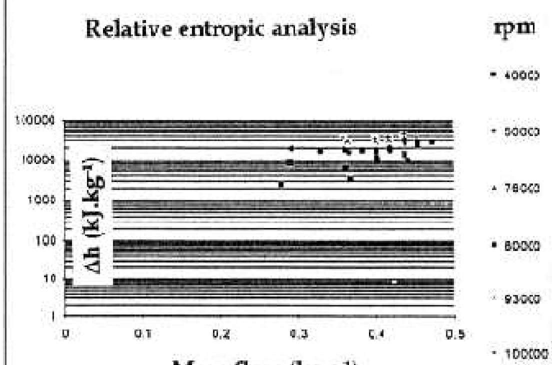

Figure 13 Relative static enthalpy losses within the rotor

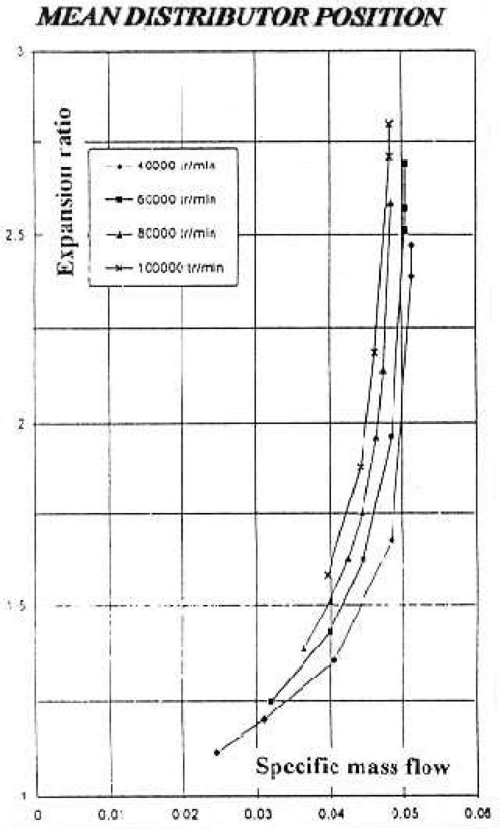

Figure 14 Turbine performance map

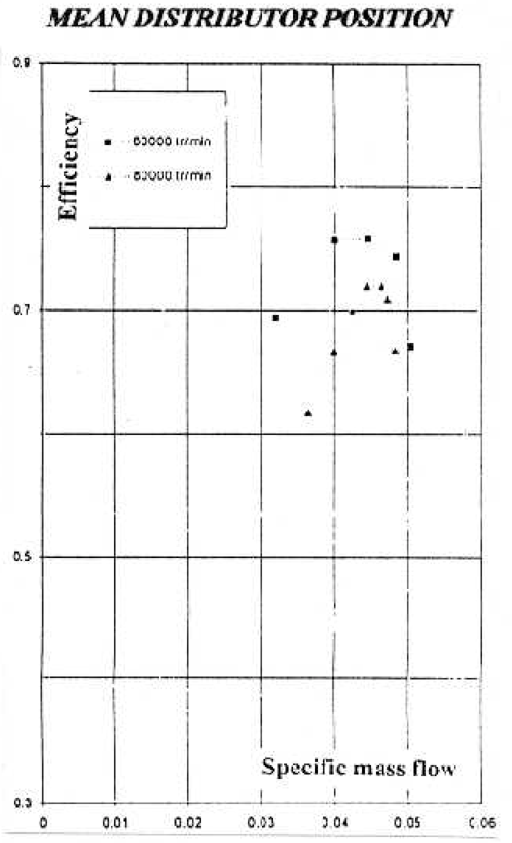

Figure 15 Turbine performance map

10