Title: **Modelling and Model-based Control of Supercharged SI-Engines for Cars with Minimal Fuel Consumption**
Authors: **R. Pfiffner, F. Weber, A. Amstutz, L. Guzzella**
Year: **1997**
Type: **Proceedings of the 16th American Control Conference (ACC), Albuquerque, NM, USA**
Abstract:
One approach to realize spark ignited engines (SI-E) with very low fuel consumption is to use small displacements and boosting. For several reasons conventional turbochargers are not the best choice for such systems. Instead, pressure wave superchargers (PWSC) offer the potential for very fast and accurate load control. In this paper a control oriented model of such an engine system is presented. The model validation is described and the main nonlinearities are identified. Using this model, a suitable control structure is derived and verified by both simulations and measurements.

Title: **Control-oriented modelling of a pressure wave supercharger**

Authors: **Felix Weber, Lino Guzzella**

Year: **2000**

Type: **SAE Technical Paper 2000-01-0567**

Abstract:

This paper presents a control-oriented mean-value model of a pressure wave supercharger (PWS) which is coupled to an SI-engine. The model is able to predict the engine's intake pressure and other main process variables. The model is validated by stationary and transient measurements on an engine dynamometer.

Title: **Modelling of a Pressure-Wave Supercharged SI Engine Including Dynamic EGR Effects**

Authors: **Felix Weber, Peter Spring, Lino Guzzella, Chris Onder**

Year: **2001**

Type: **Technical Paper 01A3010, Third International Conference on Control and Diagnostics in Automotive Applications, Sestri Levante (Genova), Italy**

Abstract:

This paper presents a control-oriented mean value model of a Spark-Ignition (SI) engine supercharged with a Pressure-Wave Supercharger (PWS). The model of the PWS is based on linear gas dynamics. It is part of an overall engine model which predicts conditions in the intake manifold such as pressure, temperature, and exhaust gas recirculation rate (EGR), as well as the states in all the other receivers. The model is validated by steady-state and transient measurements on a highly dynamic engine testbench.

Title: **Mean value modelling of a pressure wave supercharger including exhaust gas recirculation effects**

Author: **Felix Weber**

Year: **2001**

Type: **Diss., Technische Wissenschaften ETH Zürich, Nr. 14265**

Abstract:

Naturally aspirated spark ignition (SI) engines with three-way catalytic exhaust gas aftertreatment systems inherently have a poor efficiency at part-load conditions since engine torque then is controlled by changing intake manifold pressure which causes pumping losses for the spark ignition engine. One attempt at improving this drawback has been to downsize the engine and to recover the engine power by supercharging. The small supercharged SI engine operates more efficiently in the range between lower and middle loads compared to a naturally aspirated SI engine due to the smaller pumping losses.
The pressure wave supercharger represents one possibility of supercharging a downsized SI engine. Since the exhaust gases and the fresh air are in direct contact in this charger, undesirable exhaust gas recirculation through the charger is possible. Sudden high exhaust gas recirculation causes a breakdown of the engine torque. In order to guarantee good driveability, exhaust gas recirculation must be avoided. Therefore, the target of the presented work is to investigate, to model, and to explain the effects of exhaust gas recirculation within a pressure wave supercharger. The work presents a mean value system model of an SI engine supercharged with a pressure wave supercharger with gas pocket valve. The system model is able to predict with good accuracy states such as pressures, temperatures, mass flows, engine torque, and exhaust gas recirculation through the charger in steady-state and transient operating conditions. It explains why the scavenging process of the pressure wave supercharger during a load step must deteriorate. Model extrapolation demonstrates that a faster closing velocity of the gas pocket valve causes a worse scavenging. The most important part of the overall system model is the model of the pressure wave supercharger. It calculates a simplied pressure wave process based on the relations of the linear one-dimensional gas dynamics neglecting the fast dynamics of the pressure wave process. It is validated by the identification of four physically motivated model parameters. As a result, the nonmeasurable leakage losses of the pressure wave supercharger, the nonmeasurable mixing zone length, and its profile between exhaust gases and fresh air can be determined. The validated model of the pressure wave supercharger shows an error on the order of 5%. The developed mean value system model of a pressure wave supercharged
SI engine is a simulation tool. The tool may be used for system analysis, system optimization, and model based controller design in the future.

Title: **Modeling of a Pressure Wave Supercharger Including External Exhaust Gas Recirculation**

Authors: **Felix Weber, Lino Guzzella, Chris Onder**

Year: **2002**

Type: **Proc Instn Mech Engrs Vol 216 Part D: J Automobile Engineering**

Abstract:

This paper presents a mean value model of a pressure wave supercharger together with an SI engine including external exhaust gas recirculation. The model of the pressure wave supercharger is based on linear one-dimensional gas dynamics. It includes an approach for the mixing zone between exhaust gases and fresh air which permits the calculation of the exhaust gas recirculation rate within the charger. The mass flow of the recirculated exhaust gas is the combined effect of too large an exhaust gas penetration into the cell wheel of the charger or of incomplete scavenging of the cell wheel. The model of the pressure wave supercharger is validated by the identification of four physically based model parameters and shows an error smaller than 5% over the operating range investigated. The model can be integrated into an overall engine system model which predicts transient exhaust gas recirculation effects during load steps with good accuracy. The system model demonstrates that exhaust gas recirculation during transients is mainly caused by incomplete scavenging of the cell wheel and not by the exhaust gas penetration into the cell wheel being too large. Both the model of the pressure wave supercharger and the overall engine system model are validated by steady-state and transient measurements on a dynamic test bench.

Title: **Optimal Control Strategy for a Pressure-Wave Supercharged SI Engine**

Authors: **Peter Spring, Lino Guzzella, and Chris Onder**

Year: **2003**

Type: **Conference: Technical Paper ICES2003-645, 2003 Spring Technical Conference of the ASME International Combustion Engine Division, Salzburg, Austria**

Abstract:

On the basis of a control-oriented mean-value model of a spark-ignition engine supercharged with a pressure-wave supercharger, this paper introduces an operation strategy which minimizes the torque response time to driver commands. Since in pressure-wave superchargers fresh air and exhaust gas are in direct contact in the cell wheel, unwanted and excessive exhaust gas recirculation over the pressure-wave supercharger has to be limited by appropriate control actions. The most critical situation arises when large amounts of exhaust gas are recirculated during a hard acceleration, which causes the engine torque to drop sharply and thus to severely affect driveability. In order to prevent such situations, a set of actuators (throttles, valves, etc.) has to be controlled in a coordinated way. Conventional strategies cause the actuators to be closed at a fairly slow, steady rate. Our investigations show that driveability can be improved with a somewhat more complex strategy.