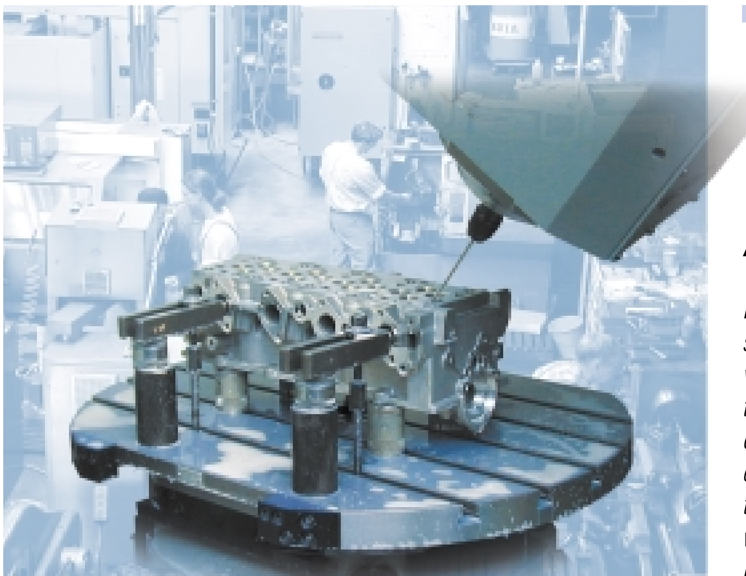
FEV-Spectrum

Technology-Highlights and R&D Activities at FEV

Issue 14 / April 2000



Engine Mechanics and Engine Assembly

In recent years, FEV has extended its services into full range engine development starting from concept through to SOP. Traditional mechanical development remains as one of FEV's core disciplines. Operating alongside this is the classical Trouble Shooting where detailed problems, both from before and after start of production, are examined and resolved with the application of specialized measuring technology or rapid CAE tools. By building its own endurance testing capability and the development of test benches as well as a methodically structured test catalogue, FEV has grown into a recognized partner in this field. Engine development is supplemented by tried and tested prototyping and engine assembly which comprises a specially equipped assembly shop, a component store as well as state of the art measuring technology and rig testing.

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21. Wiener Motoren-symposium 2000
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To ensure quality components for all the needs for the build of development and prototype engines, FEV has established a procurement service, which has developed a large network of local and international suppliers. These suppliers have proven supply status to FEV through their long-standing cooperation and ability to meet the most demanding challenges.

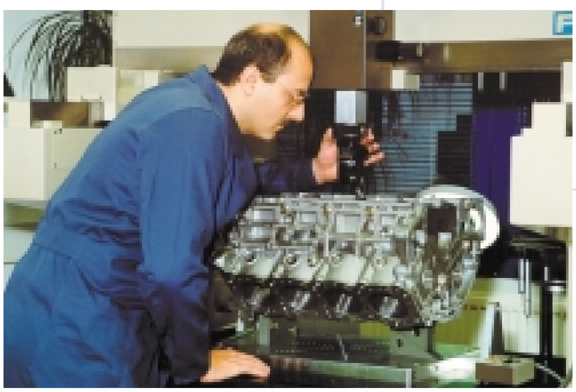
To ensure the highest quality for engine assembly, the capacities for both testing and assembly were expanded during 1997/98. A further enhancement will take place this year (after completion of the current construction program) with a move to brand new premises, containing state of the art equipment, at the Neuenhofstraße site. To support the benefits of the new build, the parts storage capacity and control has been expanded.

With the current capacity, FEV can assemble, to a high standard, special controlled engine builds, prototypes as well as mini series runs. The storage and parts control system is structured so that several engine variants can be built simultaneously.

Measuring Department

Prior to assembling test or mini series engines all components are fully inspected. The test results are recorded according to ISO 9000 procedures to ensure traceability for every individual component.

In addition to the coordinate measuring machine, a number of other metrology instruments are available to measure geometry, surface texture, hardness, etc. FEV has developed its own specialist instruments for specific measurement tasks in engine technology, for example, the measurement of cam profile, absolute valve lift or bore distortion. Endoscopes facilitate the investigation of the most delicate casting structures. Specialized companies, at short notice, conduct further special measuring tasks, such as X-ray analysis of cylinder heads.



Coordinate Measuring Maschine

Assembly Shop

The assembly shop has a build capacity of 250 engines per year which through flexible shift-work could be increased to more than 500 engines per year. It is structured to deal with different engine programs simultaneously. Construction precautions guarantee strict confidentiality between the different development programs.

During engine assembly, the components are not only carefully marked and recorded, but also all characteristic assembly data, such as tightening torque or bearing clearances, are recorded in detail. The continuity of the recording makes every assembly step comprehensible and immensely facilitates (with respect to quality assurance) fault tracking in case of future problems.

To ensure reproduction ability of the assembly procedure, accurate recording of all assembly stages is carried out taking the form of a “Build Manual”. Through close cooperation between the responsible engineers and mechanics, optimized assembling procedures are developed that are constantly improved by, for instance, parallel assembly tests.

The expert storage of all engine components is as natural as the efficient coordination of assembly data and is undertaken by highly qualified personnel adhering to a schedule. Continuous training of all responsible employees enables FEV to meet the ever-changing specific demands of engine development.

Preface

Dear Readers,

due to increased requirements coupled with shorter development times, development procedures, methods and tools play an increasingly important role in engine and vehicle engineering. In this Spectrum issue, we will show you examples of how FEV manages to meet these challenges. Optimized development procedures are a significant factor for success in the quickly changing environment of engine and vehicle engineering.

An impressive demonstration of the current dynamism in the international engine and vehicle development scene was the 8th Aachen Colloquium for Automobile and Engine Technology in October 1999: with 1400 participants, 83 technical contributions and 58 exhibitors, it has evolved into the biggest event of its kind in Europe. The 9th Aachen Colloquium takes place from October 4 - 6, 2000, focusing on topics such as presentation of new engines, Otto engine direct injection, fully variable valve train control, exhaust gas aftertreatment technologies, CAE and NVH.

We look forward to your participation in the colloquium.

Stefan Pischinger
Executive Vice President

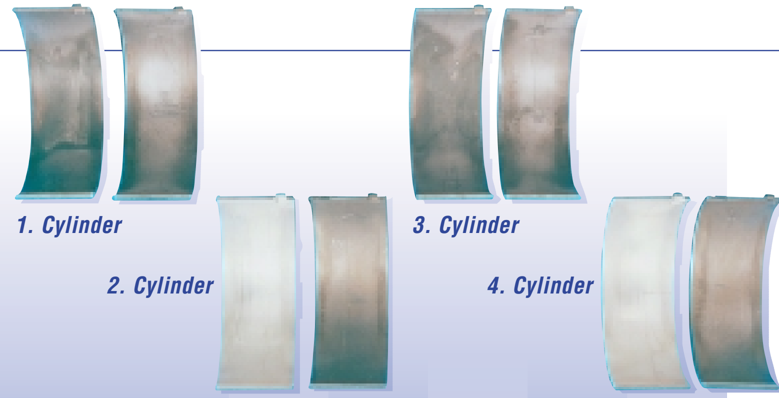
Break-in Program

Engine assembly is followed by a break-in and basic test program. Various engine data is recorded, analyzed and, together with the engine, delivered to the client.

Engine Analysis

Apart from break-in programs, a wide range of examination programs are conducted on the entire engine as well as on individual components. These examinations can be in the form of engines from the client's series production or from the marketplace being stripped down and measured. Various features are recorded, analyzed and subsequently evaluated by experienced employees of the mechanics development department. The findings can be analyzed with FEV's own evaluation schemes (ratings) or within the client's own matrix.

The evaluations can be completed or processed through a critical evaluation of the wide range of possibilities contained in FEV's databases (benchmarking). Benchmarking facilitates not only the allows the comparative evaluation of an engine with regard to special characteristics in field comparisons, but the domain of "personnel experience" can also be visualized.



Engine No.: EX 2041					
Rating Scale	Running Time (Hours)	Bearing Part Cylinder 1	Bearing Part Cylinder 2	Bearing Part Cylinder 3	Bearing Part Cylinder 4
Upper Bearing Shell	988	2	1	2	1
Lower Bearing Shell	988	2	2	2	2

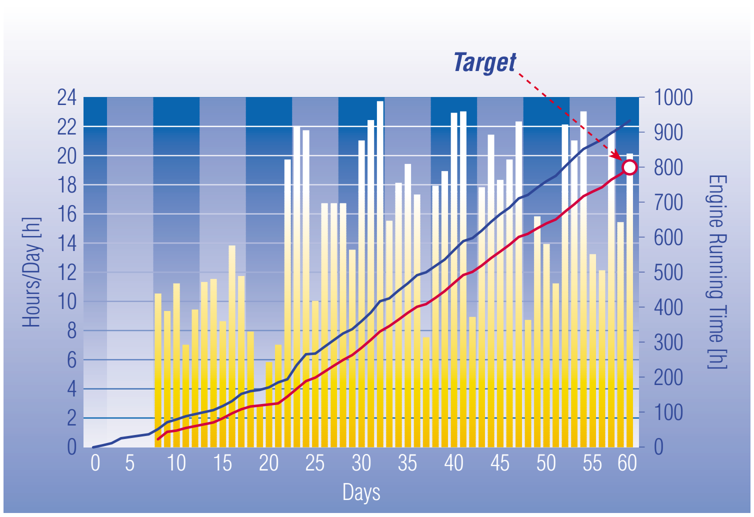
Rating 1 Excellent; 2 Acceptable; 3 „Borderline"; 4 Unacceptable

Mechanical Development

With regard to the practical testing of an engine's mechanics, a comprehensive catalogue (see spectrum no.11) of reliable test procedures is available. The basis is an extensive test program, which was compiled as a test catalogue, built on the experience from numerous development projects from the recent past. The possibility to realize flexible and variant endurance testing on our numerous test benches is only one part of the test catalogue. Not only different standardized mechanical test procedures for endurance testing can be suggested by FEV, but also data pertaining to the full operational output of an engine is realized and customized for specific application profiles.

The use of modern as well as innovative working methods and materials ensures a flexible and timely project management fulfilling the highest standards. The completion of the engines according to schedule facilitates, above all, a precise planning of all cost intensive test bench investigations. Apart from the technical preconditions, the tried and tested project management system completes optimum project realization.

◆ *Th. Koch*



Cycle Running Time/Day
Running Time in Durability Cycle
Engine Total Running Time

FEV Transient Test Bench for Automatic Transmission

Because of increasing emission limits worldwide, the need for exhaust gas emission development is greater than ever. Overseas markets, especially the US market, demand more and more sophisticated development goals. Tax reduction for vehicles which today meet future emission limits is an incentive for manufacturers of new vehicle concepts to design low-emission engines.

As an alternative to the common practice of in-vehicle applications, which are normally performed on a chassis dynamometer, high dynamic test benches are an extremely effective tool for the fast development of new exhaust gas after treatment concepts.

FEV has been using the advantages of high dynamic test benches for emission development of combustion engines with manual transmission for a long time. By means of a computer-assisted simulation tool, the actual engine is loaded under realistic conditions, including all relevant vehicle parameters, such as vehicle mass and gear ratios. A road load simulation is modeled which takes the drive train into consideration in the form of a spring/mass system. Apart from the modal analysis of limited emission components, several cold starts are possible within one day through using an external cooling system for engine and exhaust line.

By using a modular design of the test bench, engine modification time is reduced to a minimum. New emission technologies with new catalytic converters as well as new emission concepts, such as electrical heated catalysts or new secondary air strategies with variable mass flow and different feed points, can be realized independently from the existing engine concept by the test bench control system. Parallel to all hardware changes, the engine can be tested in any dynamic emission test cycle as well as under stationary conditions, for example a full load measurement, facilitating a fast compromise solution between effective emission control and minimum loss of power.

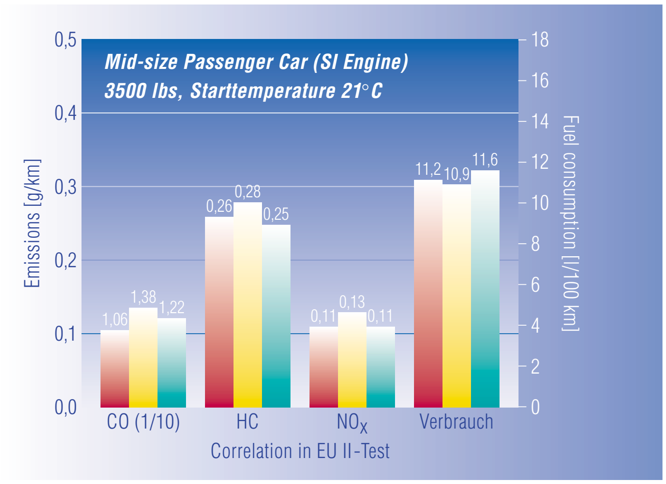
On a transient test bench, the influence of the driver, as it appears on a chassis dynamometer, is eliminated which leads to a high level of repeatability, and even the smallest influences can be reliably detected. On the other hand, since any driver behavior can be modeled by the simulation tool, a good correlation to vehicle measurements (Pic. 1) can be achieved.

In view of future emission limits in the US, the demand for new emission concepts for ULEV and SULEV targets are increasing.

The fast realization of new concepts in the US FTP 75 (Pic. 2) test cycle, with regard to SULEV emission limits, especially requires a high level of test bench flexibility during the development stage which FEV is able to offer with its transient test benches.

A particular need for the US market is the testing of powertrains with an automatic gear box. To satisfy this, FEV has modified one of its transient test benches to meet this requirement.

Picture 3 shows a 4-cylinder SI combustion engine within the framework

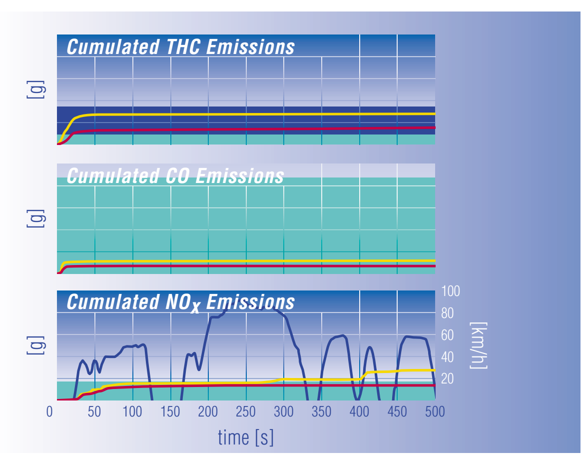


Pic. 1: Correlation with chassis dyno

FEV Transient Test Bench

Chassis dyno 1

Chassis dyno 2



Pic. 2: Emission Concept for SULEV Limits/FTP 75

Baseline Analysis

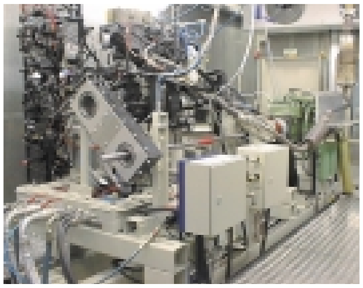
FEV Calibration with optimized Secondary Air System

Vehicle Velocity

SULEV Limit (NMOG)

ULEV Limit (NMOG)

of an exhaust gas after treatment development for the US market. The engine can be mounted directly from the vehicle into the test bench using



Pic. 3:
FEV Transient Test Bench for engines with automatic transmission

the standard automatic gear box. In the case of a front-wheel drive vehicle, both half shafts are transmitted to one central shaft. This solution involves no intervention from the differential gear, and the engine can be quickly mounted back into the vehicle at any time. When testing a rear-wheel drive vehicle, the test bench configuration is much simpler, since the cardan shaft can be directly connected to the load unit.

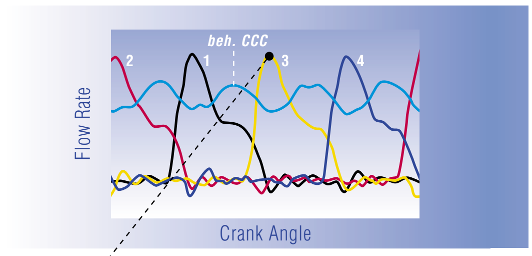
While running an engine with automatic transmission, a maximum wheel shaft torque of 2000 Nm, a maximum engine power of 200 kW and a vehicle velocity of up to 200 km/h can be simulated. Thus, all relevant test cycles for emission development can be performed. ◆

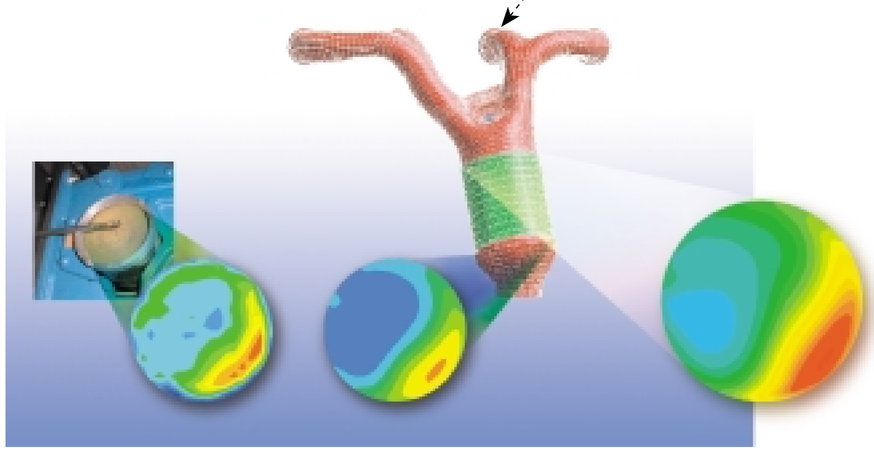
Rodeland

3D-Optimization of Exhaust Flow

The computational and experimental optimization of flow properties during layout and design of exhaust manifolds is a highly efficient tool to reduce development time and cost and achieve stable and low exhaust emissions.

Increasingly restrictive exhaust legislation requires the development of more and more sophisticated exhaust aftertreatment systems. To meet low emission limits, the light-off time of catalysts must be as short as possible.



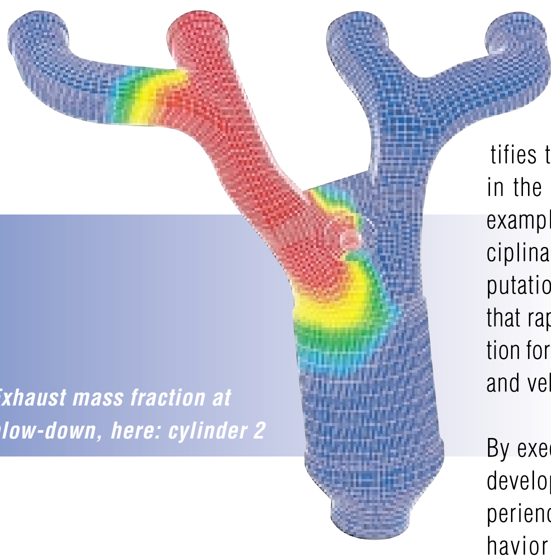


Concurrently, the available volume for the converter is restricted by reduced packaging area. Furthermore, the exhaust flow needs to sweep the catalyst as uniformly as possible to guarantee optimum conversion of pollutants.

A quick catalyst light-off can be achieved in close-coupled arrangements. However, thermal and fluid mechanical stresses of the catalyst tend to increase, the closer it is placed to the engine. The optimization of exhaust-flow minimizes such stresses and makes the most of the converter volume. In an ideal development process, this flow optimization supports the design already in its layout phase.

In cooperation with Volkswagen and other manufacturers, as well as suppliers, FEV has developed a standardized method to analyze and optimize the duct geometry of the exhaust system and the flow distribution in the catalytic converter. This procedure is based on an integrated computational and experimental approach.

The experimental flow analysis is carried out under environmental boundary conditions, i.e. in cold air flow. It quickly reveals the catalyst flow distribution of prototype manifolds. Validity and transferability of the measured results to engine operation is ensured by meeting Reynolds Numbers in both flow experiment and engine operation.



Exhaust mass fraction at blow-down, here: cylinder 2

Using the CFD model, flow is simulated at steady-state for each cylinder separately or under transient conditions, i.e. including the pulsation and interaction of flow from subsequent cylinders under hot engine operation conditions.

The analysis of local flow distribution detects possible unfavorable aspects of converter admission, e.g. insufficient dwell time due to high velocities or overload of the matrix by hot spots. Such an analysis also points to the causes of these undesired flow patterns, leading to a well planned and calculated redesign of pipe shape, junctions and diffusers.

Furthermore, flow can be analyzed at the exhaust oxygen sensor position. It shows, if single cylinders will not be recognized by the sensor or if they will be significantly underrepresented. If so, the sensor position and/or the manifold geometry is optimized to improve the prerequisites for a fast, sufficiently accurate and, if possible, cylinder selective AFR control.

Moreover, origins of maybe unnecessary pressure losses are detected. A simulation of the revised design immediately verifies the success of the measures and quantifies their impact on flow uniformity in the catalyst. This procedure is an example of a highly efficient interdisciplinary cooperation of design, computational and experimental analysis that rapidly leads to an optimum solution for the target combination of engine and vehicle.

By executing this analysis procedure, developers gather comprehensive experience about the manifold flow behavior that can help to reduce the number of design iterations. The better understanding of complex flow phenomena through CFD analysis contributes to the continuous improvement of future stage 1 layouts.

Computational and experimental exhaust flow optimization in manifold and converter may at first seem to cause additional expenses. However, in the further course of product development, it turns out to be an excellent investment into a faster and more cost efficient development process that leads to a competitive advantage. ◆

C. Schernus, M. Breuer

Plant Expansion

At the beginning of the year 2000, the 3rd plant expansion was completed at FEV's Neuenhofstraße site. FEV now has three buildings housing testbenches at the site at its disposal.

The focus of the new test house is a state of the art assembly area for all components marketed by FEV's business area, test and instrumentation divisions. The area contains stand alone test benches – specially built as containers – as well as all pertinent peripheral subsystems, such as different conditioning facilities for oil, water, air and fuel as well as electronic components for automated test-benches and recording measurement data.

In another area of this building will be a workshop to support the test operations with facilities to premount engines on test benches and apply the instrumentation. In addition there will be an engine assembly area which will be capable of building mini series engines.

In total, the new house has a usable floor space of 2.500 m^2 and is fully synchronized with the present infrastructure of the site. ◆ *Schütze*

IMPRESSUM

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