Integral Process Engineering
for a Smart Series Production
Production – Profit Relevant Intersection between Development and Market Demand

The available time for development and market launch for a new generation of engines is constantly decreasing. To implement an innovative approach, it is not only necessary to consider the specific aspects of mass production, but also to aim for early cooperation with system suppliers and to include the processing and the production assembly demands of the OEM. Only then can a certain degree of maturity be ensured for an innovative and robust engine concept at the Start of Production (SOP). Consequently, production planning must already be well integrated into the process of developing ideas and the concept phase, due to both time and economic considerations (Figure).

Advantages FEV provides through process engineering:

- Reduction in processing time for development and process commissioning in production → Earlier SOP effects profitability
- Avoidance of unexpected efforts and unscheduled delays during development and process engineering phase → No profit loss against business plan
- Involvement of an improved production efficiency → Reduction of production and unit costs

FEV Production Engineering bridges the gap between the creativity that is inherent to the process of innovative powertrain development, the design process, and the specific requirements associated with production. The challenging market requirements also play a decisive role in this process.

The utilization of advanced planning further opens possibilities to improve productivity along with a time-related profitability benefit during the product development process. The adjoining figure illustrates the macroeconomic benefit associated with an early product introduction (SOP). Combining an earlier SOP with lower development costs and the associated acceleration in the revenue stream, results in a financial break-even point that occurs much earlier.

FEV Motivation for Process Engineering

Fields of services

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<th>Methodical support services</th>
<th>Production support services</th>
<th>Advanced support services</th>
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<td>&gt; Variant management</td>
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<td>Training &amp; documentation</td>
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Based on FEV’s experience, a tightly integrated cooperation and simultaneous approach with product development and production planning is a key factor for the success of each new engine development or engine upgrade and for implementation into regular production.
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The final part and component manufacturing costs are primarily effected by their design and concept. Consequently, the basis for the eventual costs and cost structure of a product will be defined very early in the project.

The practice of the “KIS” principle (Keep it simple) and using the Simultaneous Engineering (SE) approach between development activities and the process department as well as early involvement of potential suppliers are key elements of the FEV component design process.

- Only rectangular-oriented drilling and milling
- No angled machining
- Main oil gallery and oil supply bores to main bearings are cast-in
- No long drilling operations (cycle time)

Simultaneous Engineering:
- Verification of engine design with machining process and equipment supplier
- Analyzing fastener accessibility

Simple solutions are preferable to complex approaches.
- Machining is avoided as much as possible to minimize investment costs. Whenever possible functions are designed as cast.
- In cooperation with assembly planning, adequate clearance for assembly tools is provided.
- Complex functions are combined into modules and shifted out of the main components. Modules that are supplied have already been quality checked. This considerably reduces machining and assembly costs.
- Plant constructors and tool manufacturers are involved to realize simple and cost effective machining processes. This includes a clarification of clamping concepts together with all of the specified tolerances. This results into improved quality with less effort in the production.
- The structure of the part considers the expected machining forces, so that even deformations at even high cutting speeds are avoided.
- Application of standard tools is discussed already during the first prototype design stage to avoid additional future costs during mass production.
- Undercuts and small drillings are not allowed to keep tool fracture and defective machining to a minimum.

High flexibility in the mainstream line assembly processes is extremely important with respect to variant management and process adaptations. The assembly concept must be supported by engine design, for example by shifting assembly processes of engine sub-units, modules and accessories, to a line that is adjacent to the mainstream line.

The use of an integral oil-filter and water pump module simplifies not only the machining processes (only one plane to be processed), but also the assembly by shifting sub-assembly and quality control to the supplier.
Design for Manufacturing (DFM)

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Considering the accessibility of cylinder head bolts for assembly and maintenance

Connect harness module

Pre-assembled engine modules

Engine modules pre-assembled by supplier or beside the mainstream assembly line
Market trends, combined with local and global boundary conditions, significantly determine the direction of future product technology and design. Calculable investments, short realization time till SOP, high quality requirements with capable processes and competitive manufacturing costs are challenges that tomorrow’s production strategy will face. FEV’s process and production engineering translates the product design into industrial manufacturing concepts. The competition-driven necessities of an economical production also have an impact on product development. The professional knowledge from both worlds provides an ideal basis for the development of future market-oriented production strategies. 

Existing production facilities have often unused capacity or unknown potential with regard to expanding capacity, process design or the manufacturing of upgraded or new products. As opposed to a green field solution, the implementation of a new product on an existing production line requires very specific input requirements for product development and design. The shared usage of equipment limited process flexibility and adaptability forces product detail design parameters that have to be considered already in the concept phase (e.g. clamping points, cylinder bore distance, block height or material selection). If the critical parameters are known from the beginning, they can be easily incorporated into the product design. The modification effort for production and processes can be reduced appreciably. Therefore a general condition is the simultaneous engineering between development and design on the one hand and process and production planning on the other hand.

**Benefits:**
- Reduction of capital expenditures
- Load increase on existing manufacturing lines
- Decrease in realization time
- Use of available process and organization knowledge
- Smooth change over between old and new production

**Development of Market-driven Production Strategies**

**Re-use of Existing Production Facilities for New Powertrain Components**

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Retrenchment of capital expenditures by using existing production facilities: Saving potentials in different operation areas are possible.
The integral view of the product life cycle (PLC) includes the aspect of a successive product adaptation even after the market launch, to maintain its profitability.

**Cost Engineering**

To support this PLC management, an active and independent Cost Engineering System is worthwhile.

**Motivation for cost engineering:**
- Cost Pressure
- Time Pressure
- Variety of Variants
- Increasing Outsourcing
- Proceeding Globalization

**Integral Cost Calculation: Key cost-driver elements**
- Customer orientation concerning price and required product features
- Cost comparison of different engine concepts before development
- Simulation of prospective product costs during development
- Analysis of the effects of design changes
- Cost comparison of different production concepts
- Analysis of functional costs
- Elimination of unnecessary costs
- Reduction of costs for product variants
- Cost reduction by optimization of material, manufacturing and assembly
- Cost analysis of competitive products
- Comparison of production costs at different production locations

**Example: Analyzing production processes using software tools**
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### Cost Engineering

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### Methodology

- **Software-Tools**
  - Professional Cost Calculation Tools
  - Cost Calculation Tools developed by FEV
- **Database**
  - Benchmarking
  - Materials
  - Tools
  - Manufacturing Processes
  - Machines
  - Component Parts (Prototypes + Production)
- **External Database**

### Product Life Cycle

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<td>Development / Design</td>
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<td>Production Engineering</td>
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<td>Series Production</td>
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### Cost Transparency

- Customer orientation concerning price and required product features
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- Simulation of prospective product costs during development
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- Cost comparison of different production concepts

### Cost Reduction

- Analysis of functional costs
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### Example: Analyzing production processes using software tools
Planning and Engineering of Production Facilities

The Simultaneous Engineering approach is supported by integral manufacturing planning (product structuring, process and production concepts, integral layout development and work system design).

Digital Factory – Process Planning

Motivation
The digital or virtual factory is the generic term used for a comprehensive network of digital methods and models. The digital factory is already more than a mere idea. It has been specifically introduced in the automobile industry as an integrated tool that is used through several steps of the product design, product development and product manufacture processes. The basic idea of the digital factory is the parallel, synchronous work of product development and process design (simultaneous engineering).

Process graph
- Parameter
- Work steps
- Allocation product

Time analyses
- Method (MTM, UAS…)
- Customer specific

Product
- BOM
- Structure

Premises
- Production rate
- Location

Virtual process planning is an essential component of the digital factory planning. It supports the comprehensive manufacture planning from product structuring and continuing with the process concept, production concept, integral layout generation and a work system design.

Simulation
- During planning process

Layout
- Variants
- Required space

Ergonomics
- Analyses

Line balancing
- Optimization

Production concept
- Resources
- Work stations
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Process description
- Parameter
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Process graph
- Sequence
- Allocation product

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A Product Life Cycle (PLC) can vary between a few years and, in some cases, decades. The knowledge and awareness of potential risks and opportunities are a precedent for making decisions for innovative products prior to their market launch. An integral business case study provides answers to achieve success, by providing critical parameters and boundary conditions, which are important for a successful realization of the product idea.

FEV’s production engineering department has developed complex investigation models for an integral PLC analysis, which includes some of the following input parameters (more than 80 different parameters are available):

- Production / Market strategies (volume over time, location factors, degree of automation, etc.)
- Component costs based on a parts list, a distinction between purchased parts and in-house manufacturing
- Net cost of in-house production on the basis of the chosen production strategies
- Inflation rates differentiated by material, labor, energy and market
- Production models and OEE analysis

The integral view of development, process engineering and implementation as well as the involvement of alternative production strategies (based on defined assumptions) points out strengths and weaknesses of a particular concept. This makes a prioritization and a focusing on the essentials possible during the realization process.

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Development of product cost structure during the course of the PLC

- Development & validation cost/engine
- Material cost with efficiency benefit using standard parts
- Setup cost + tooling costs
- Sum of other costs/year
- Maintenance cost/year
- Equipment costs
- Manufacturing overhead costs
- Extra costs occupancy costs
- Selling expenses
- Administrative overhead costs (G&A)
- Min. profit

Profit trend and profit sensitivity analysis

Factory Assessment to Evaluate Process Capabilities and Quality Assurance in Mass Production

Business Case Studies – Integral view into the Future

**Initial meeting**
(Introduction, procedures, mutual understanding of audit procedures, objectives, on-site organization etc.)

**Line walks**
(On-site audit ~2 ½ days, checking manufacturing processes, procedures and evidences, detect strengths and weak points, discussion with operators and process owners)

**Summary of audit results**

**Management feedback**
(First feedback and impressions, detected strengths and weak points, room for improvements)

**Review of the agreed improvement plan**

One day review audit on-site

**Audit results & improvement recommendations**
(Audit report)

**Process Survey Tool for Manufacturing Process Management**

COSTREDUCER'S QUALITYCube

**Preparation**
(Schedule, questionnaire, audit adjustment with client, process descriptions layouts, QA system)
The visualization of the enterprise processes is the basis for the implementation of a comprehensive and integral organization and process management system.

FEV’s Production Engineering Department uses high-performance, modular built-up software as a process management tool.

Benefits and Value Added
- Visualization of organizational and workflow structures
- Presentation of the information flow at interfaces
- Access to stored information and linked documents
- Link between processes
- Navigation through all processes via World Wide Web and intranet portal

Customer-oriented and quality-sensible business management

FEV business process engineering turns customer-oriented process concepts into efficient workflow designs and organizational structures. The resulting concept represents a good basis for an ISO 9001 certifiable quality management system.
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FEV Global Competence Network

Full service in-house competence for:
- Transmission design
- Diesel and gasoline systems
- NVH & vehicle physics
- Powertrain mechanics
- Vehicle electronics & mechatronics
- Vehicle applications
- Hybrid technology
- Benchmarking
- On-site engineering services

FEV engineering centers, subsidiaries and representatives — spread across the globe, close to customer

Utilization of in-house test cells and test centers across the globe

Long-term manifold FEV project expertise in many industrial powertrain and engine applications

Manufacturing of test systems for the global market

Network of experienced senior consultants for on demand support

Global FEV network of production part suppliers

Global customer base of automobile and engine manufactures

Prototype part supplier network

FEV production equipment supplier global network