

# DIRECT INJECTION 2-STROKE ENGINES

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## INTERNATIONAL WORKSHOP & CONFERENCE

### A 2-Stroke Chainsaw with Injection : Development and Customer Experience

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**Rueil-Malmaison**  
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# Agenda



- 01 Introduction**
- 02 Injection technology under severe conditions at reduced cost**
- 03 Injection integration and design of the MS 500i**
- 04 Feedback from the market**
- 05 Summary**

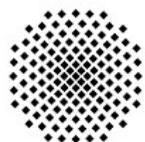
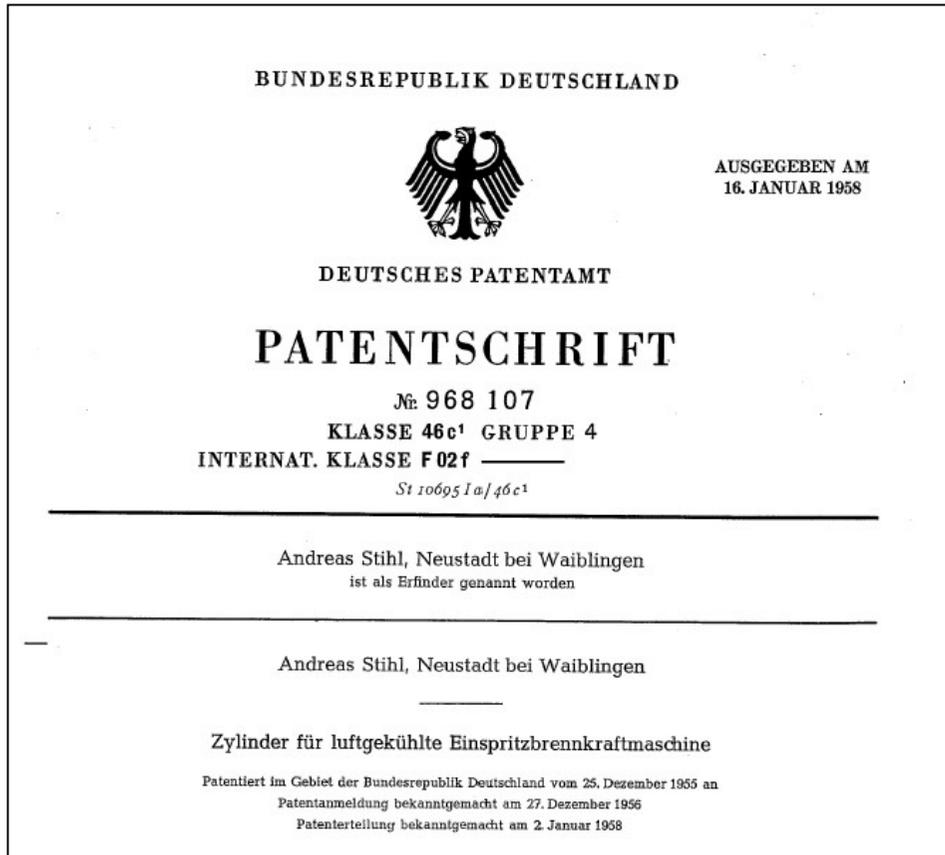
***STIHL***



# INTRODUCTION



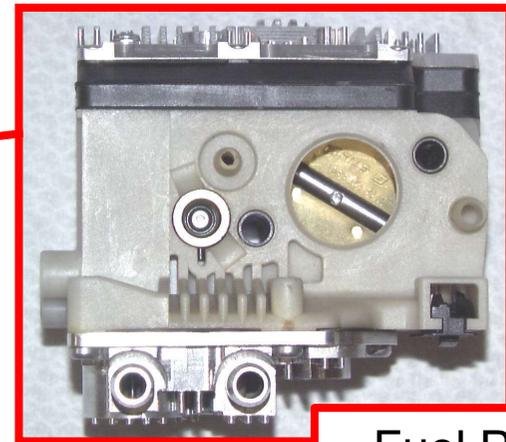
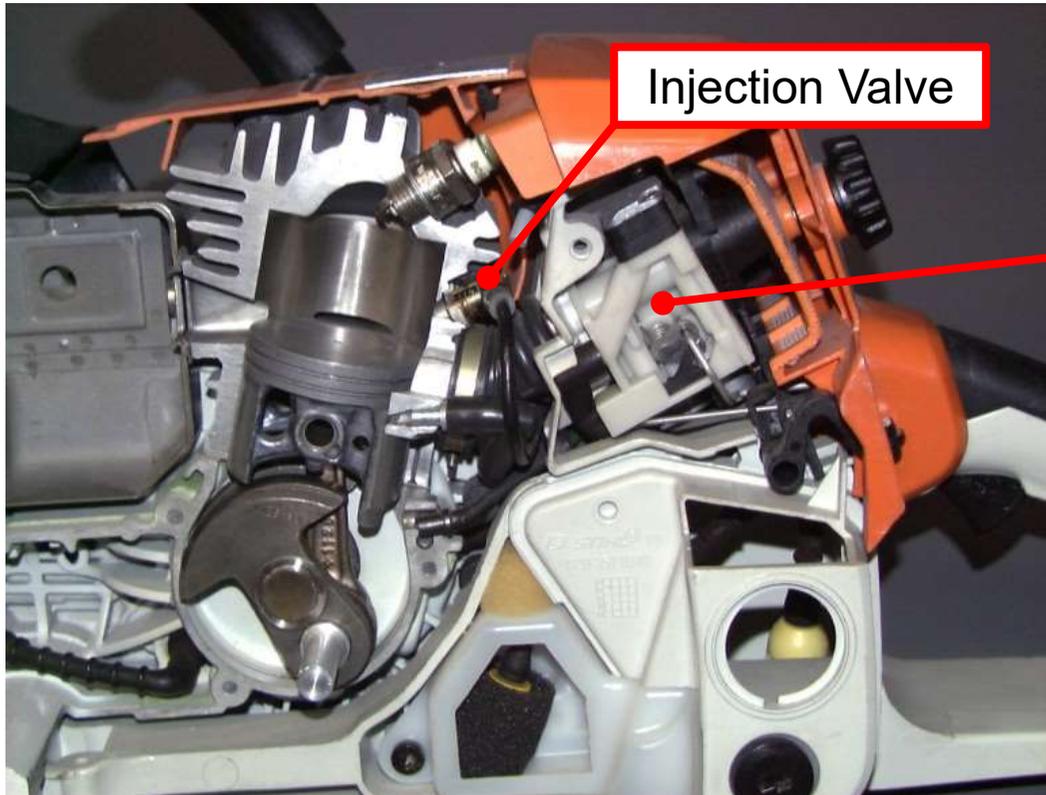
# 1958: First STIHL-Patent on an Injection System



**Universität Stuttgart**

Ca. 1960: Masterthesis of Hans-Peter Stihl:  
*A chainsaw with injection*

# 1993: Prototype with direct injection



The project was stopped due to very high production costs

## 1993: Prototype with direct injection

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The project was stopped due to very high production costs

The major cost and weight drivers were:  
Mechanical high pressure injection pump  
Separate lubrication system with oil pump and reservoir  
Expensive electronics at that time

# Nevertheless: If you are convinced, don't give up:

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- Stop the project
- Wait some years



- You are still convinced about the advantages and the market need ?
- Stand up and start again by analyzing and eliminating the obstacles



**Analyze**

Identify the cause of the problem.



gg86950200 GoGraph.com

# Next steps: Injection Chainsaws at STIHL



2012  
Concept study  
only, no  
production:  
Carbon Concept  
with injection



2018  
Series Launch:  
MS 500i



# 2018 (60 years later): MS 500i

Project overview



**Project aim** The first chain saw with injection

Unique operating logic

High control quality of environmental factors

World-best power-to-weight ratio

Mapping control

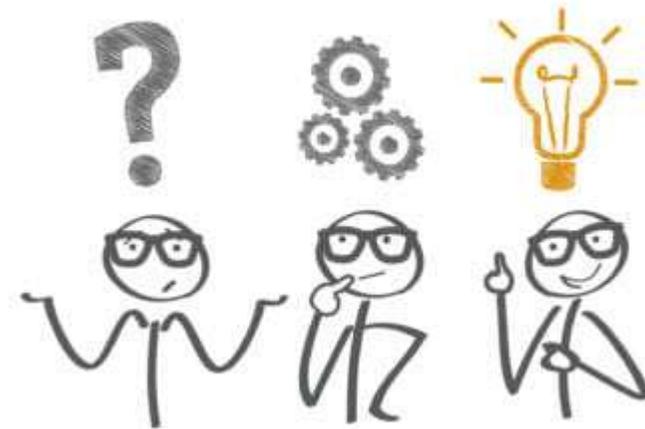


**Displacement**  
79.2 cc

**Power / torque**  
5.0 kW / 5.4 Nm

**Weight**  
6.2 kg

**INJECTION  
TECHNOLOGY UNDER  
SEVERE CONDITIONS AT  
REDUCED COST**



# STIHL Injection

## Motivation



### Demands for hand-held power tools

#### Customer:

- High performance (power and torque)
- Easy starting
- Perfect running behavior of engine
- Durability

#### Others:

- Emission regulations lead to increased requirements on carbureted systems
- Fuel quality: different ethanol rates worldwide
- Customer wants to use mixed fuel (fuel / oil at 50 : 1)



→ **Electronically controlled injection system as a compromise-free concept**

→ **Mixed fuel lubrication**

# STIHL Injection

## Motivation



### Basic conditions for hand-held products

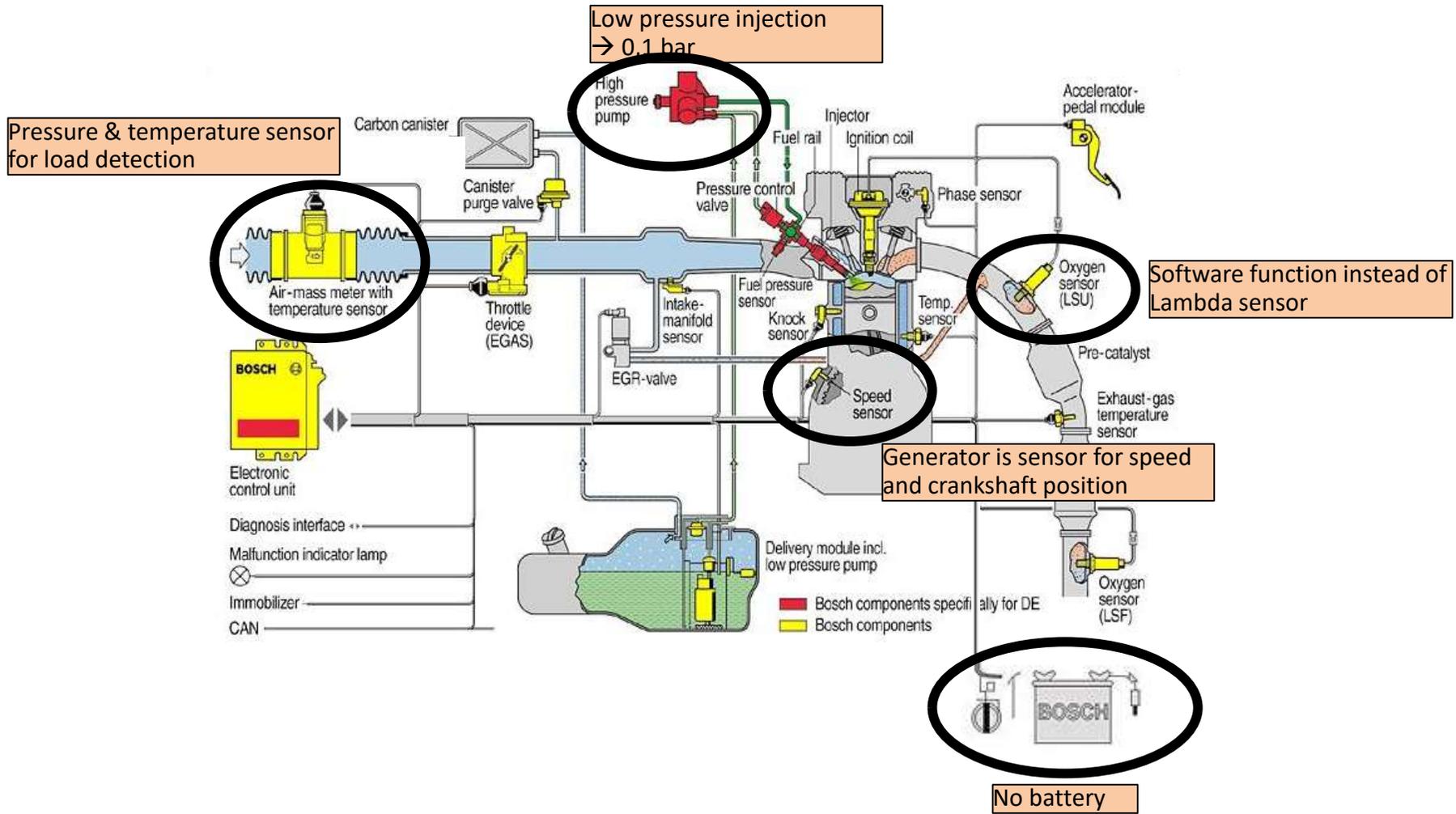
- Engine speed up to 15,000 rpm
  - 4 ms per revolution
  - max. 2.5 ms per injection
- Low weight, narrow space
- Operation in any position
- Robustness (although vibration up to 200 m/s<sup>2</sup>)
- Maintenance-free system even after long periods without use
- Cost premium only a bit above electronic controlled carburetor

### Conclusion

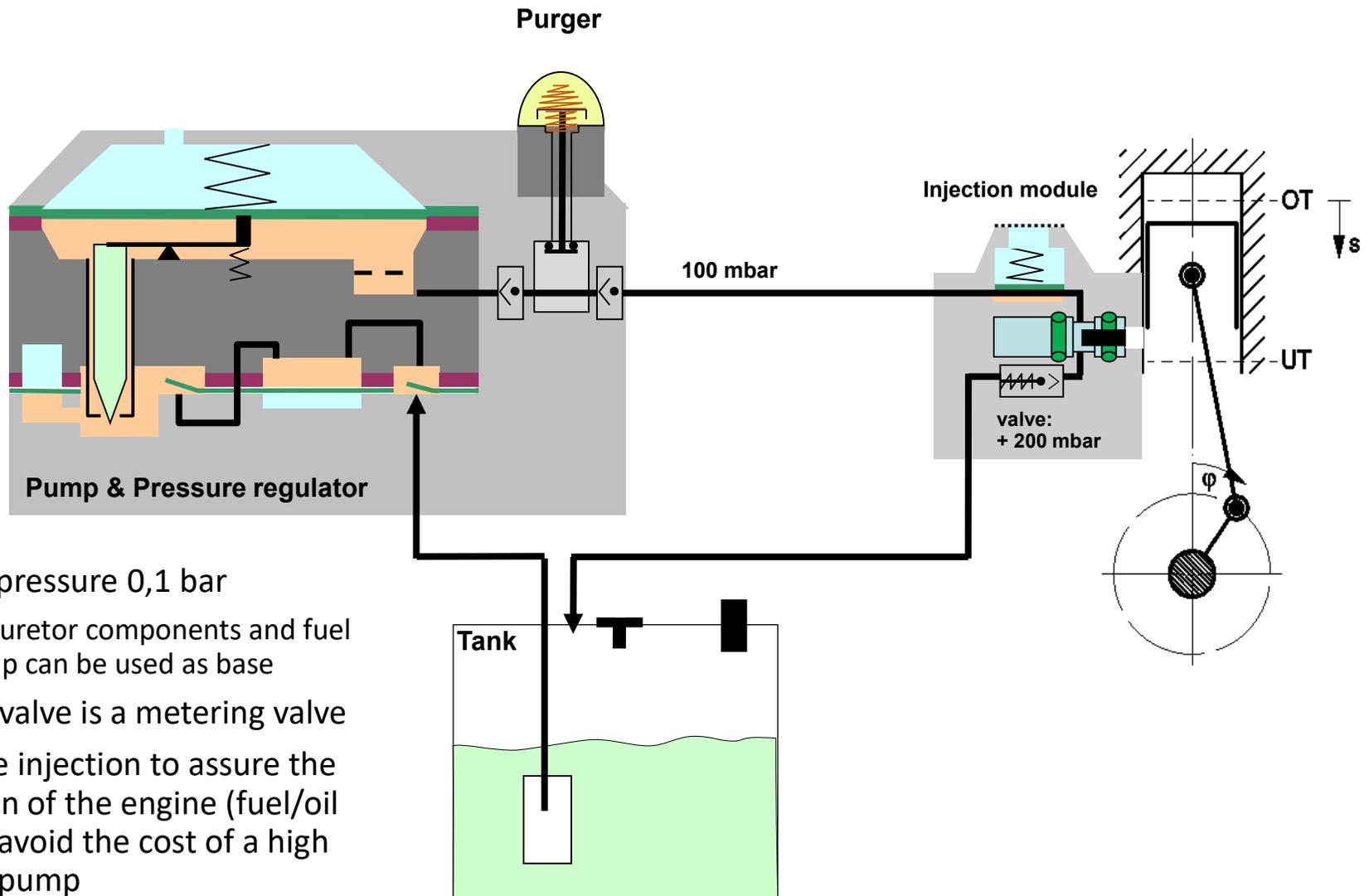
State of the art systems (automotive, bike) not suitable for hand-held power tools

**→ Newly developed injection system  
for the specific needs of hand-held engines**

# BOSCH Motronic vs. STIHL Injection



# Fuel System MS 500i

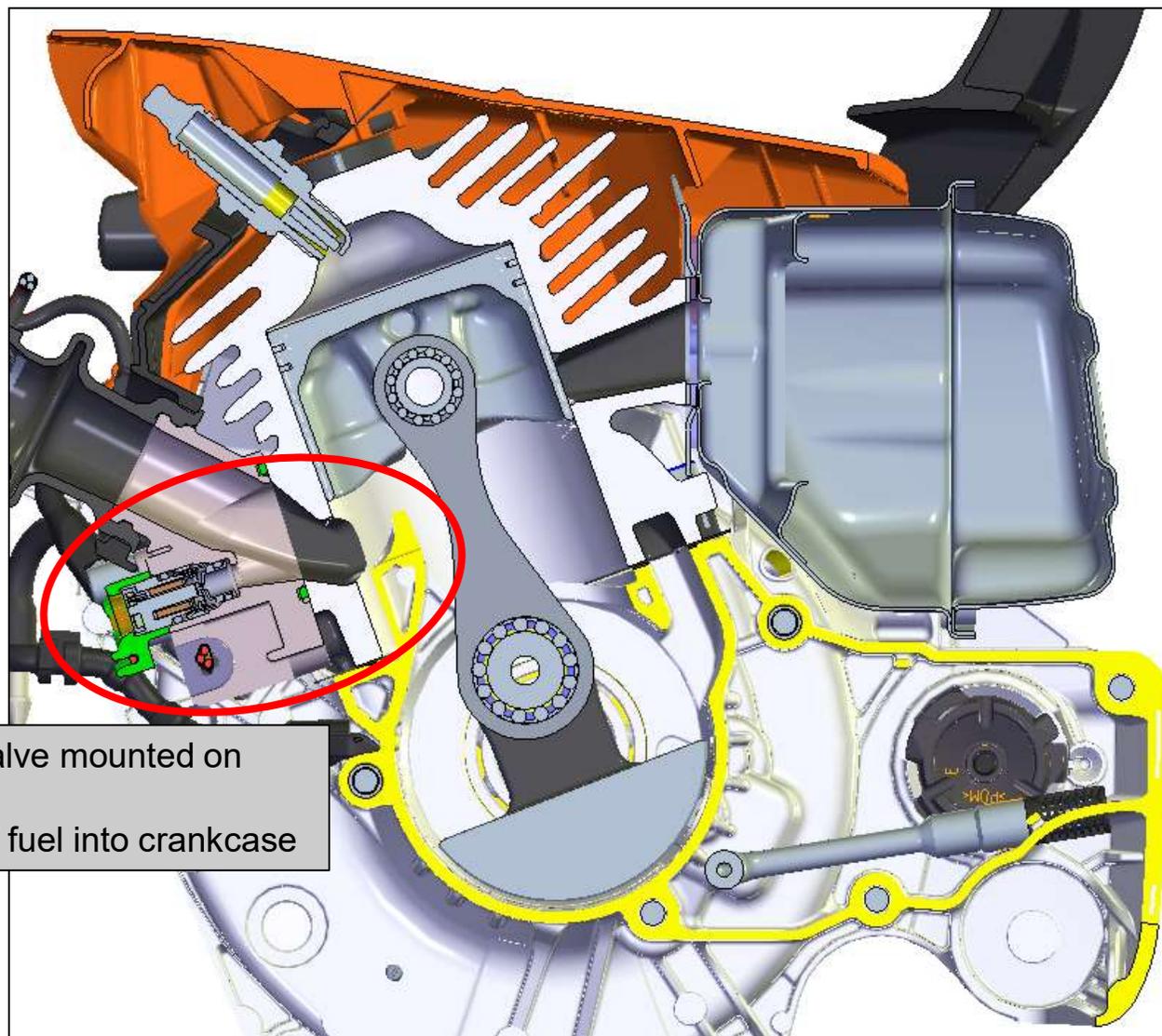


- Low fuel pressure 0,1 bar
  - carburetor components and fuel pump can be used as base
- Injection valve is a metering valve
- Crankcase injection to assure the lubrication of the engine (fuel/oil mix) and avoid the cost of a high pressure pump

# MS 500i

## Injection into crankcase

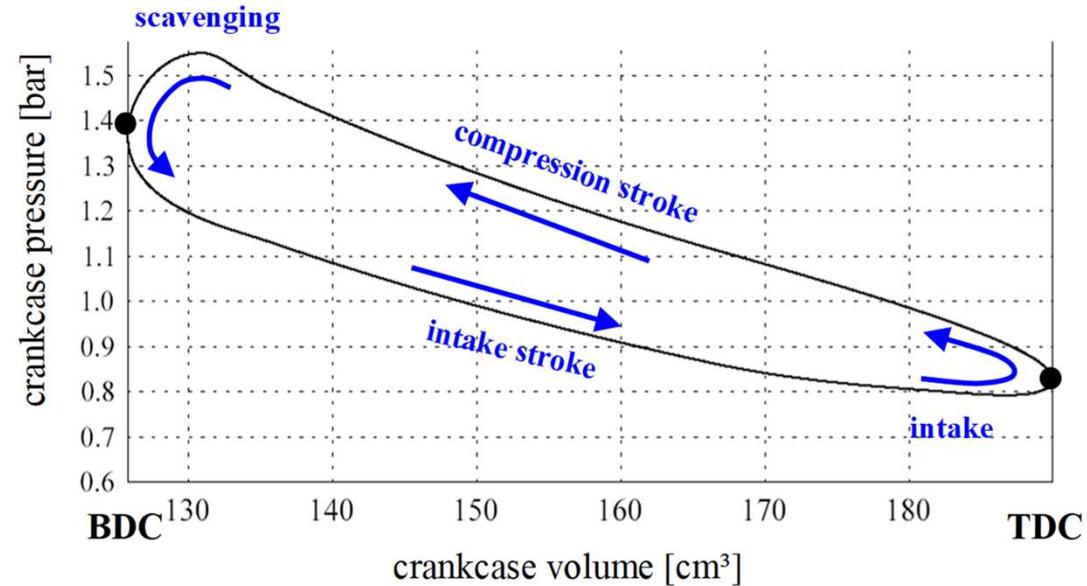
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- Injection valve mounted on cylinder
- Injection of fuel into crankcase

# Operating Principle of the Injection System I

Load Detection



Sensor for pressure and temperature

Calculation of air mass by the general gas equation

Measuring frequency is once per revolution, up to 250 Hz

Cyclis-synchronous information of air mass in cylinder

No air mass or air flow sensors, no moving parts

# Operating Principle of Injection System II

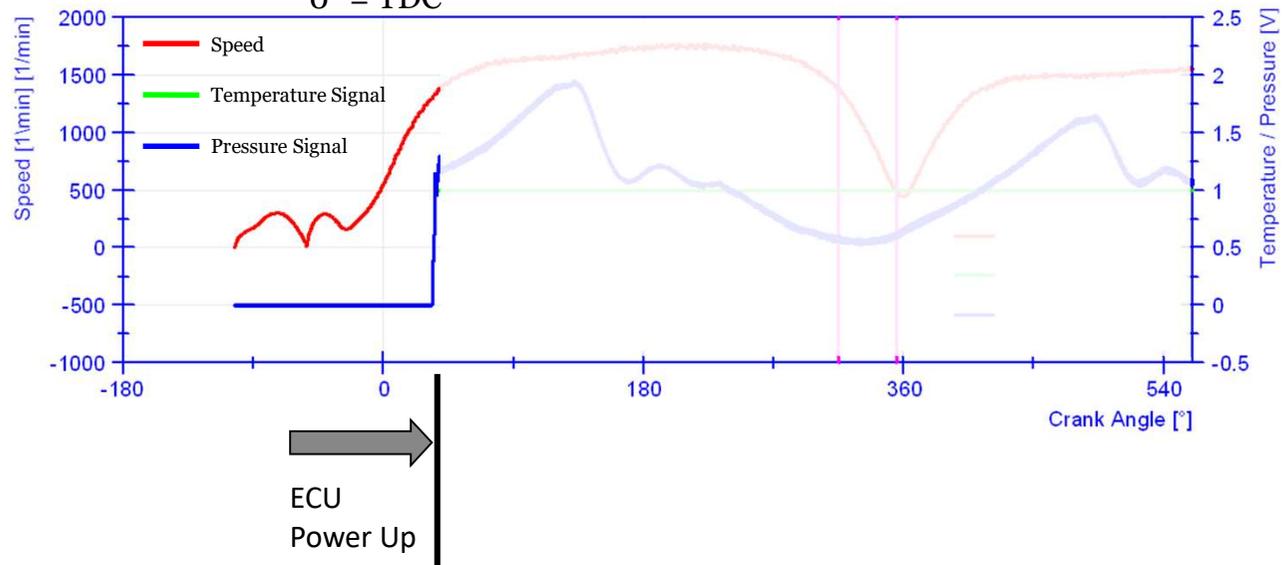
## Starting without energy storage like a battery:



ECU Power Up Sequence, booting the ECU



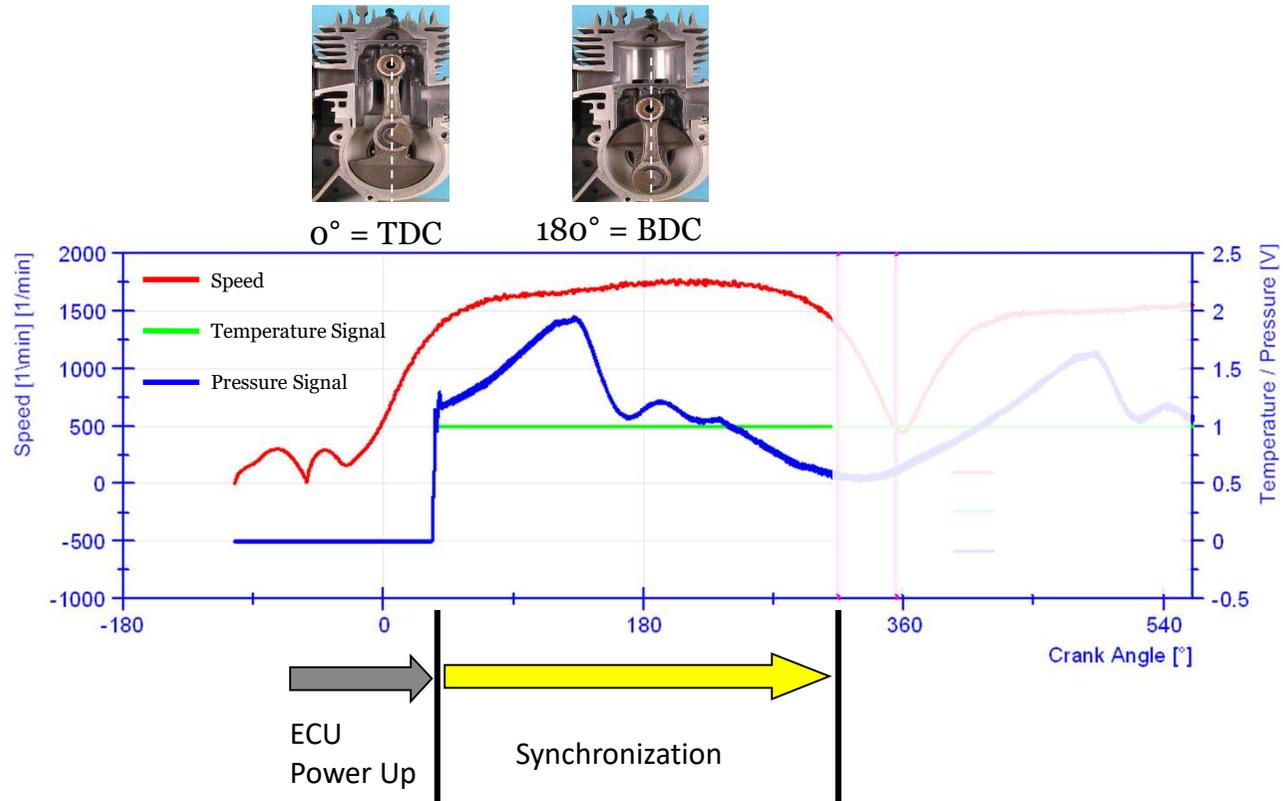
0° = TDC



# Operating Principle of Injection System III



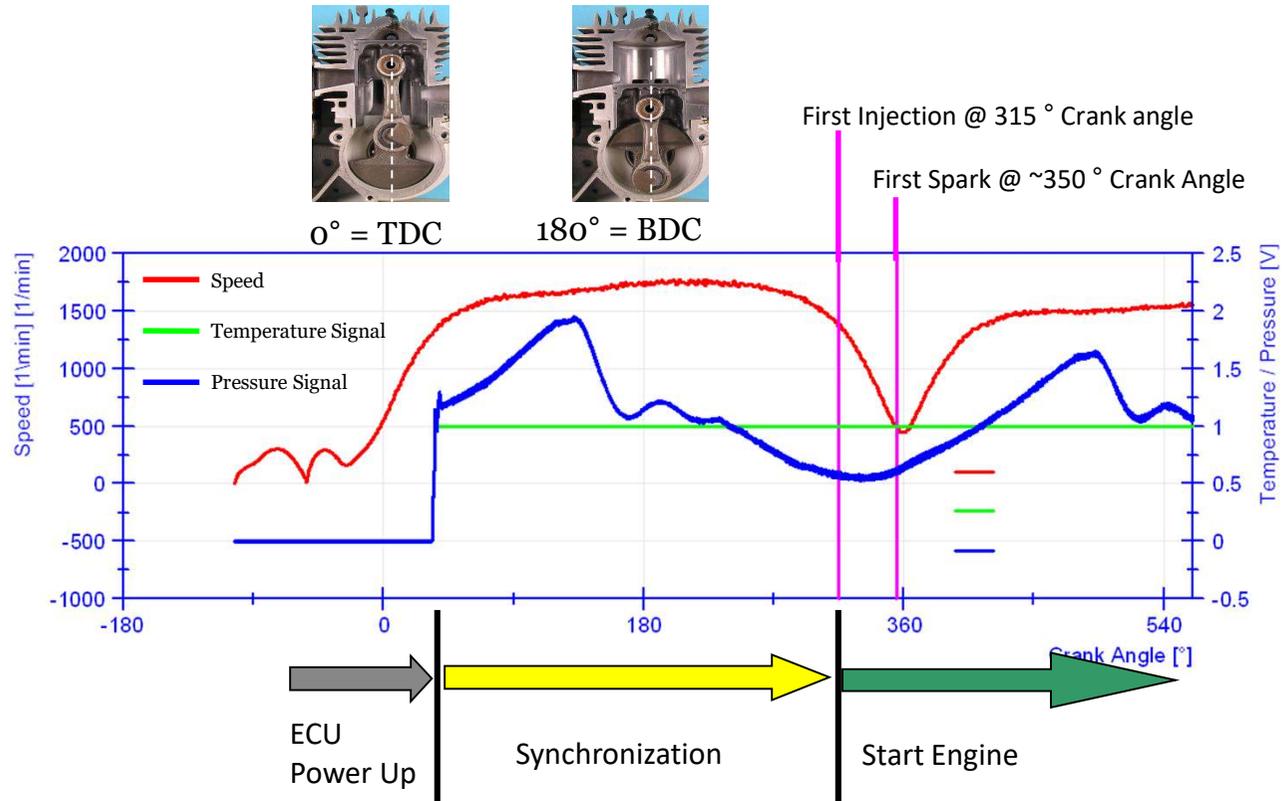
ECU Power Up Sequence



# Operating Principle of Injection System IV

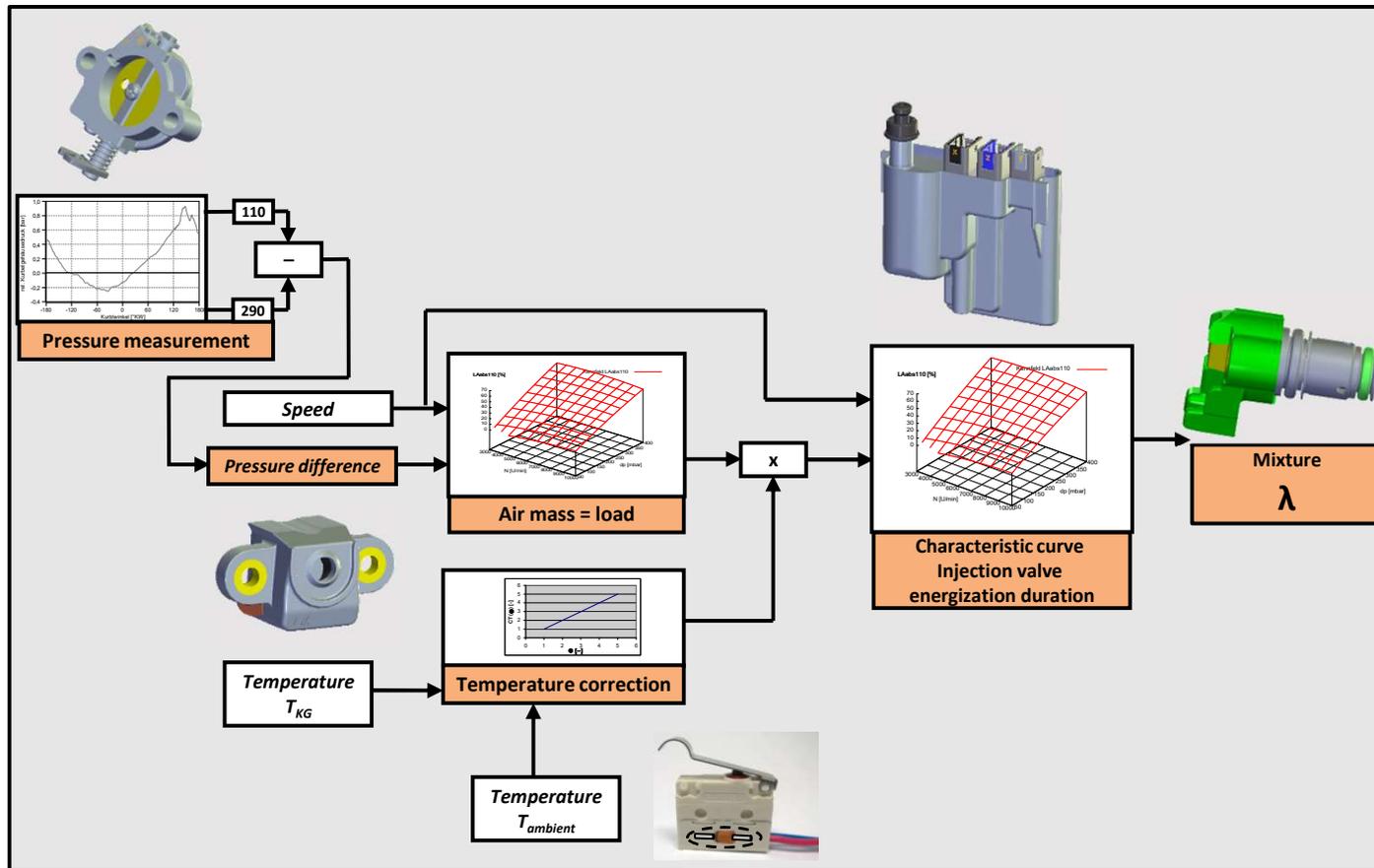


## ECU Power Up Sequence



# MS 500i

## Injection – load detection

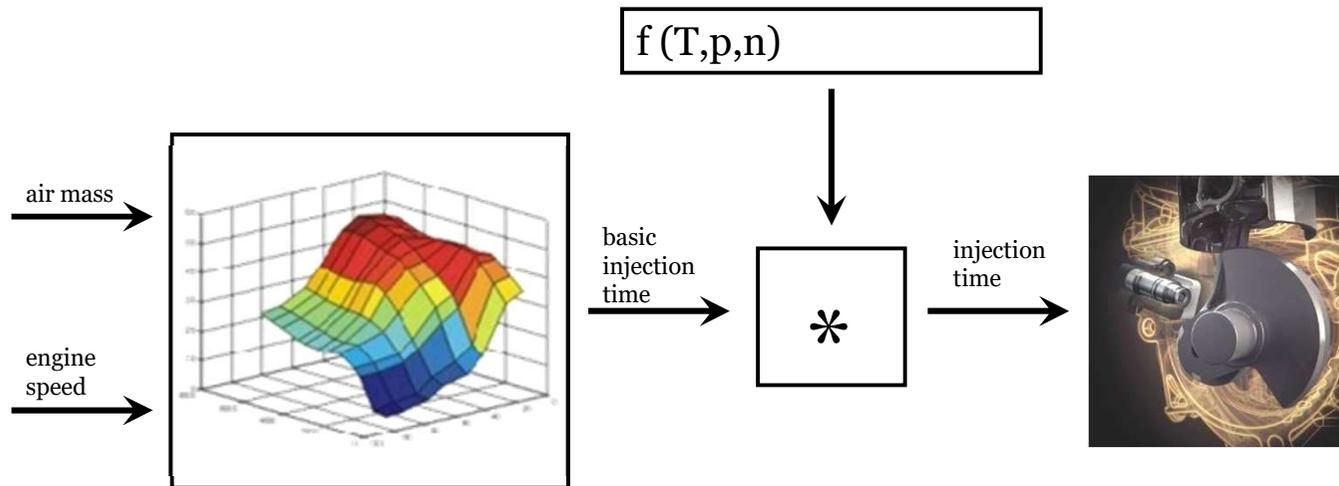


# Operating Principle of Injection System

Engine management functions



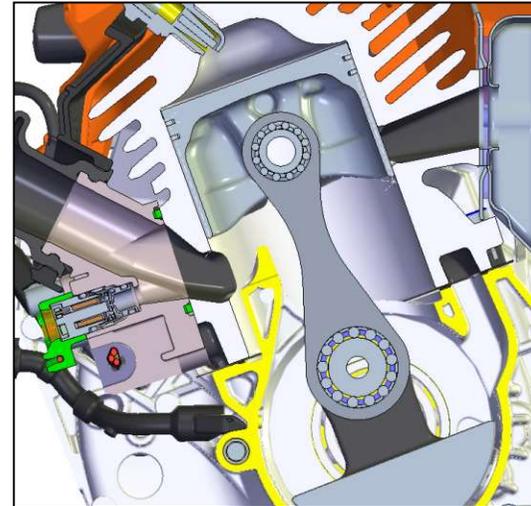
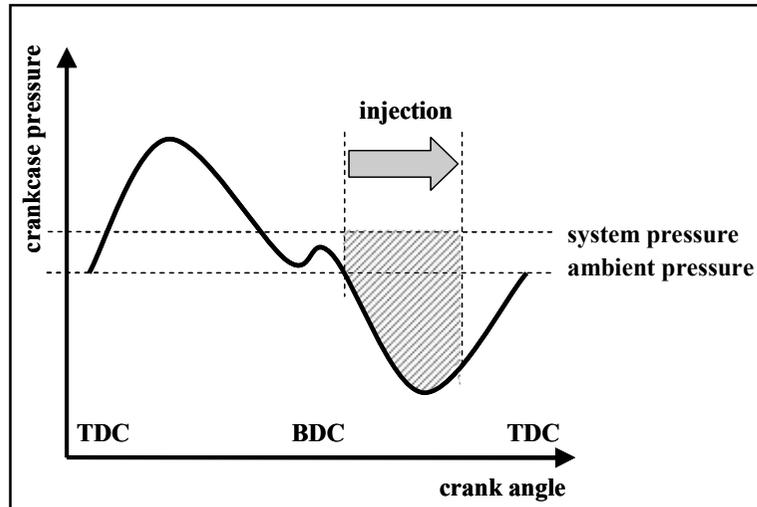
- Start controller
- Lambda controller (full load)
- Idle speed controller
- Fuel cut-off at deceleration



→ **Self adjusting system** due to closed-loop controllers

→ No Lambda sensor needed

# Injection process



Point of injection

Time of injection

Injection pressure

Pressure drop at injection valve

Crankcase

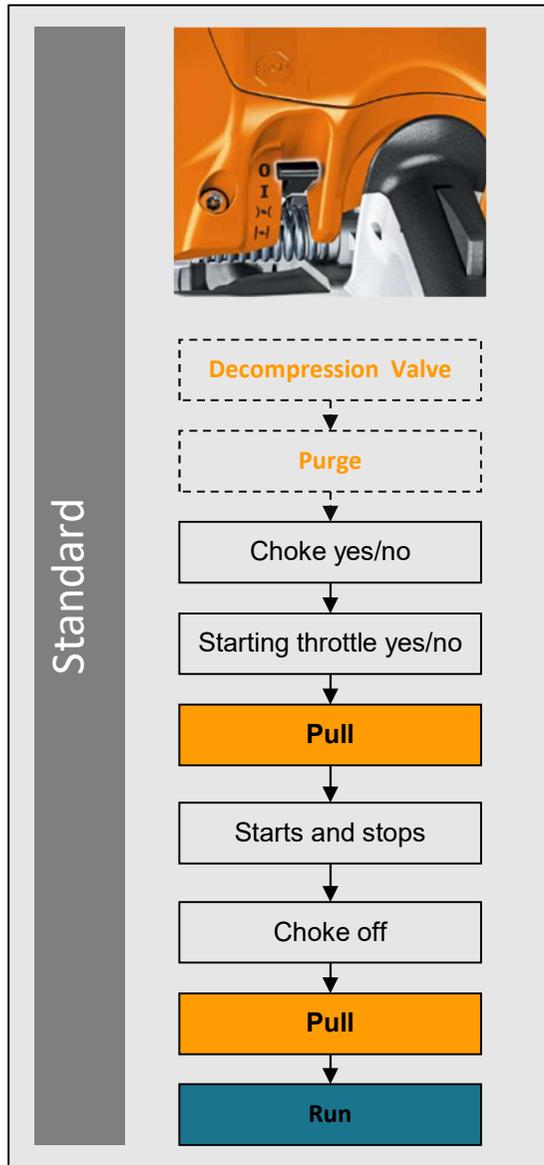
Movement of piston to TDC direction

→ negative pressure in crankcase

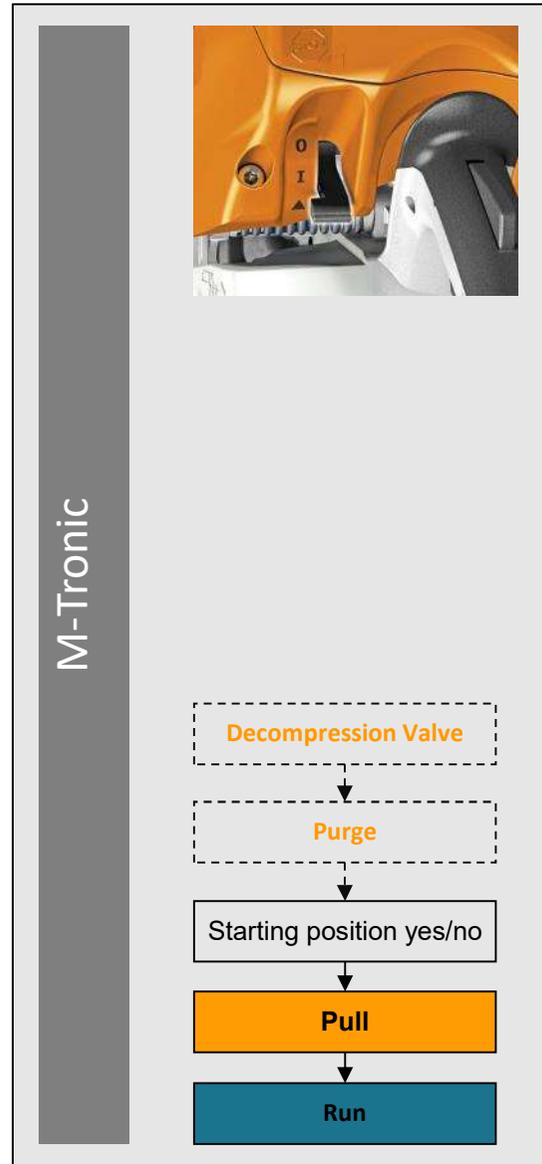
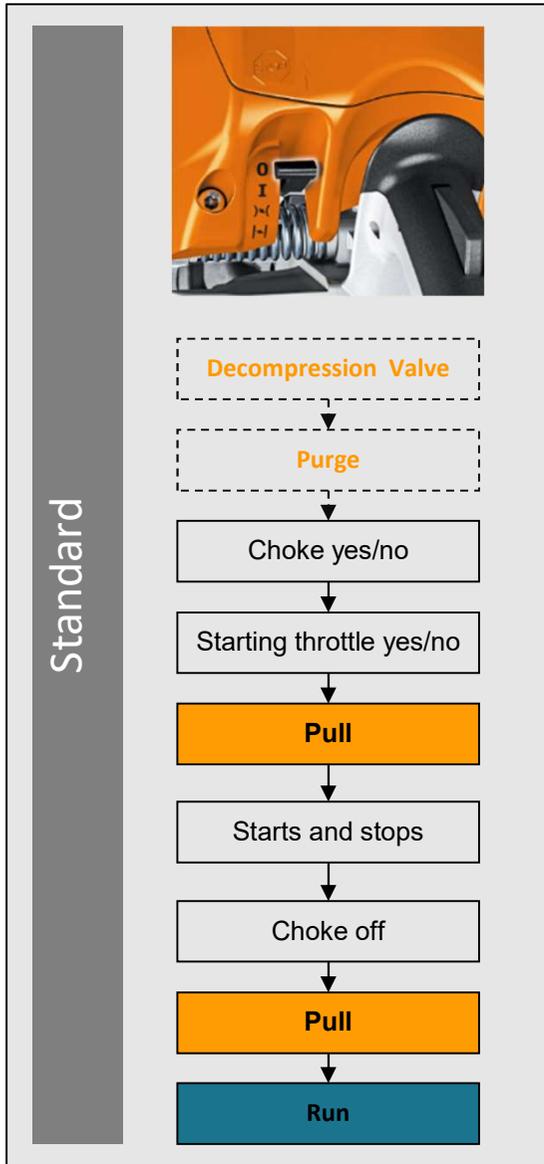
100 mbar above atmospheric pressure

100-450 mbar

# Starting of a regular, carbureted chainsaw

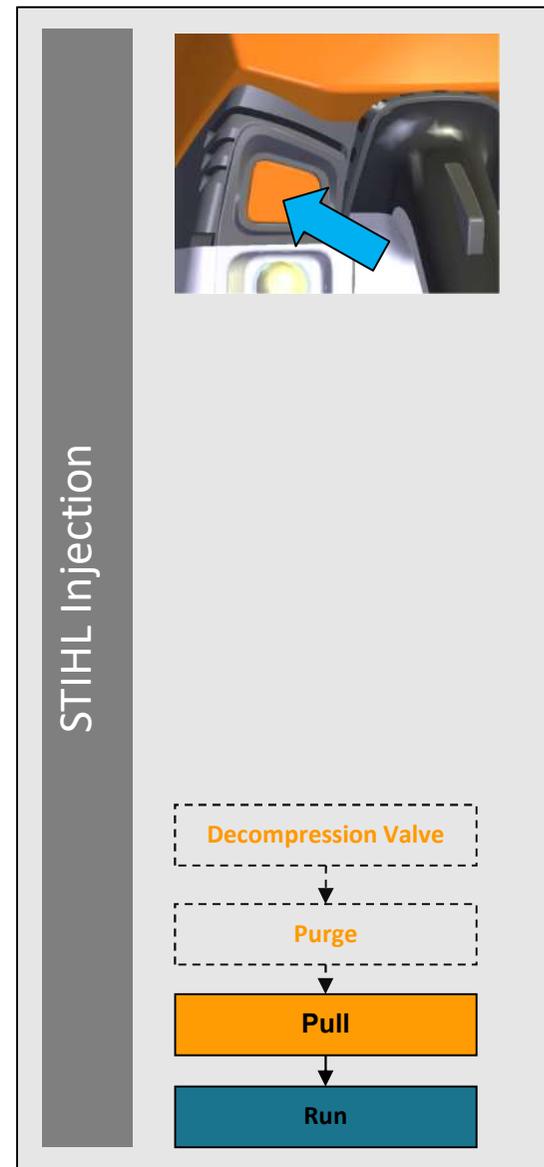
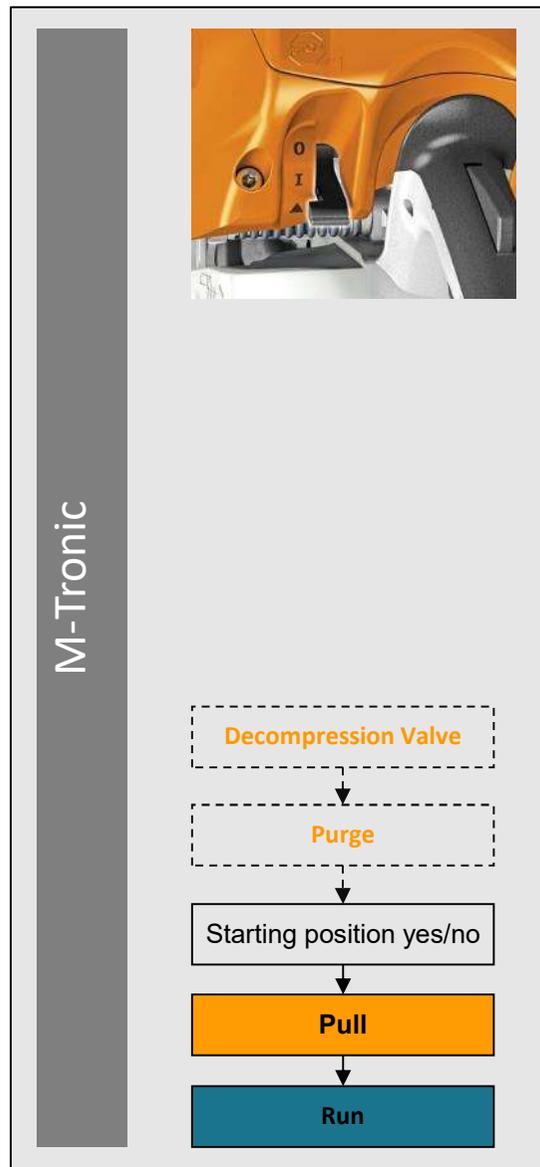
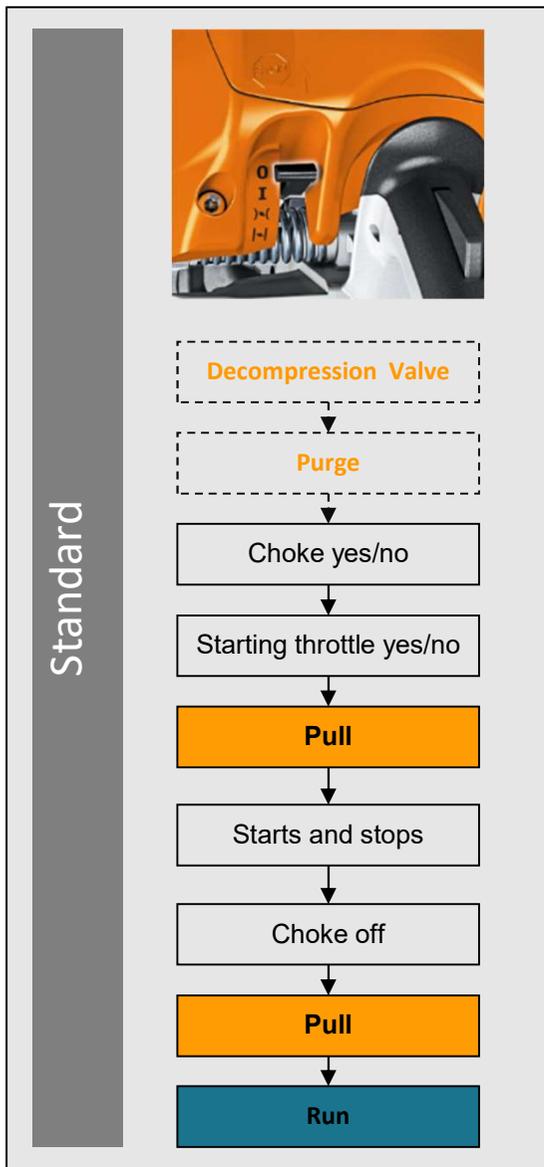


# Starting of a chainsaw with electronic controlled carburetor (M-Tronic)



# Starting with Injection

## MS 500i



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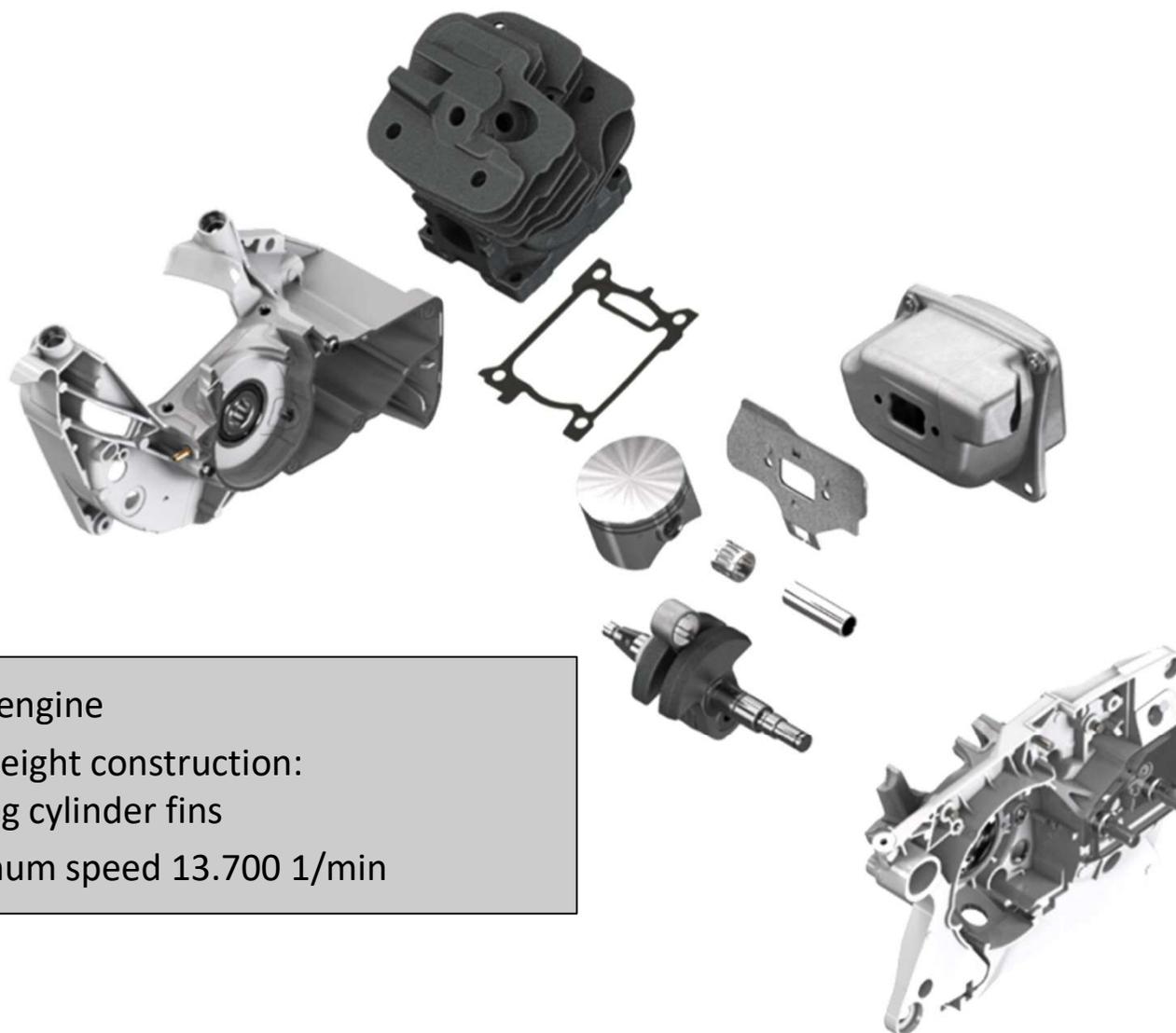


# **INJECTION INTEGRATION AND DESIGN OF THE MS 500I**

# MS 500i

Core engine

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- 2-Mix engine
- Lightweight construction:  
slanting cylinder fins
- Maximum speed 13.700 1/min

# MS 500i

Engine including injection components



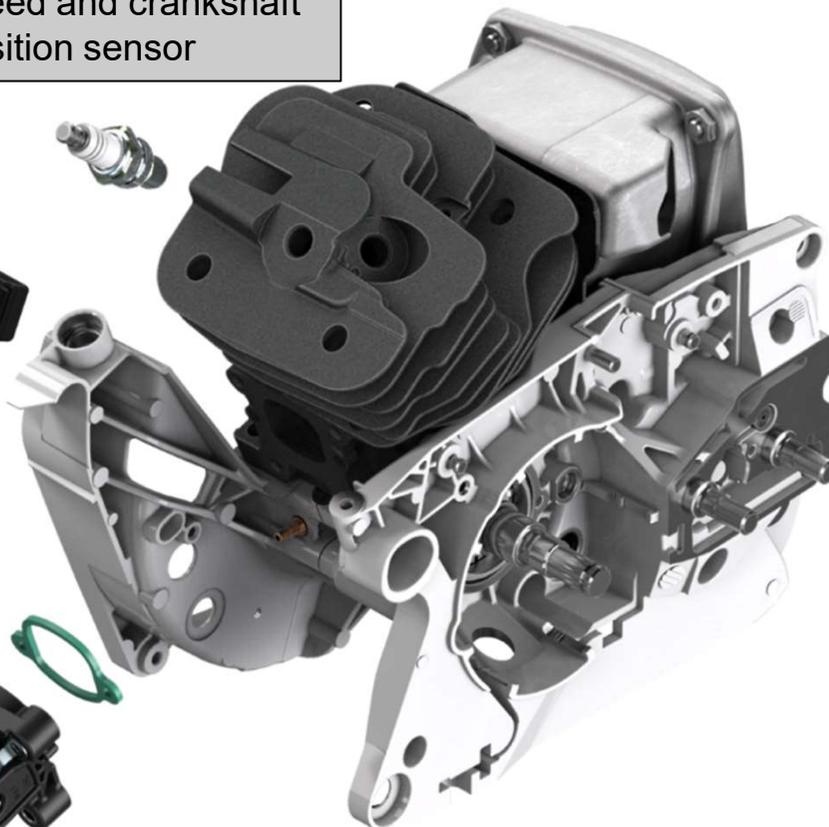
Flywheel:  
• With integrated magnet ring

Generator  
• Serves also as a speed and crankshaft position sensor

Pressure/temperature sensor: Mounted at side of crankcase, below generator

Injection valve

Injection module:  
• Includes injection valve, fuel filter and pressure damper  
• Mounted on the cylinder



# MS 500i

Injection components, complete

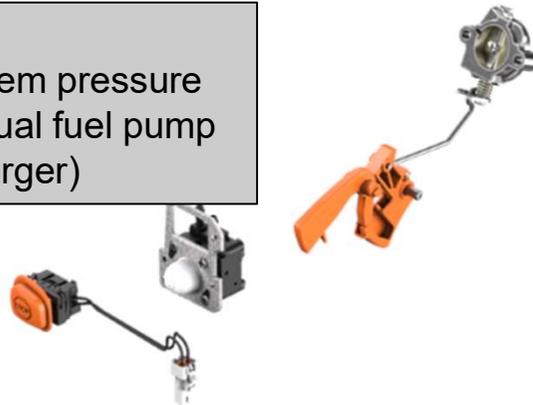
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Throttle shutter body:

- Direct link to throttle trigger
- Fully closed when idling / starting

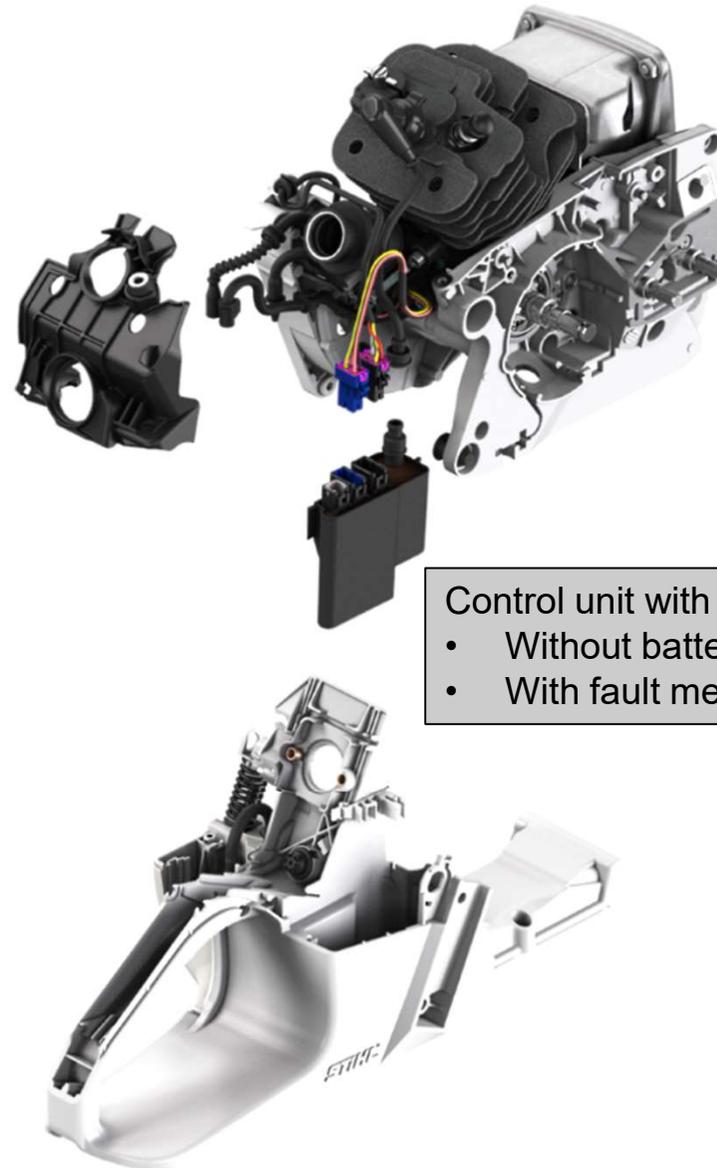
Injection pump

- 100 mbar system pressure
- Including manual fuel pump for starting (purger)



Stop switch

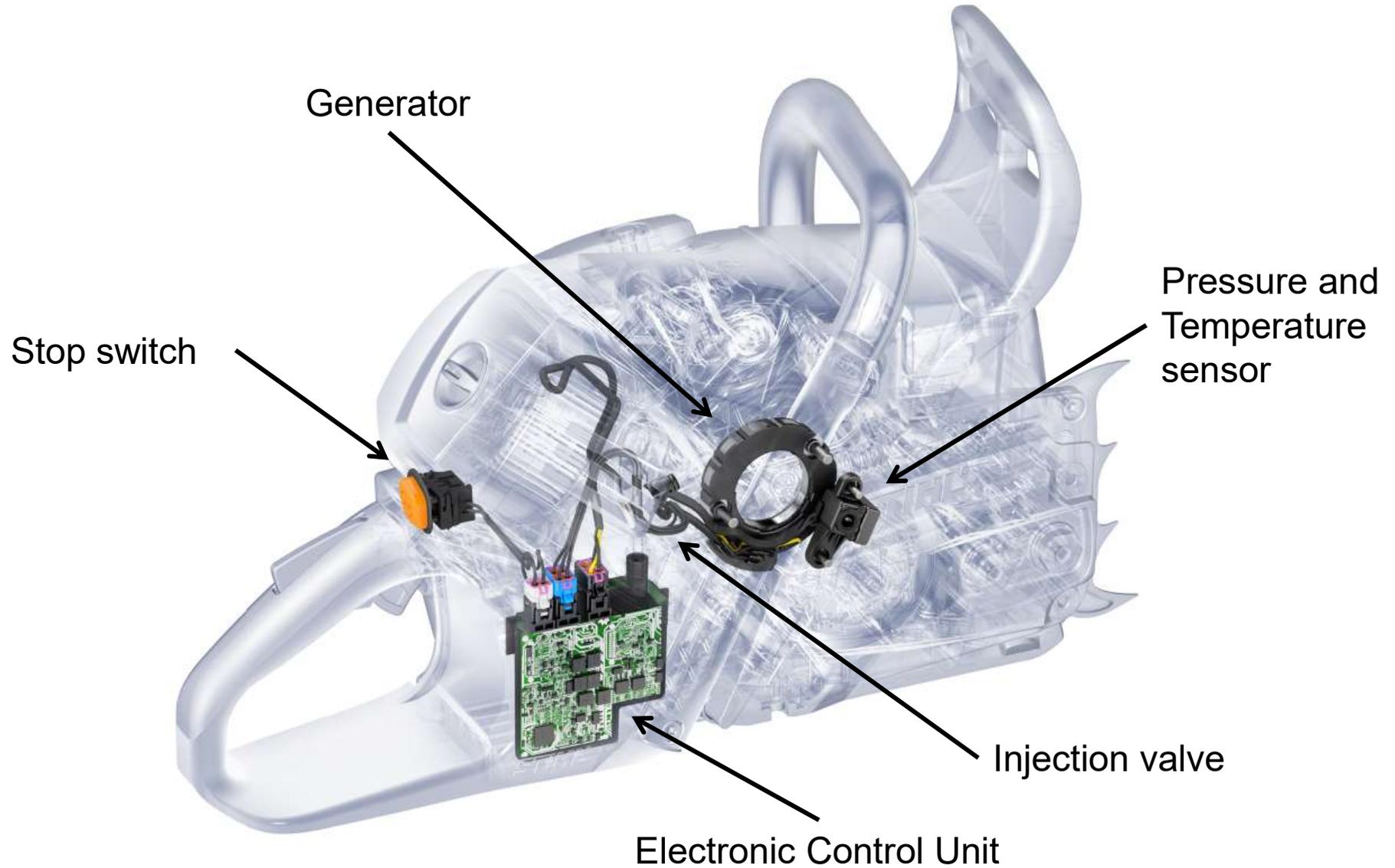
- Machine switches off when actuated, then ready to start again straight away
- Integrated temperature sensor



Control unit with ignition coil

- Without battery
- With fault memory

# MS 500i Injection – electrical components



# Design MS 500i

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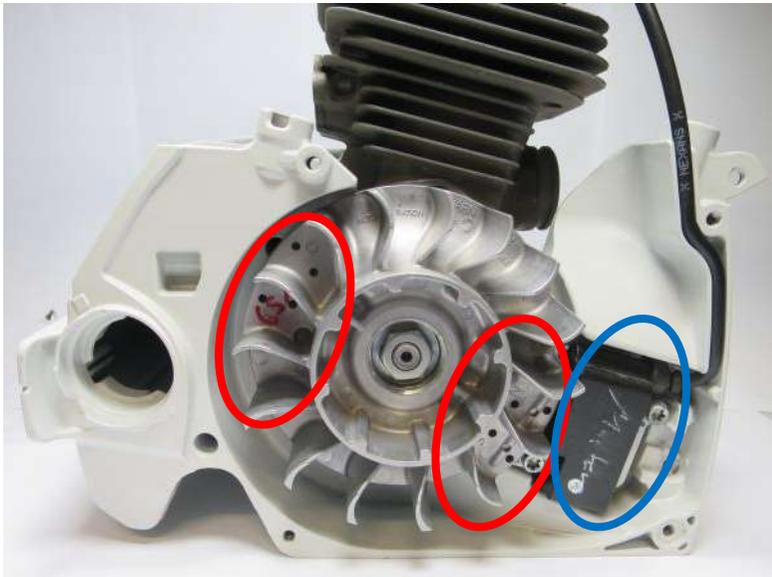


# MS 500i

## Injection: Lightweight sideeffects



Carburetor engine 5 kW



Cooling air supply has heavy losses due to

- Magnets in flywheel
- Ignition module in spiral

Injection engine 5 kW



Efficient cooling air supply

- No irregularities in flywheel
- Optimum spiral

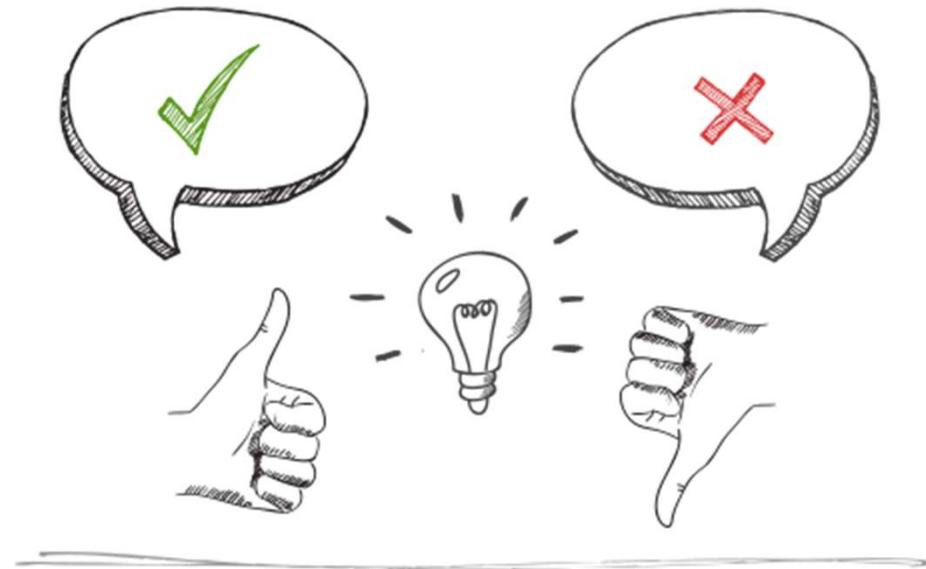
→ Smaller fanwheel diameter results in lower engine height

→ Lower blade height results in narrower machine

→ No ignition module results in shorter engine

→ Lighter flywheel results in lighter crankshaft

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# FEEDBACK FROM THE MARKET



# Feedback from saw operators



“Perfect combination of power and maneuverability”

“Chain saw starts exceptionally well”

“Intuitive operation of stop switch”

“Best saw I’ve ever used”

“Do we really have to give it back?”

“Don’t need a 661 any more”

“Super saw”

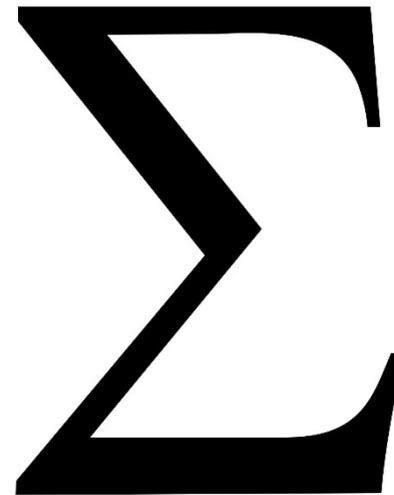


Some customers even made movies:

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**SUMMARY**



# The first to market chainsaw with injection

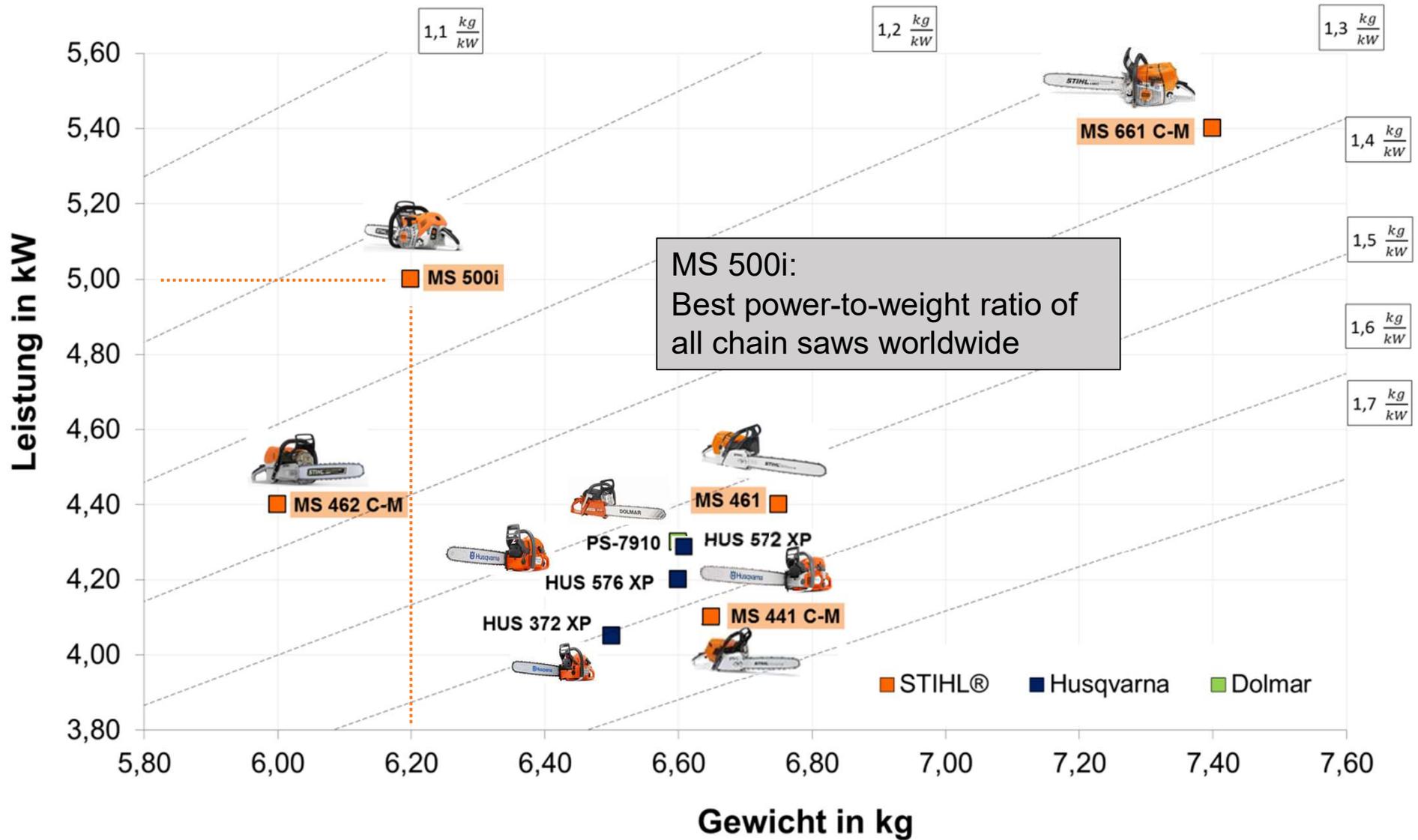
**STIHL**

The first chainsaw worldwide  
with electronic controlled fuel  
injection

Newly developed injection  
system for specific needs of  
hand-held engines



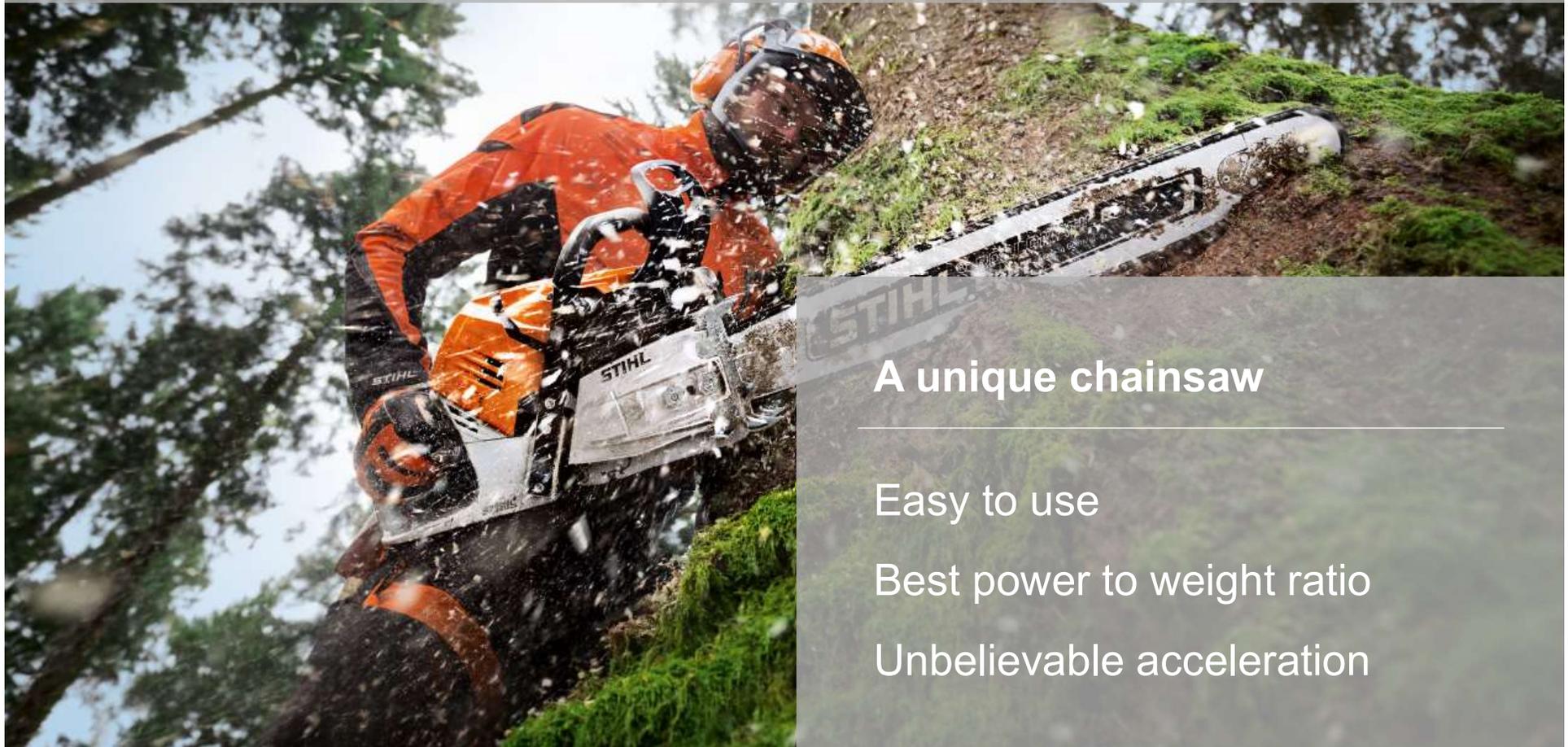
# Power to weight ratio of chainsaws > 70 cm<sup>3</sup>



# MS 500i – The view of the customer



„MS 500i: You don`t need it – but you must have it !“



A unique chainsaw

Easy to use

Best power to weight ratio

Unbelievable acceleration

# In consequence:



Happy people

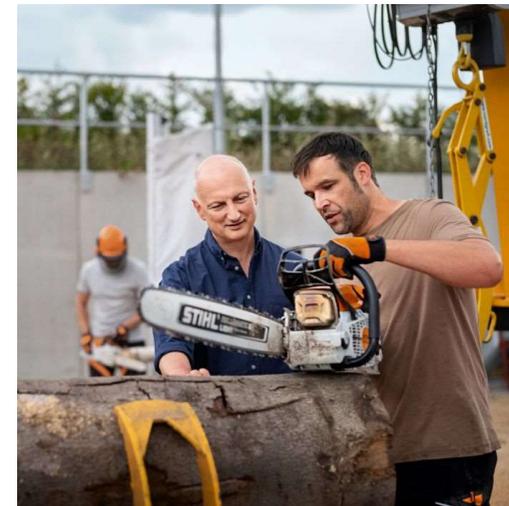


Happy Customers and Dealers

My co-author (thanks to him !)



Happy Engineers



Happy Shareholders

