

DIRECT INJECTION 2-STROKE ENGINES

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**

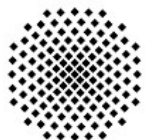
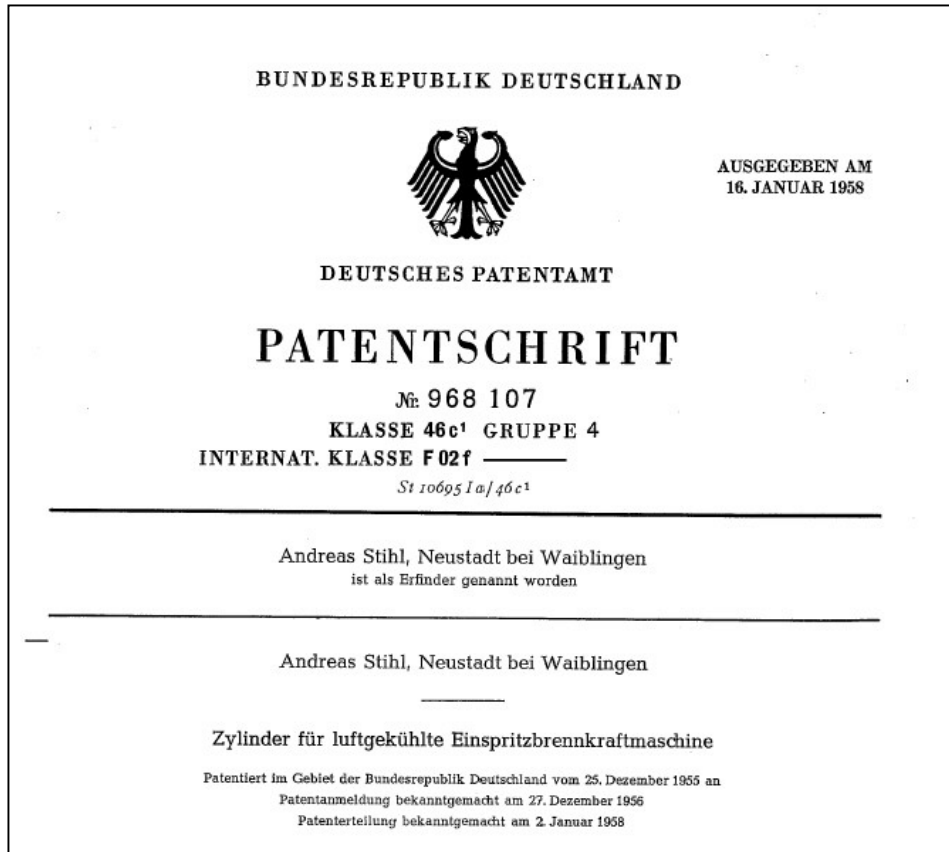
STIHL



INTRODUCTION



1958: First STIHL-Patent on an Injection System

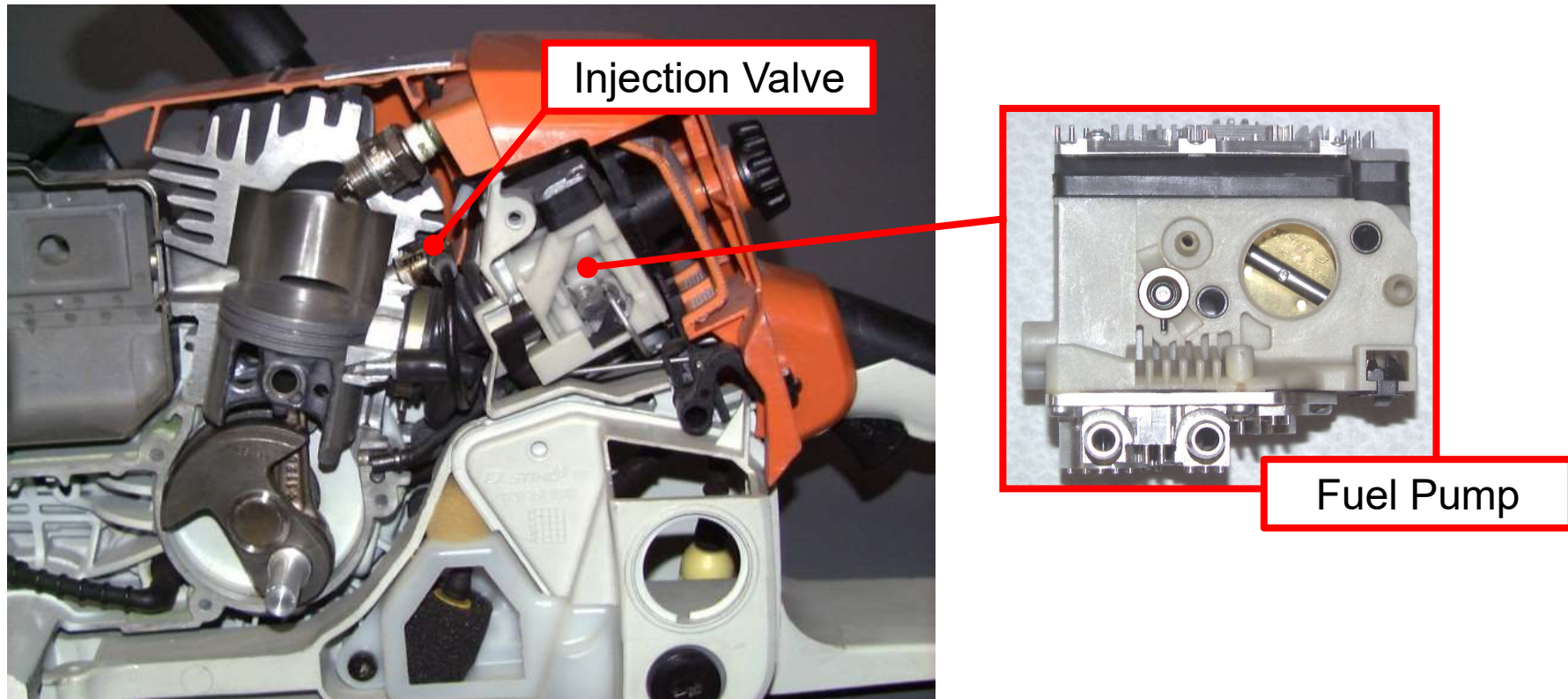


Universität Stuttgart

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

1993: Prototype with direct injection

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The project was stopped due to very high production costs

1993: Prototype with direct injection

STIHL



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

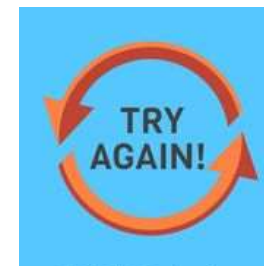


- You are still convinced about the advantages and the market need ?
- Stand up and start again by analyzing and eliminating the obstacles



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

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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

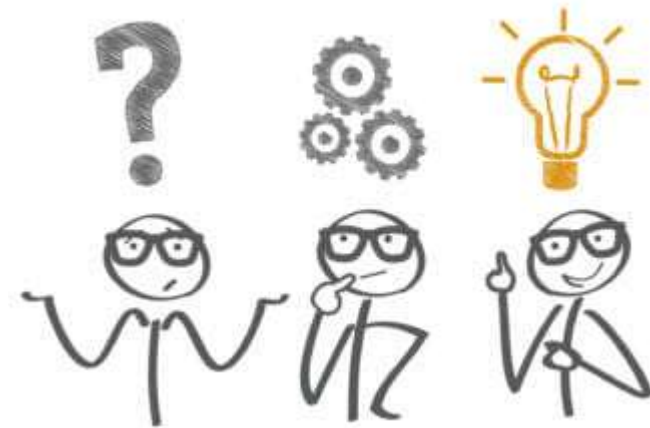


Displacement
79.2 cc

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/s²)
- Maintenance-free system
 - even after long periods without use
- Cost premium only a bit above electronic controlled carburetor

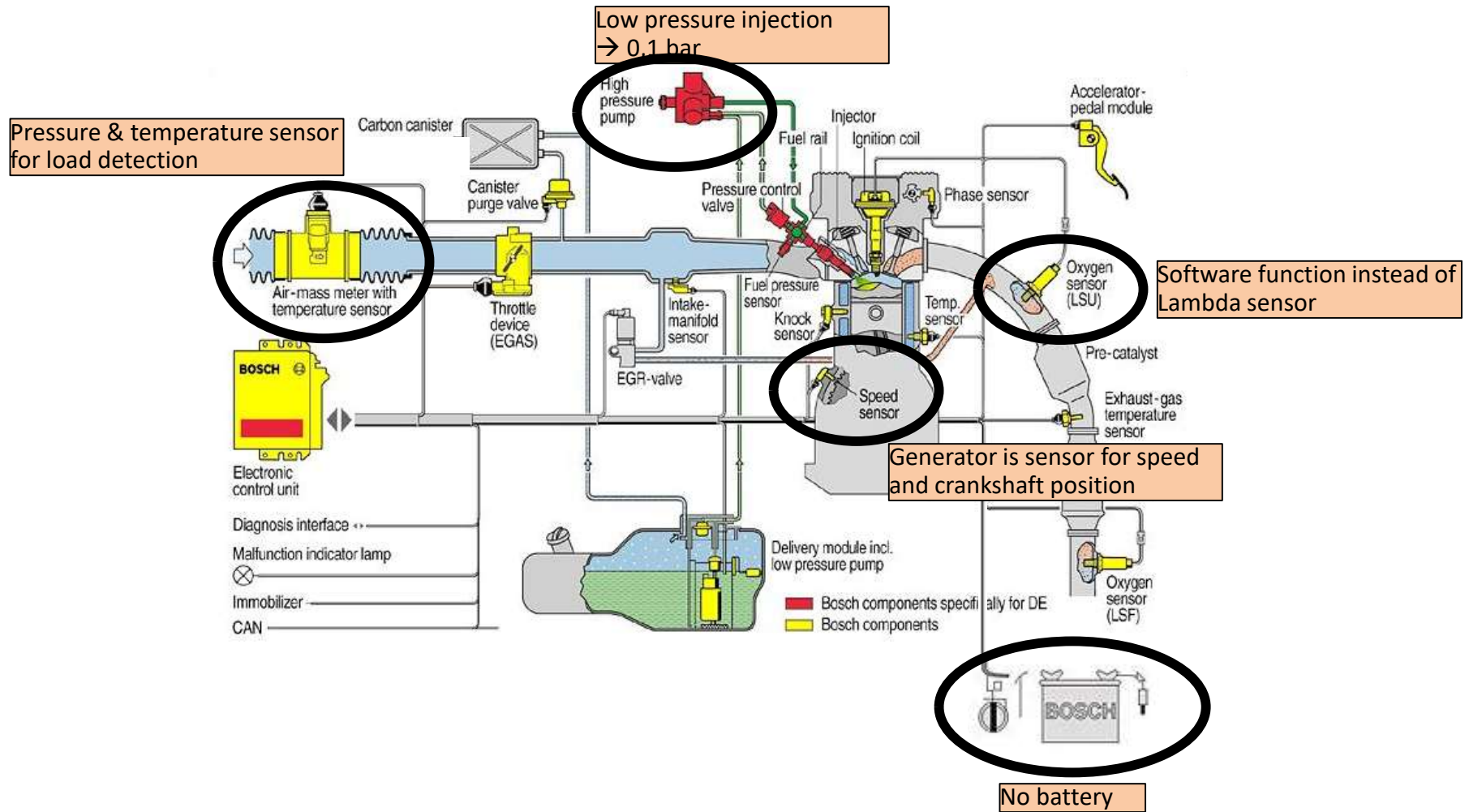
Conclusion

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

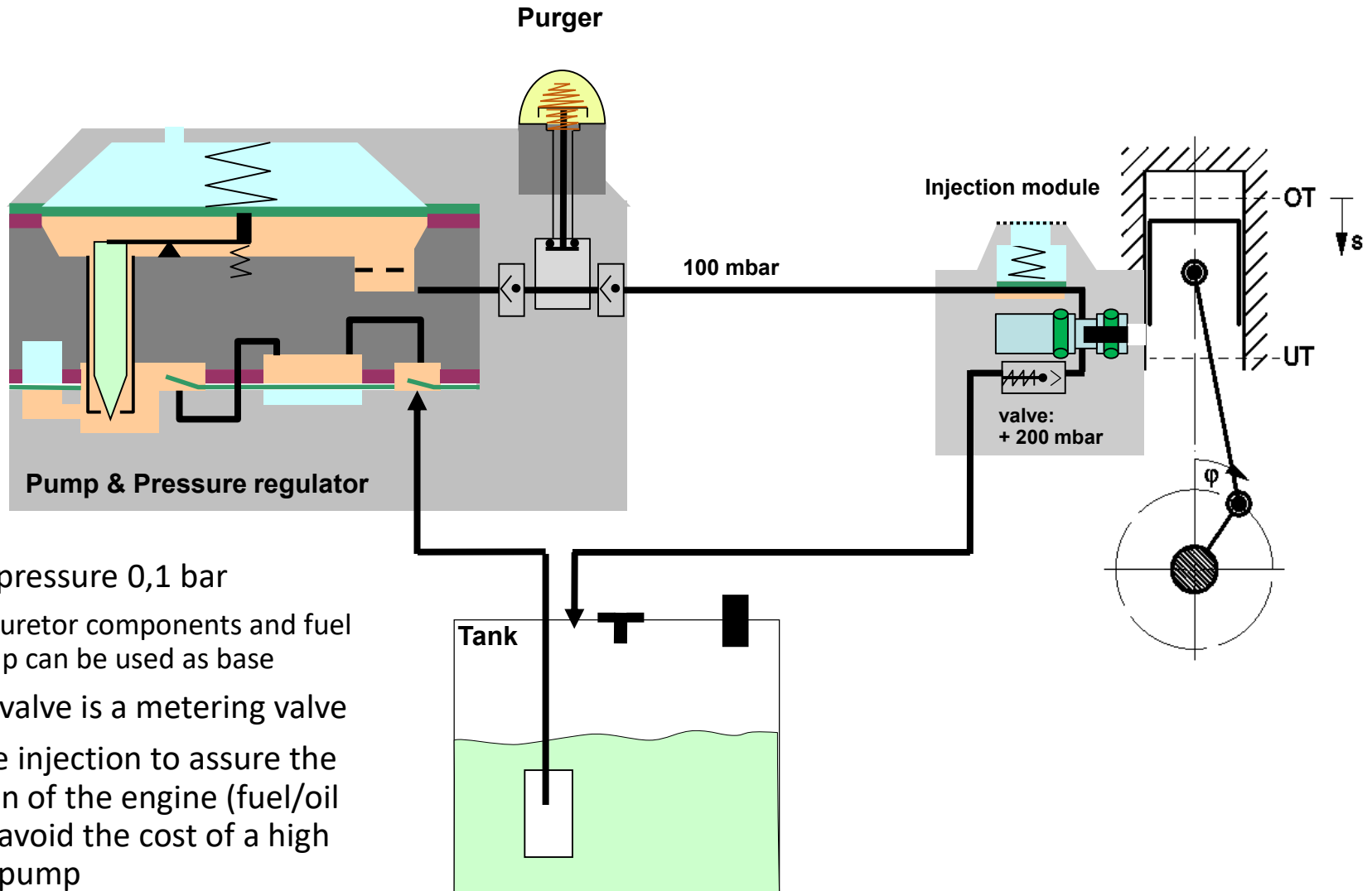
**→ Newly developed injection system
for the specific needs of hand-held engines**

BOSCH Motronic vs. STIHL Injection

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Fuel System MS 500i

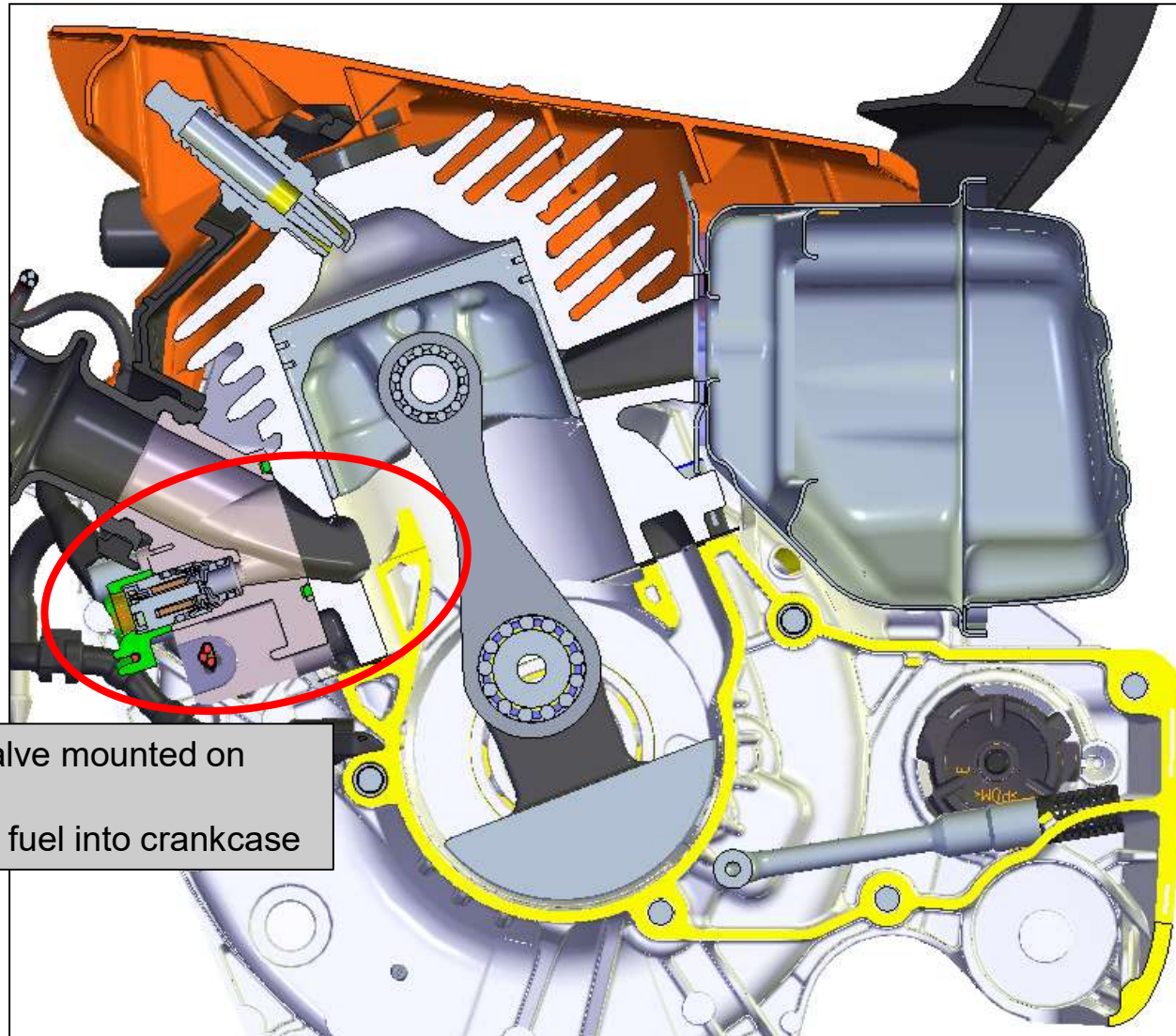


- Low fuel pressure 0,1 bar
 - carburetor components and fuel pump can be used as base
- Injection valve is a metering valve
- Crankcase injection to assure the lubrication of the engine (fuel/oil mix) and avoid the cost of a high pressure pump

MS 500i

Injection into crankcase

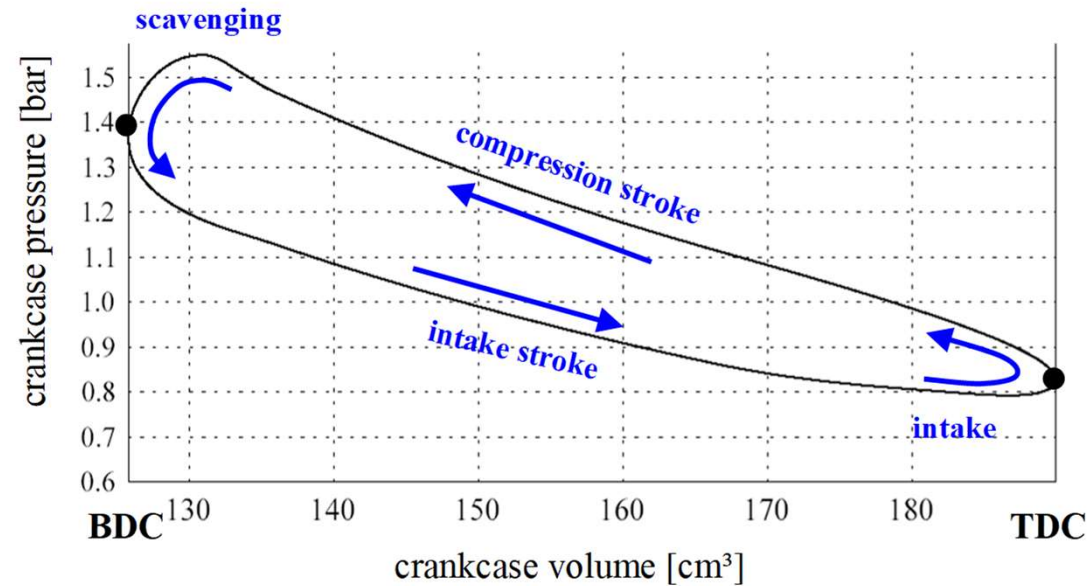
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- Injection valve mounted on cylinder
- Injection of fuel into crankcase

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

Cyclus-synchronous information of air mass in cylinder

No air mass or air flow sensors, no moving parts

Operating Principle of Injection System II

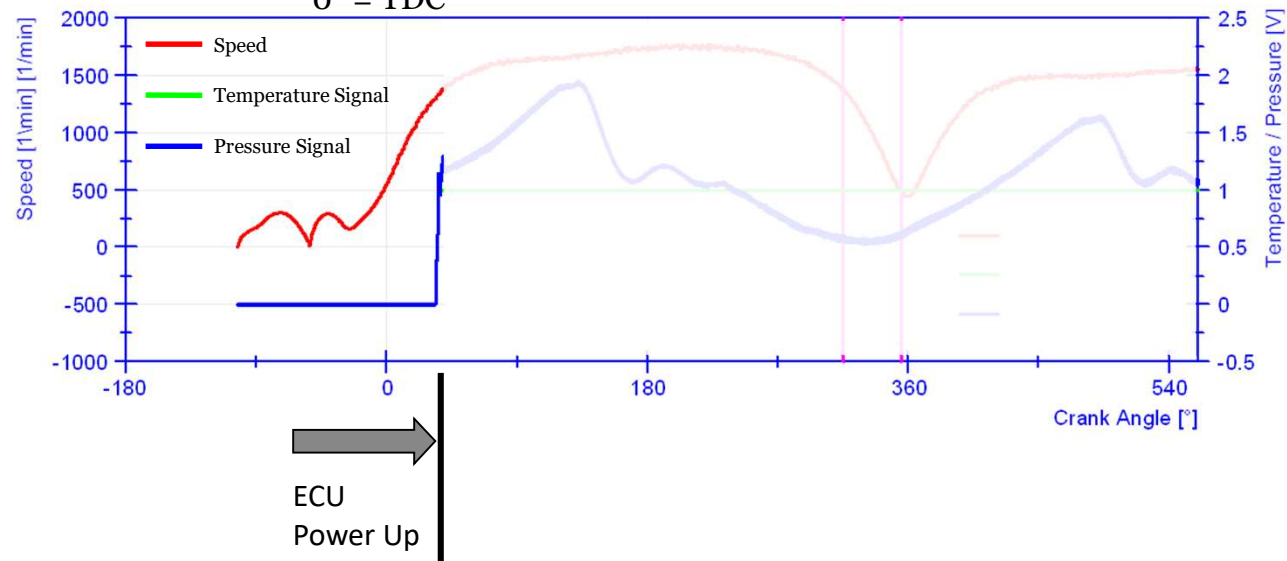


Starting without energy storage like a battery:

ECU Power Up Sequence, booting the ECU

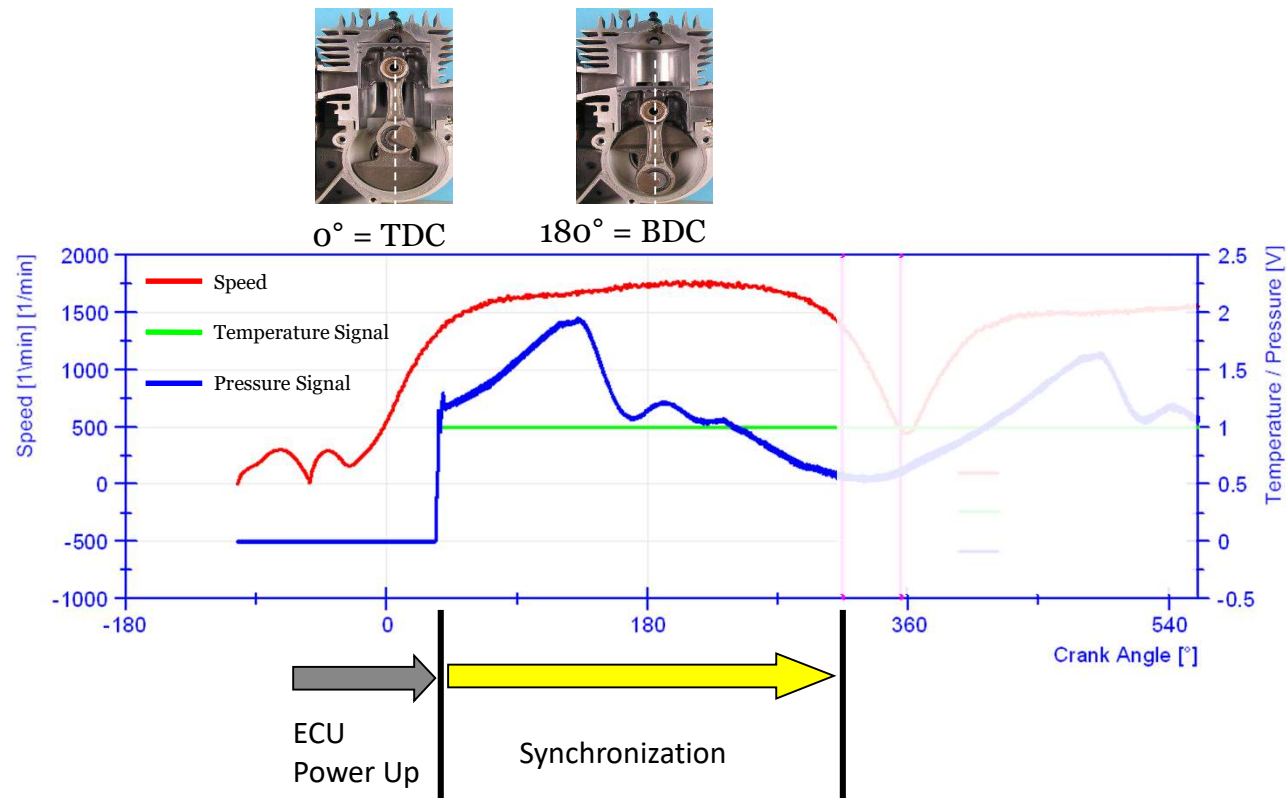


0° = TDC



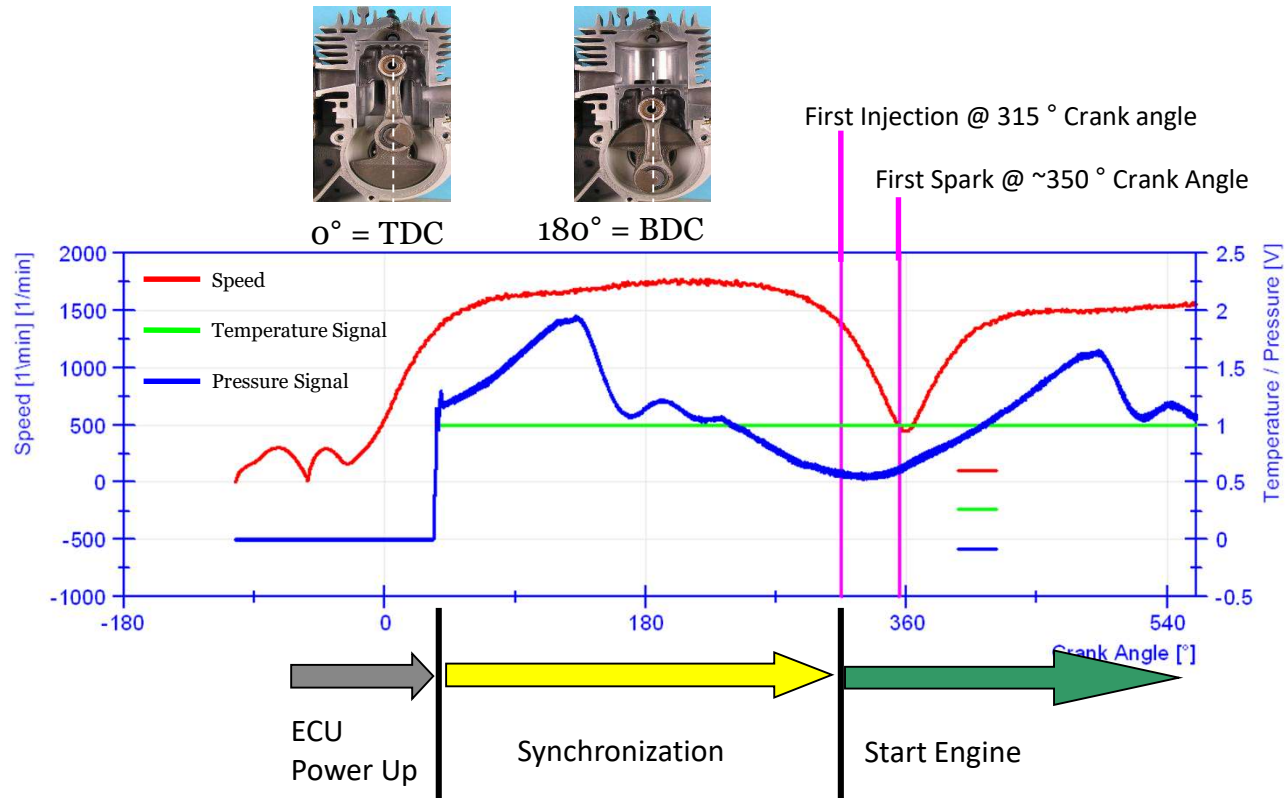
Operating Principle of Injection System III

ECU Power Up Sequence



Operating Principle of Injection System IV

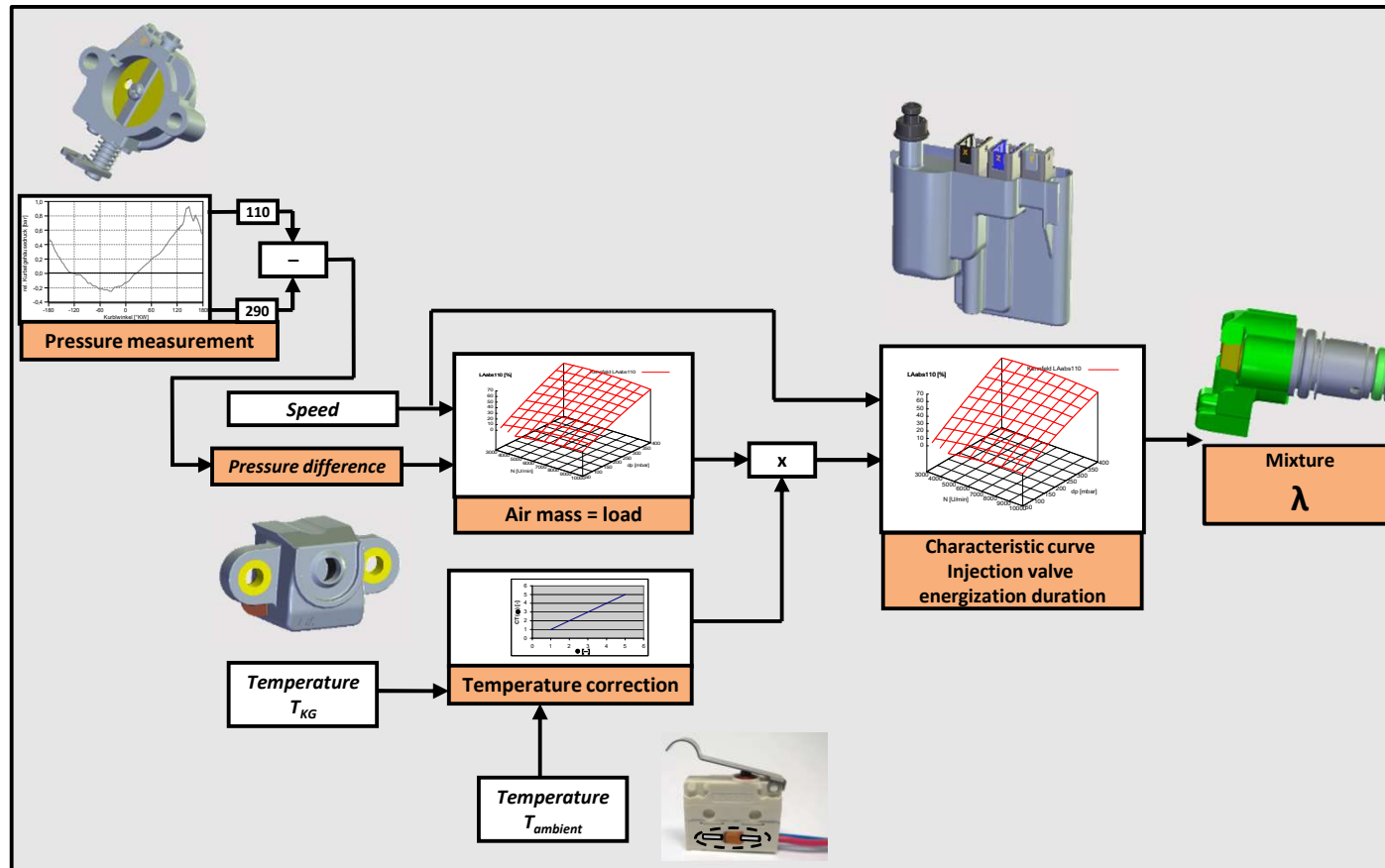
ECU Power Up Sequence



MS 500i

Injection – load detection

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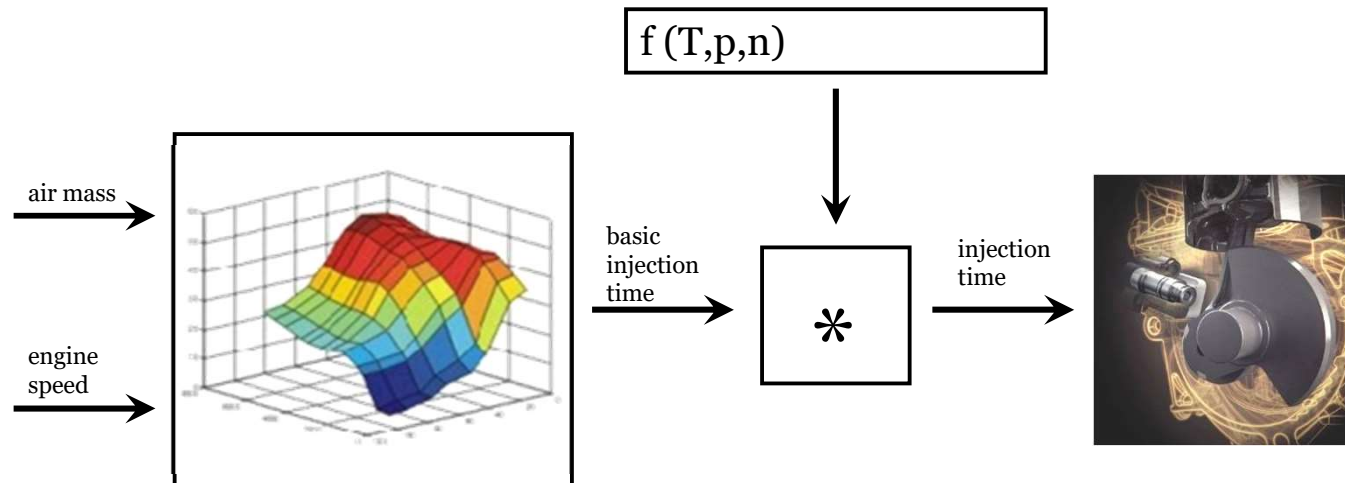


Operating Principle of Injection System

Engine management functions



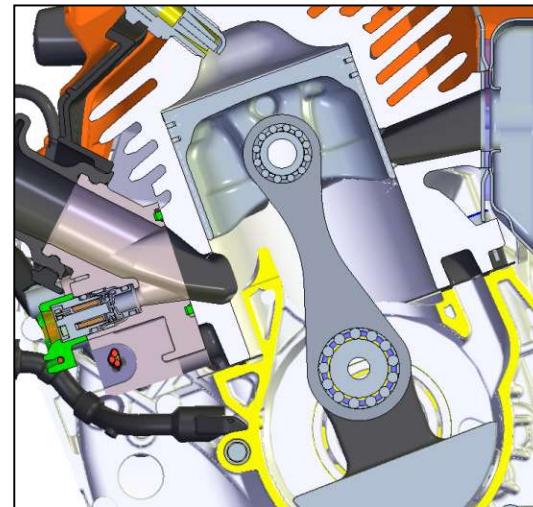
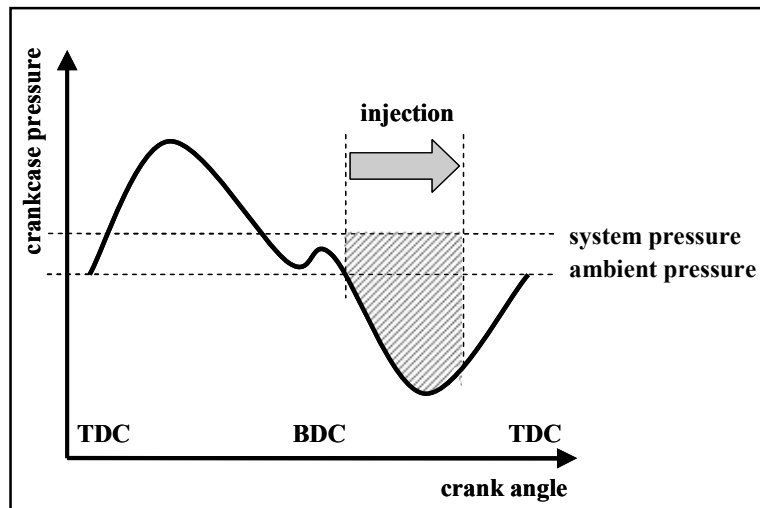
- Start controller
- Lambda controller (full load)
- Idle speed controller
- Fuel cut-off at deceleration



→ **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

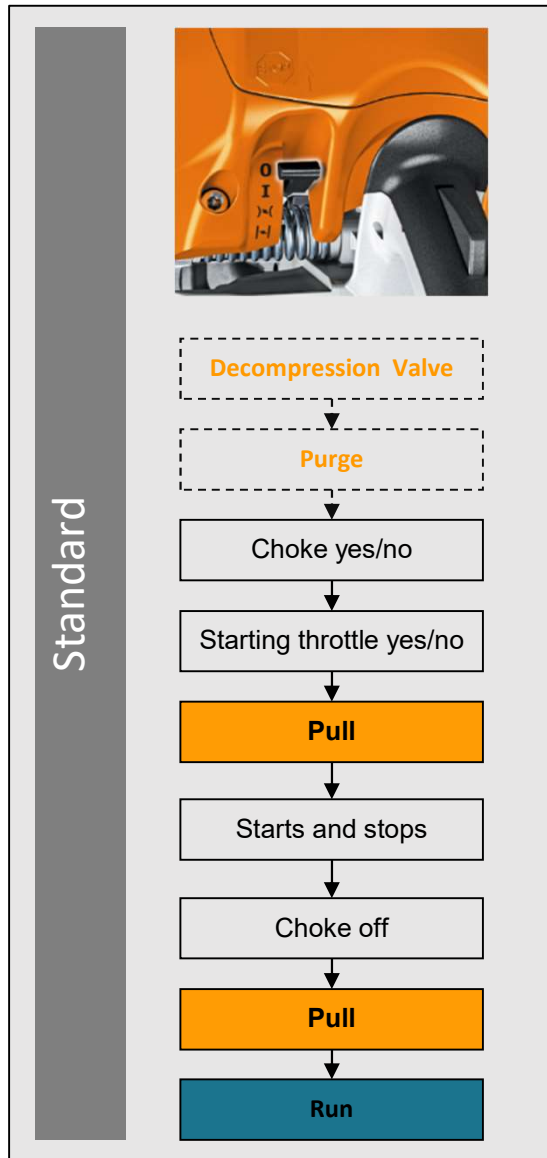
→ negative pressure in crankcase

100 mbar above atmospheric pressure

100-450 mbar

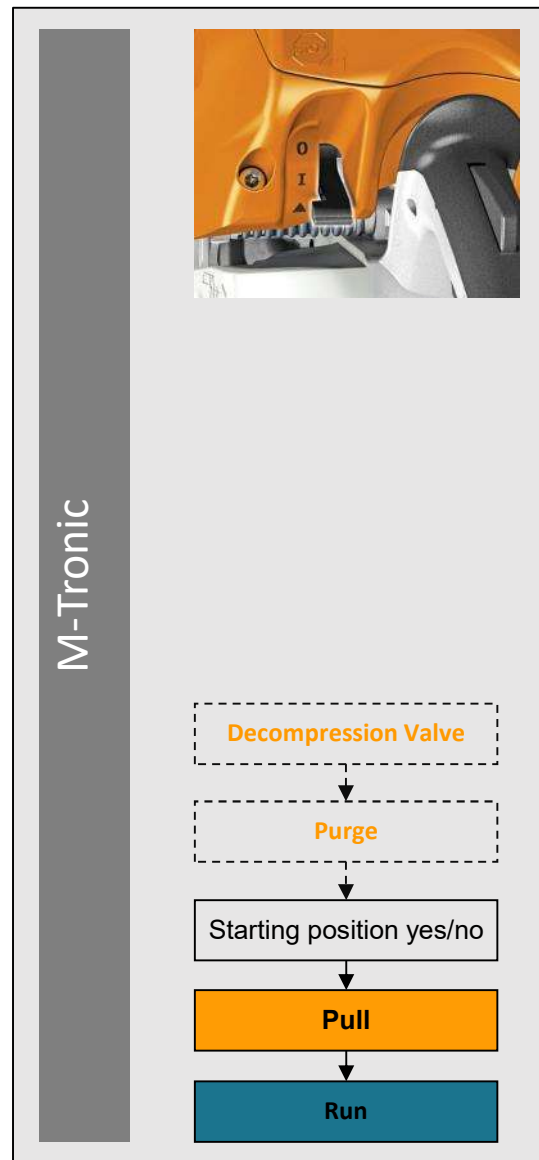
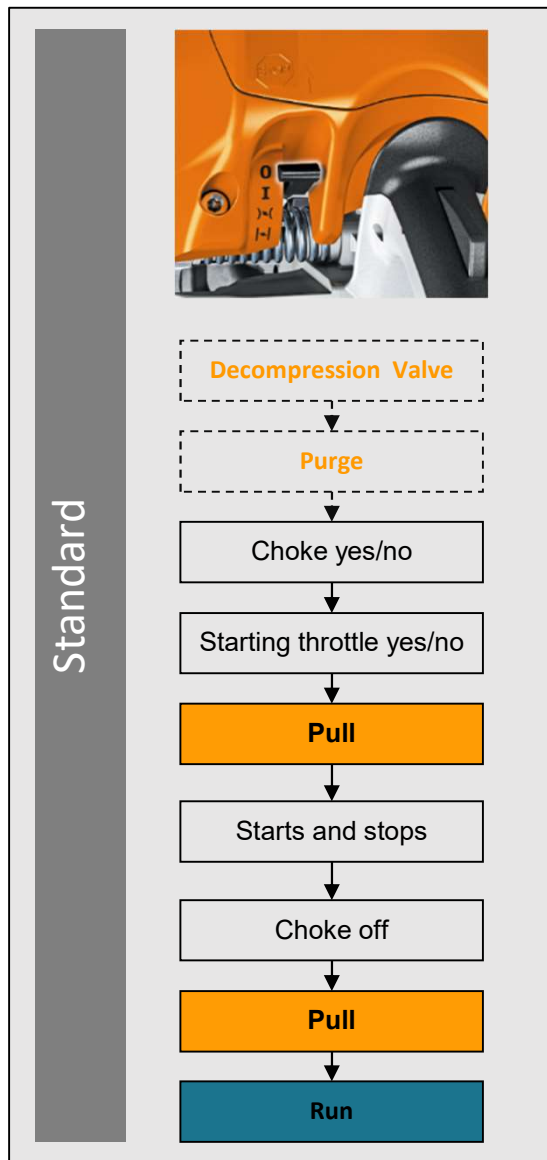
Starting of a regular, carbureted chainsaw

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

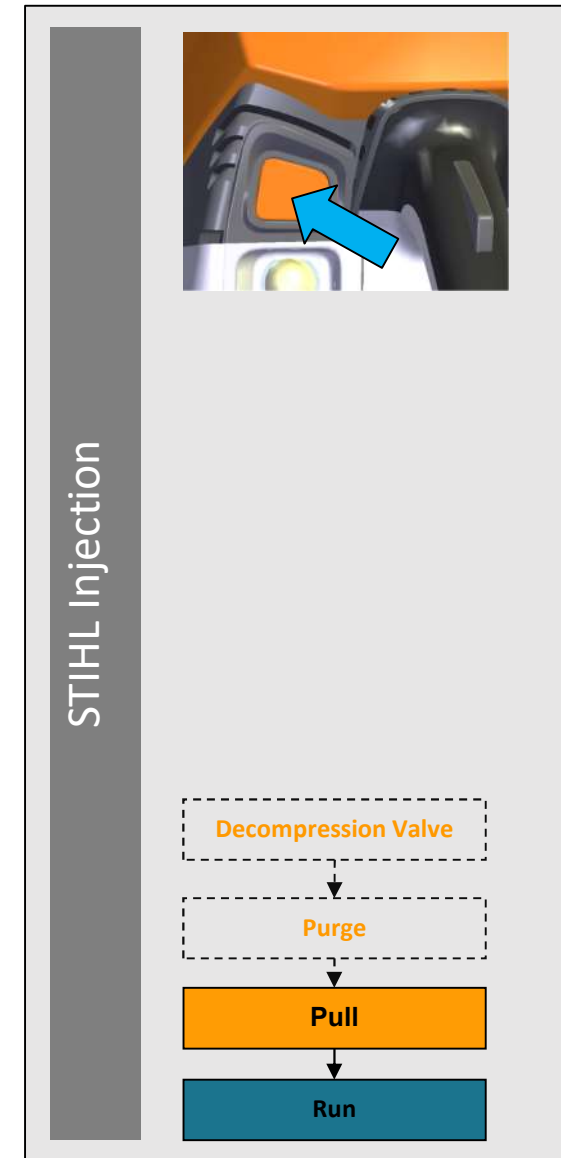
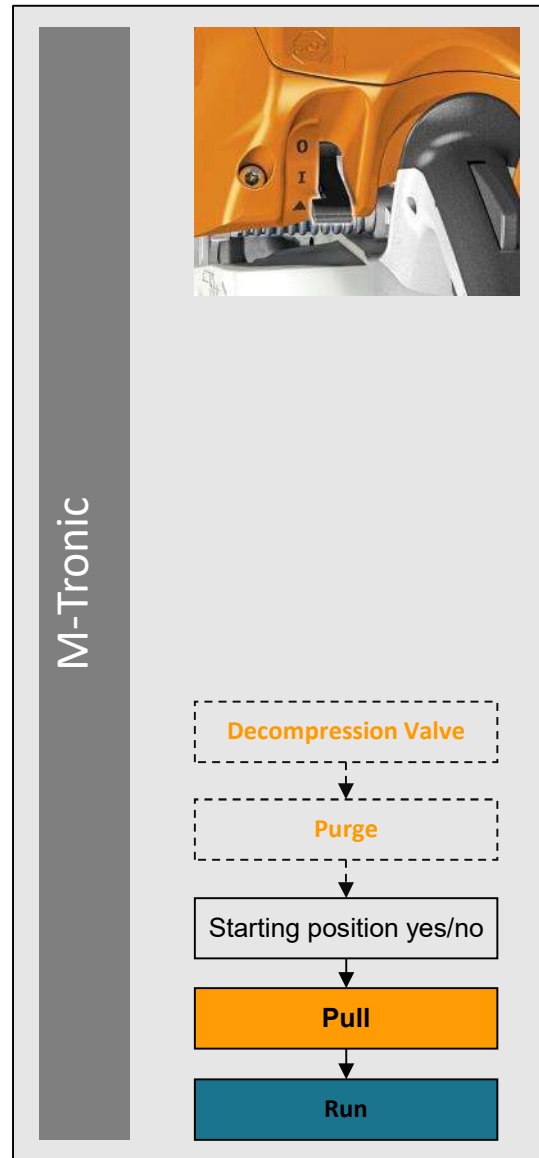
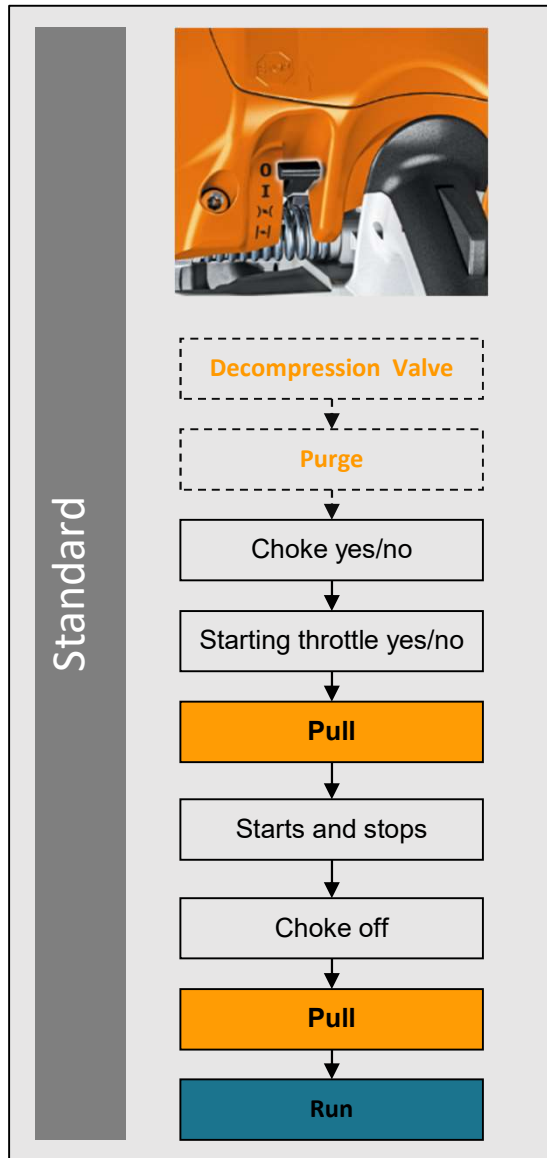
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Starting with Injection

MS 500i

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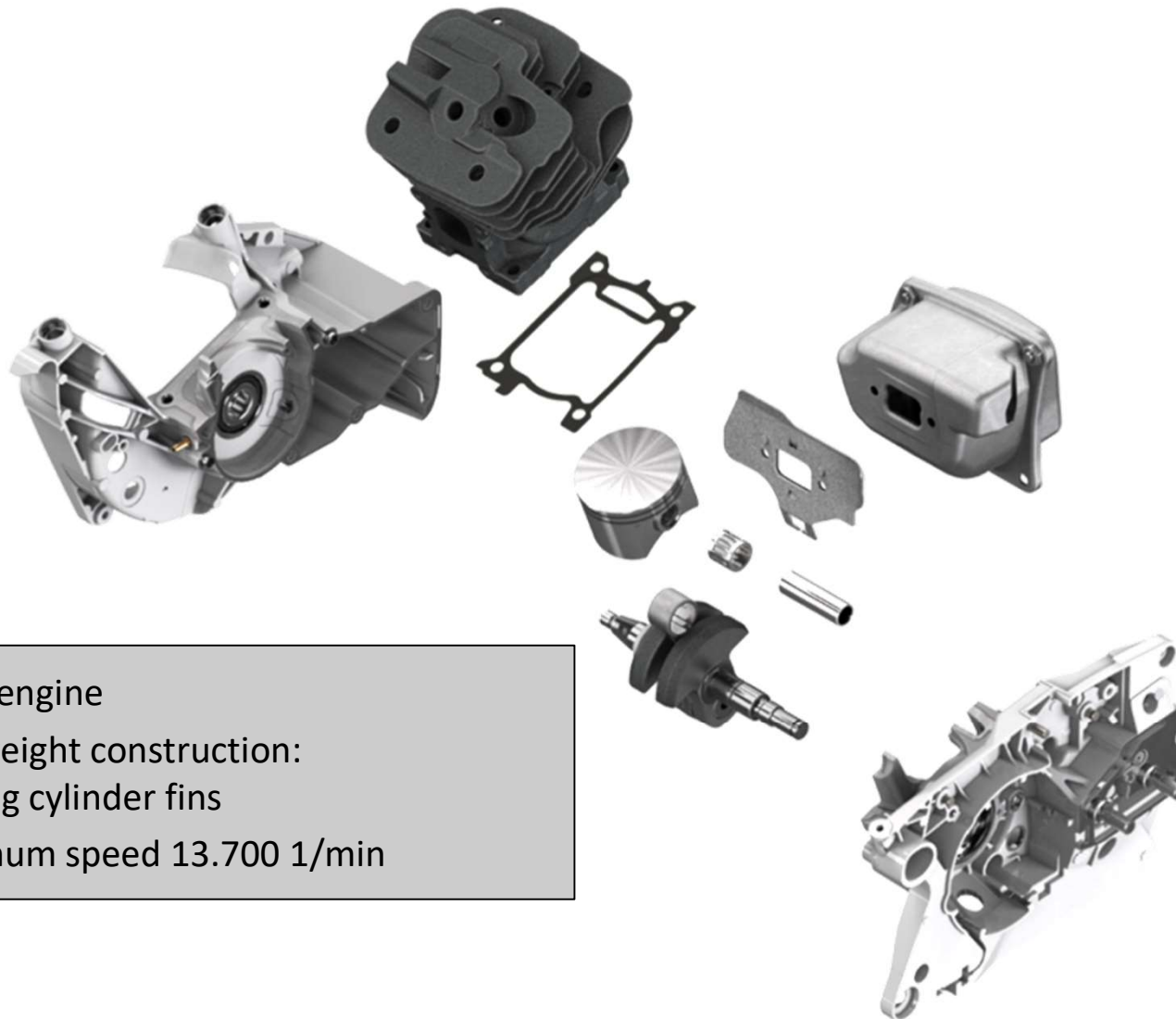


INJECTION INTEGRATION AND DESIGN OF THE MS 500I

MS 500i

Core engine

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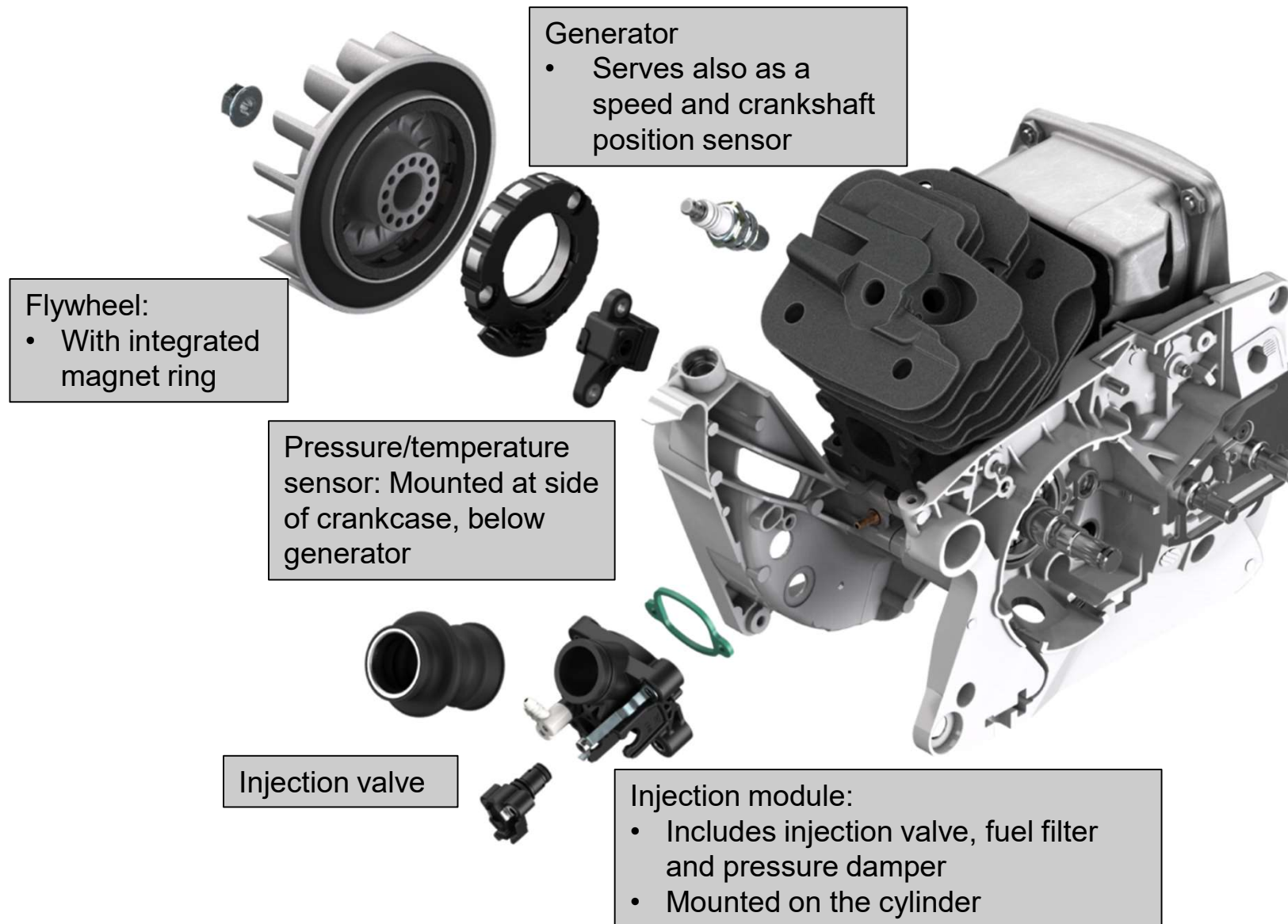


- 2-Mix engine
- Lightweight construction:
slanting cylinder fins
- Maximum speed 13.700 1/min

MS 500i

Engine including injection components

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MS 500i

Injection components, complete

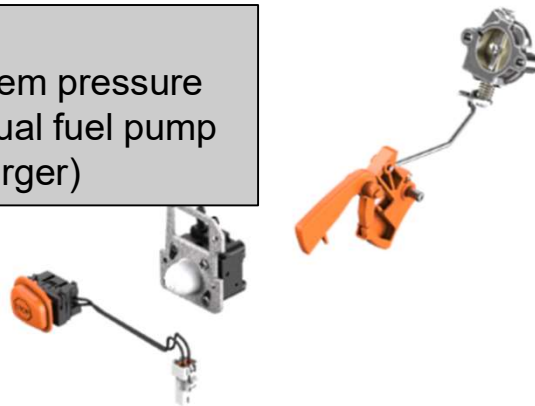
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Throttle shutter body:

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

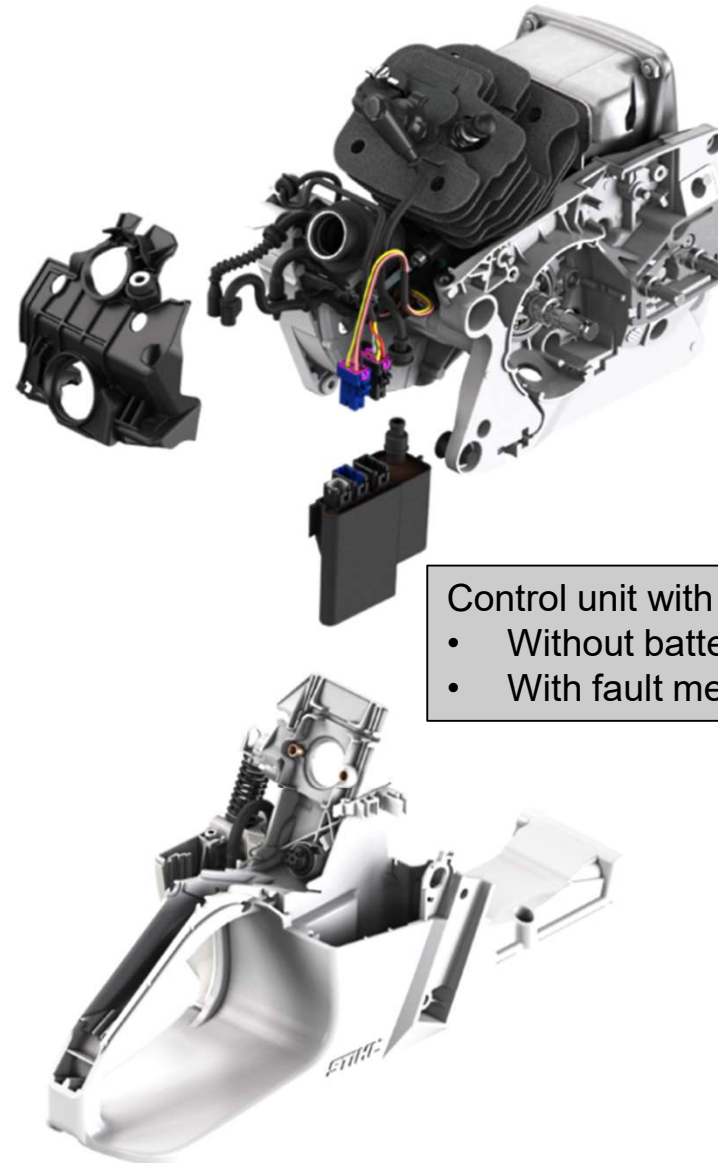
Injection pump

- 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



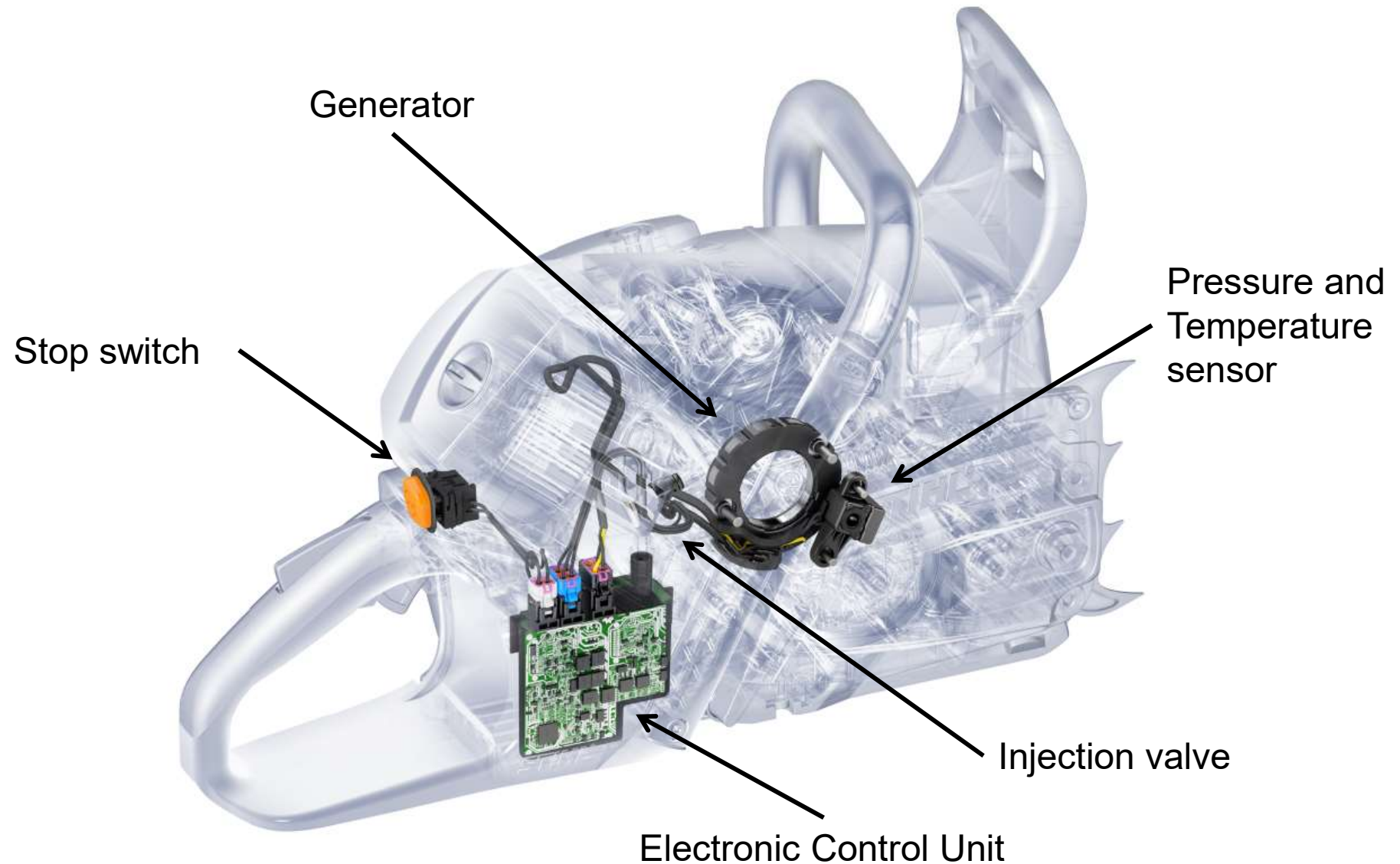
Control unit with ignition coil

- Without battery
- With fault memory

MS 500i

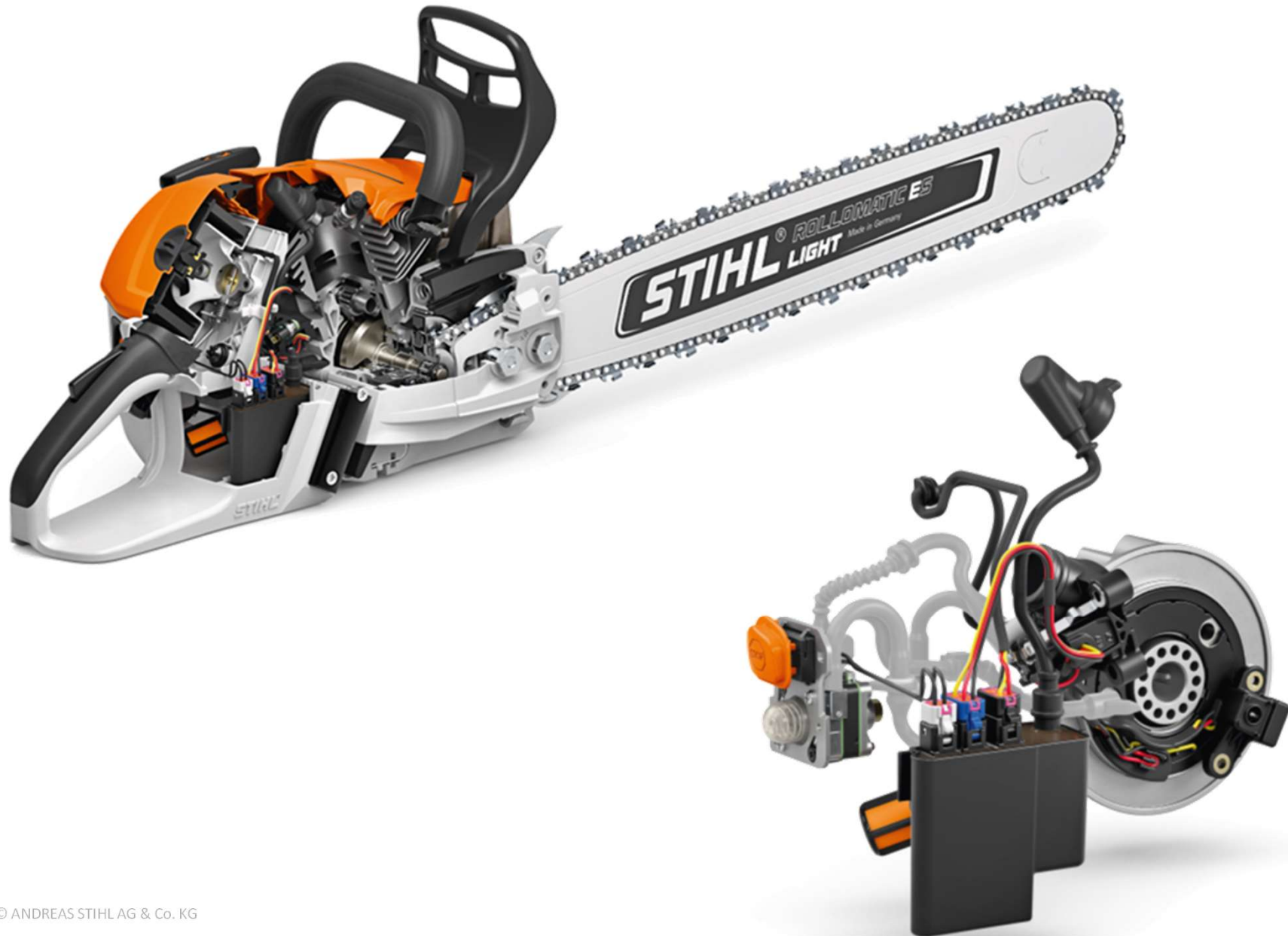
Injection – electrical components

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Design MS 500i

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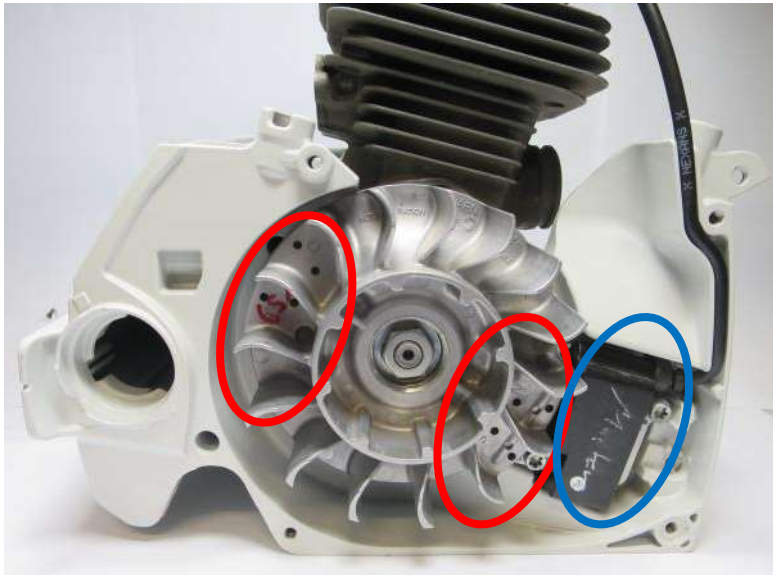


MS 500i

Injection: Lightweight sideeffects

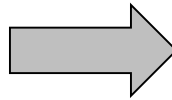
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Carburetor engine 5 kW



Cooling air supply has heavy losses due to

- Magnets in flywheel
- Ignition module in spiral



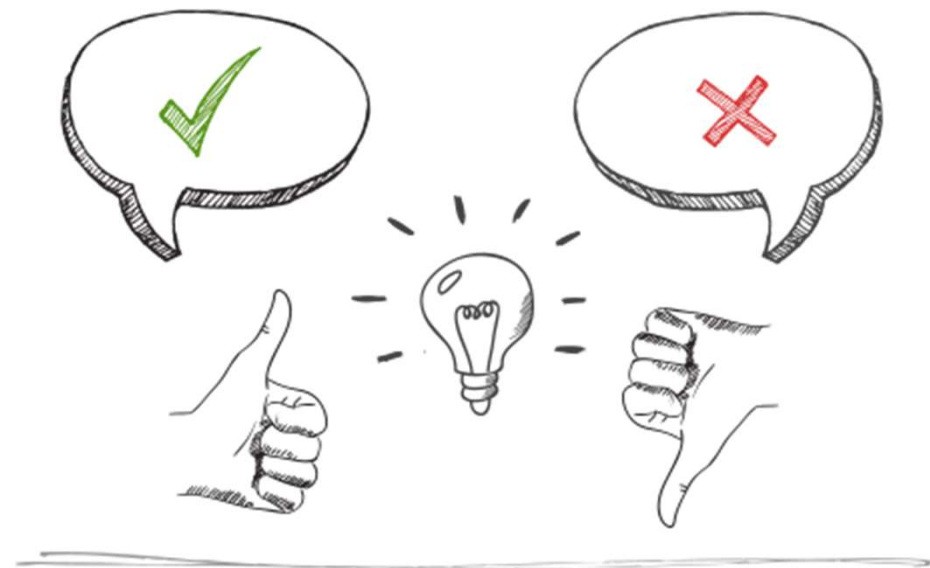
Injection engine 5 kW



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



FEEDBACK FROM THE MARKET



Feedback from saw operators

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“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

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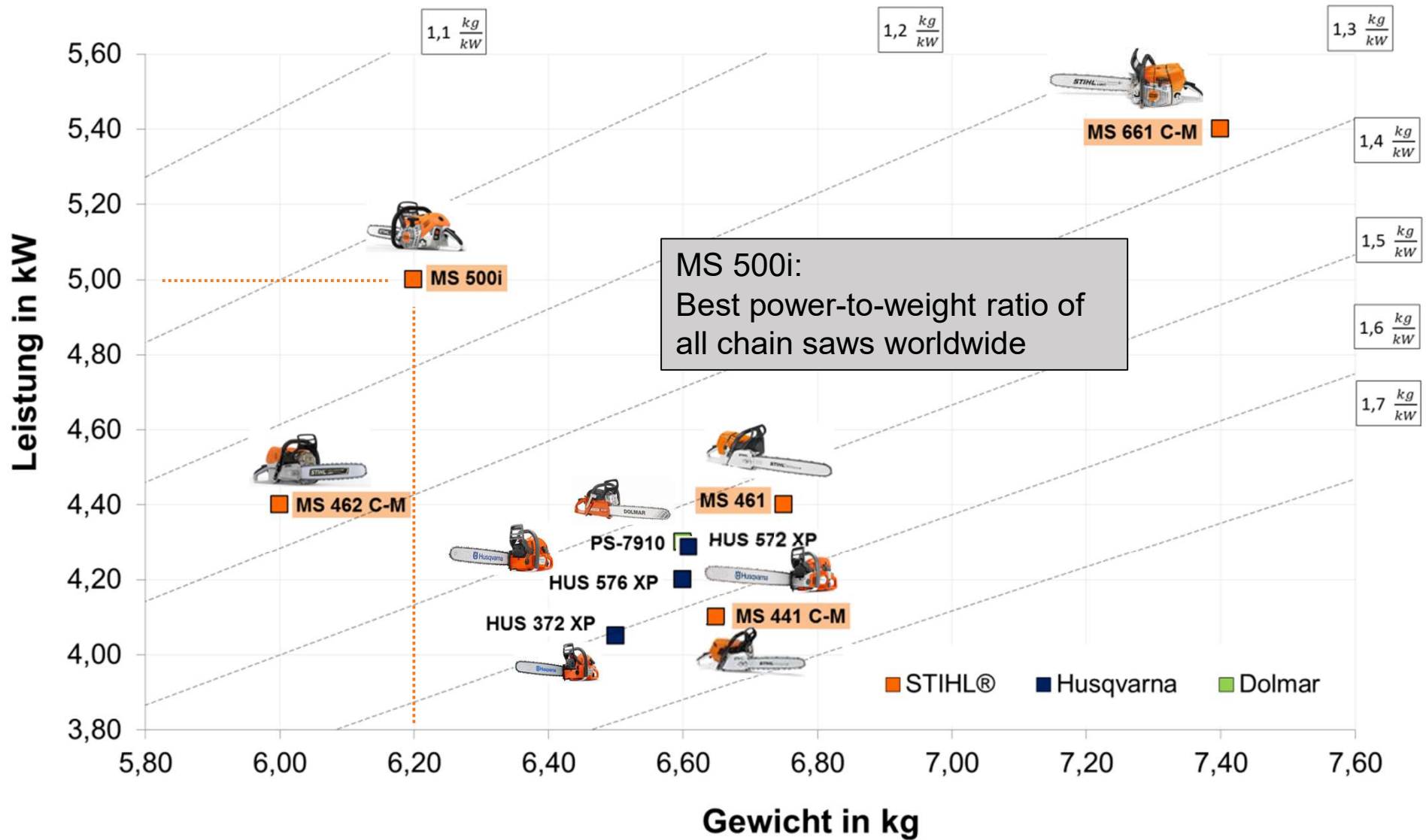
The first chainsaw worldwide
with electronic controlled fuel
injection

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



Power to weight ratio of chainsaws > 70 cm³

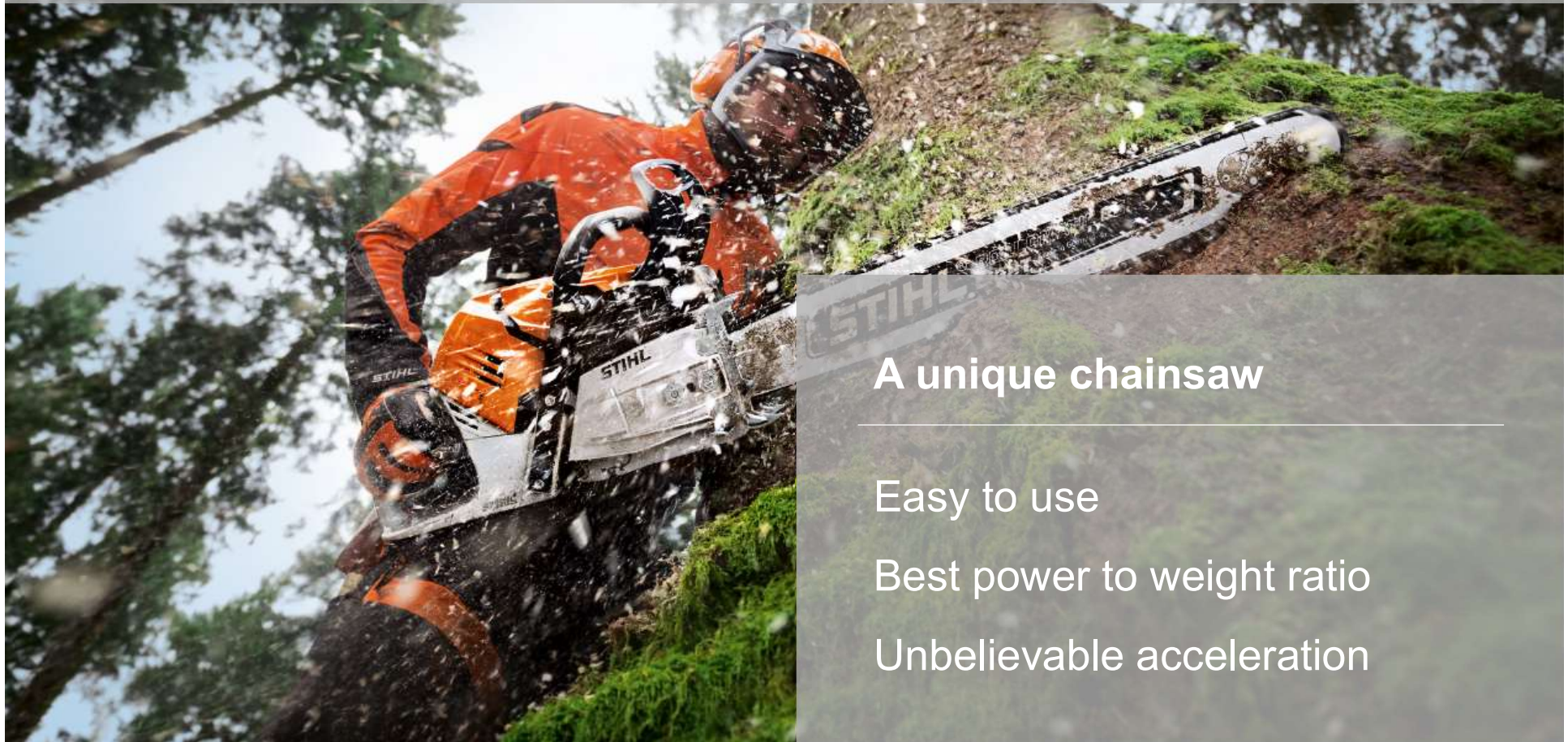
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MS 500i – The view of the customer

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„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

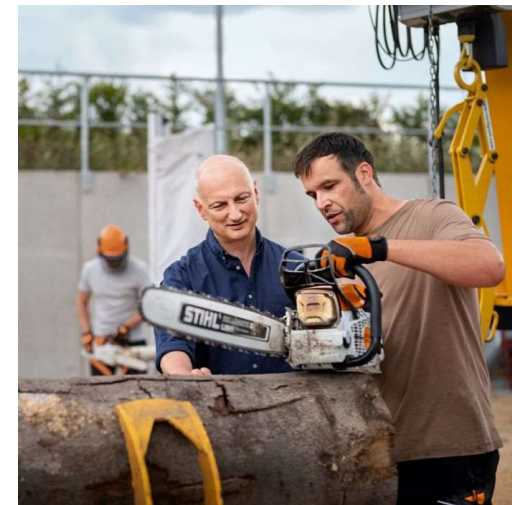


Happy Customers and Dealers

My co-author (thanks to him !)



Happy Engineers



Happy Shareholders

