



FMV Temadag

Levetidsforlængelse af industrielle komponenter

Additiver i sintergods

Sten Millot
Senior Technology Manager – Sinter Technology
FJ Industries A/S

Your reliable partner in powder metal, casting and machining



FJ • INDUSTRIES

Content

- About FJ Industries A/S
- The Press & Sinter technology
- LPS – Liquid Phase Sintering
 - Fe-based Steel
 - Stainless Steel
 - High Speed Steel



Content

- **About FJ Industries A/S**
- The Press & Sinter technology
- LPS – Liquid Phase Sintering
 - Fe-based Steel
 - Stainless Steel
 - High Speed Steel



Global footprint

Overview of FJI production sites

Total:

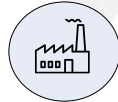
Production site: 24.300 m²

Annual volume:
66 m. finished goods

FTEs: ~ 52 white collar
& ~ 168 blue collar

Ferritslev, Denmark

*Knowledge center within sintering,
casting and machining*



Technologies: Sintering and machining

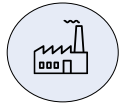
Production site: 14.800 m²

Annual volume: 39.9 m. finished goods

FTEs: ~ 30 white collar & ~ 68 blue collar

Huskvarna, Sweden

*Highly specialized unit in warm
compaction and high temperature
sintering*



Technologies: Sintering

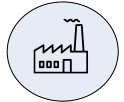
Production site: 2.500 m²

Annual volume: 5.8 m. finished goods

FTEs: 2 white collar & 18 blue collar

Ningbo, China

*Highly competitive unit with core
competences in machining cast
components*



Technologies: Sintering, casting and machining

Production site: 7.000 m²

Annual volume: 20.3 m. finished goods

FTEs: ~20 white collar & ~ 82 blue collar



Core technologies

Powder metal components

1.



Cast and machined components

2.



Description:

Pressing / Sintering

- Fully customized production process, in which powder metal is pressed using a precision tool and afterwards sintered

Casting / machining

- Fully customized production process, in which raw cast components are machined

Industry application:

- Highly complex components for a variety of industries

- Primarily automotive (Tier 1 and 2 suppliers)

Production facility:

- Denmark, Sweden and China

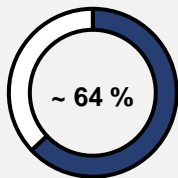
- China



Powder Metal

- Cost-efficient serial production
- Net shape parts with complex geometry & tailor made properties
- Small tolerances with high repeatability
- Environmental friendly process with low material waste
- Steel, Stainless steel and Bronze

*Powder metal share
of revenue*



Powder metal components for a broad range of industries



Actuators



Automation



Automotive



Compressors



Forestry and garden



Gears



Household appliances



Hydraulics



Locking systems



Motors



Other



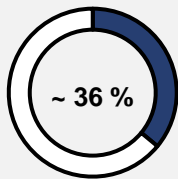
Power tools



Casting / machining

- Sand, shell and investment castings
- Various iron and steel grades
- Near net shape
- Medium/large series
- Machined to final shape

*Casting / machining
share of revenue*



Cast, machined metal components mainly for automotive



EGR systems



Engine



Exhaust system



Fuel rail



Fuel tanks



Industry (non automotive)



Quality focus

All our
production
sites are
certified
according to
IATF 16949

IATF 16949 certification

- A worldwide recognized standard related to quality management.
- All processes are conducted in compliance with world class automotive standards.
- A guarantee for professionalism for non-automotive customers



Customer feedback and audits

- Continuous dialogue with customers in order to receive feedback on quality and delivery performance.
- Our customers perform audits at our production sites to review the quality.



Content

- About FJ Industries A/S
- **The Press & Sinter technology**
- LPS – Liquid Phase Sintering
 - Fe-based Steel
 - Stainless Steel
 - High Speed Steel



The Press & Sinter technology

Conventional Powder Pressing Process:

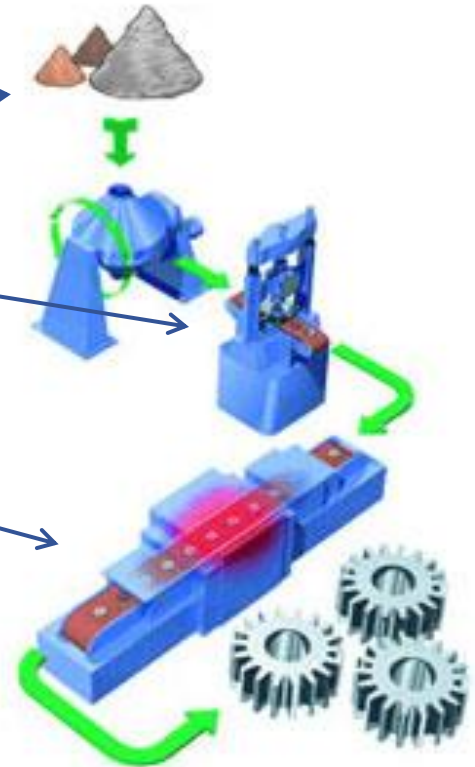
Mix the powder with additives and lubricant.

Press the powder in a tool forming a green part.
Uniaxial process.

Sinter the parts in a belt furnace.

Key processes:

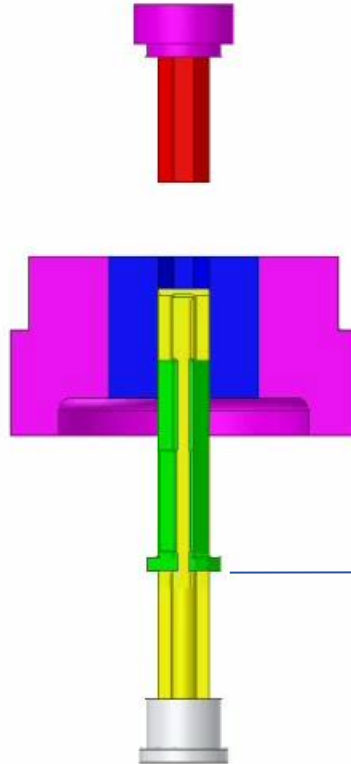
- Powder mixing (Alloying the powder)
- Powder pressing (Forming the shape)
- Sintering (Strengthening the part)



The Press & Sinter technology

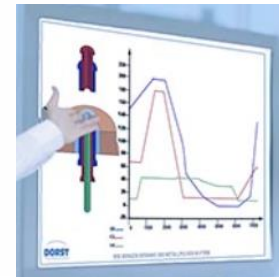
Steps:

1. Filling position
2. Closing the tool
3. Compressing
4. Redraw upper piston
5. Ejection from the die
6. Withdraw lower core
7. Back to filling position



Filling height
~ 2,5 x item height

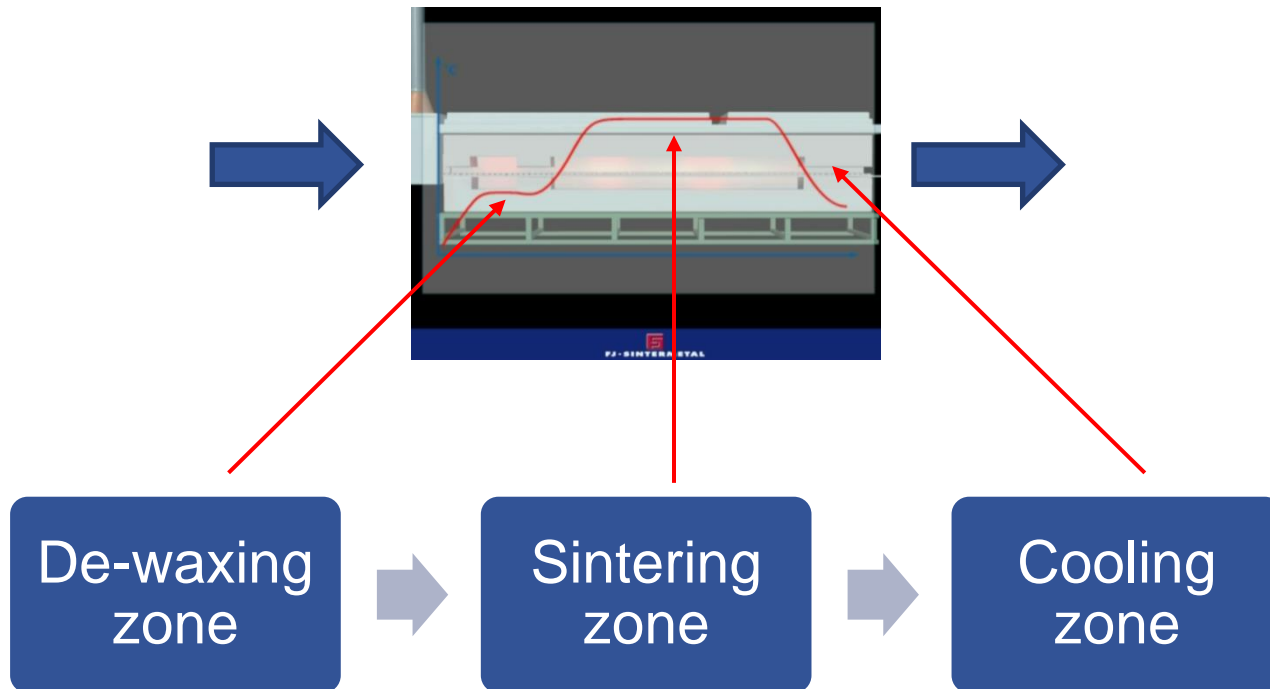
Lower punches at fixed position



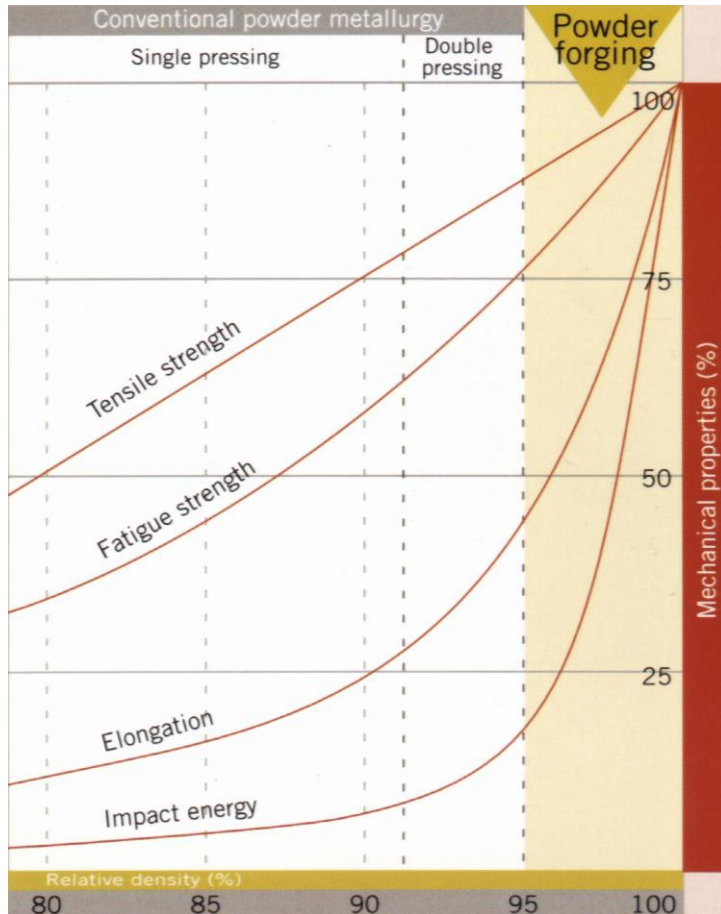
The Press & Sinter technology

The sintering is done in a belt furnace where parts are placed on trays which are transported slowly through the furnace.

Parameter: Time, temperature and atmosphere



The Press & Sinter technology



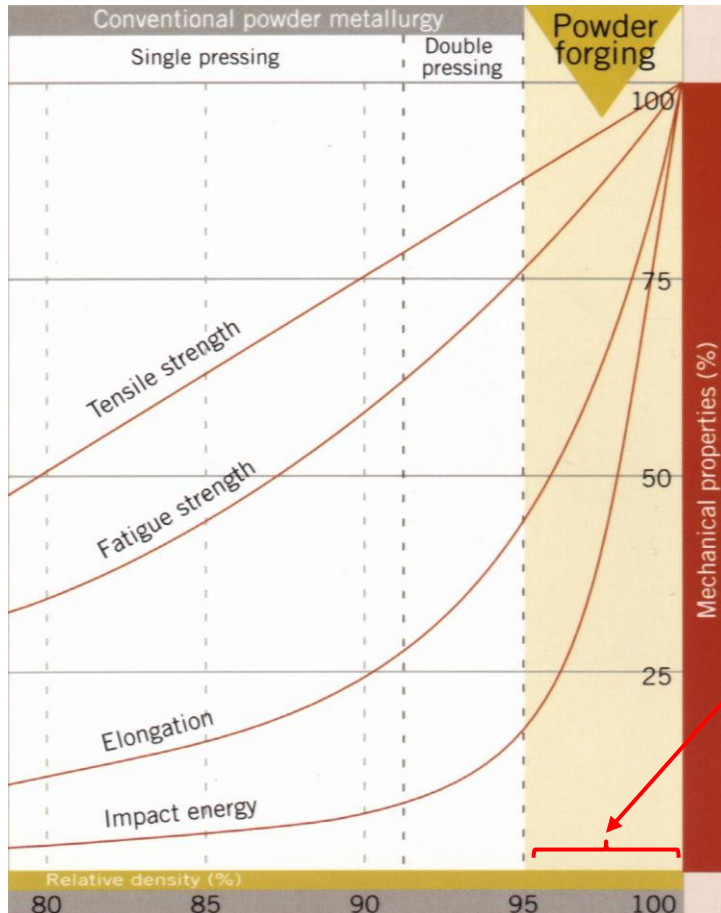
It is possible to produce components up to 92% of relative density with single pressing and 95% of relative density with double pressing.

Mechanical properties in relation to the relative density improving:

- - Tensile strength
- - Fatigue strength
- - Elongation and ductility
- - Impact energy



The Press & Sinter technology



Question:

How is it possible to reach this area with relative density between 95 and 100% to get the highest mechanical properties?



LPS – Liquid Phase Sintering

Answer:

By using LPS – Liquid Phase Sintering



-
- About FJ Industries A/S
 - The Press & Sinter technology
 - **LPS – Liquid Phase Sintering**
 - Fe-based Steel
 - Stainless Steel
 - High Speed Steel

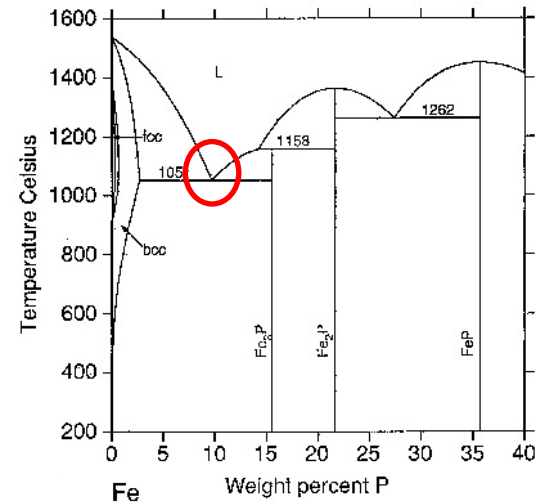


LPS – Liquid Phase Sintering

Adding iron phosphide (Fe_3P) to the mix it is possible to increase the sintering activity.

At 10%P and at 1050°C an eutectic phase occurs and create a liquid phase for a shorter period. The phosphorus defunds into the material and transform to a phase with liquidus.

When the concentration of P reduces again due to P-distribution in iron, a solid phase is created at the surface of the powder particle.



Fe-P phase diagram



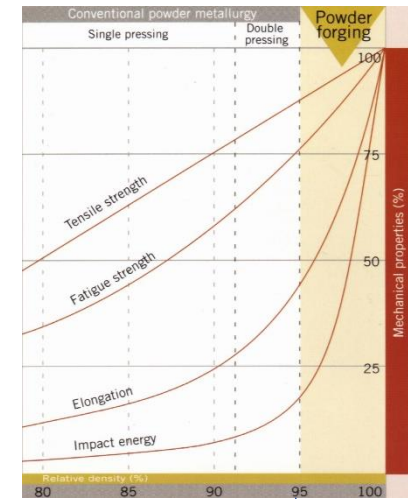
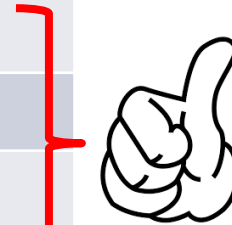
LPS – Fe-based Steel

Astaloy Mo + 0,5P [Fe + 1,5% Mo + 0,5% P] (NB: No carbon addition)

Warm compacted at 600 MPa and sintered at 1250 °C in formier gas (90% N₂ + 10% H₂) for 1 hour.

Mechanical properties:

	Standard	WC + HT
SD g/cm ³	7,13	7,46
RD %	91	95
DC %	-0,8	-1,2
HV10	112	153
UTS MPa	380	504
YS MPa	287	364
A %	8,2	19,1
%C	0,02	0,02



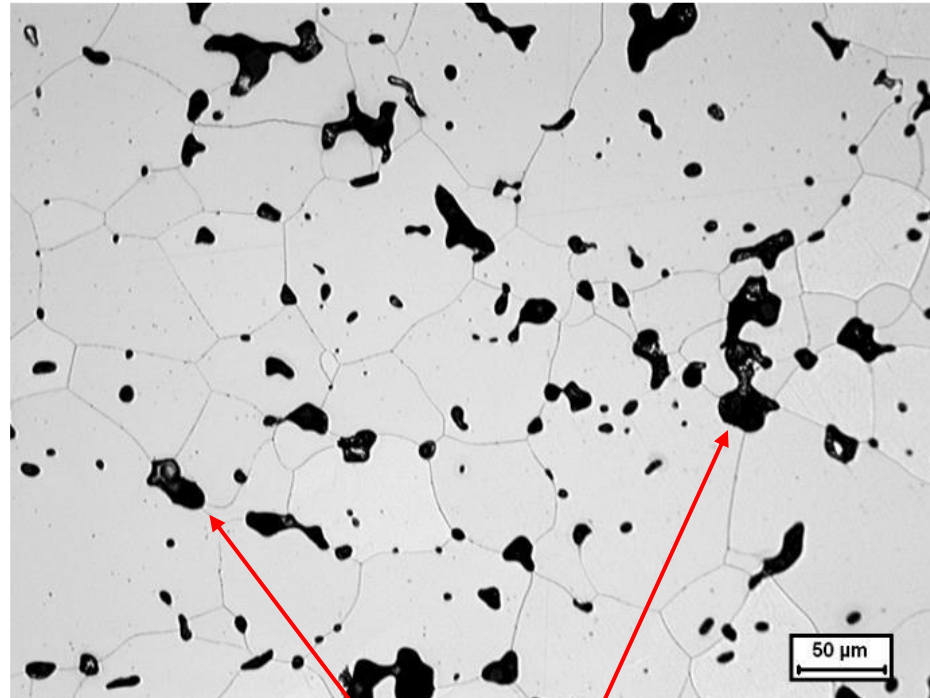
SD of 7,46 = RD of 95% at the lower limit:



LPS – Fe-based Steel

Astaloy Mo + 0,5P [Fe + 1,5% Mo + 0,5% P] (NB: No carbon addition)

Microstructure :



Rounded pores due to LPS and HT sintering
100% ferritic structure



FJ · INDUSTRIES

LPS – Stainless Steel

316 LHD [17% Cr + 13% Ni + 2,5% Mo – C < 0,03%]

and

SS 100 [19% Cr + 19% Ni + 6,5% Mo – C < 0,03%]

The powders are mixed with X% Fe₃P, pressed at 600 MPa and sintered at 1160 °C in pure hydrogen for 1 hour and compared to standard mix without Fe₃P.

References:

Standard	316 LHD	SS 100
SD g/cm ³	6,75	6,72
UTS MPa	270	340
YS MPa	187	246
A %	8,2	6,4
DC %	-0,9	-1,2



LPS – Stainless Steel

Results:

LPS	316 X=4%	316 X=5%	316 X=6%	SS 100 X=4%	SS 100 X=5%	SS 100 X=6%
SD g/cm ³	6,84	7,05	7,19	7,38	7,57	7,69
RD %	87	90	92	94	96	98
UTS MPa	473	498	487	440	468	494
YS MPa	300	329	366	354	398	424
A %	17,0	19,1	13,0	4,9	4,4	4,4
DC %	-1,8	-2,8	-3,4	-3,8	-4,8	-5,1

Good result
elongation

Good result
strength

Increased density but also bigger dimensional changes means difficult to keep narrow tolerances.



LPS – Stainless Steel

Mo content have big influence on the sintering activity with Fe_3P addition.

LPS	316 X=4%	316 X=5%	316 X=6%	SS 100 X=4%	SS 100 X=5%	SS 100 X=6%
SD g/cm ³	6,84	7,05	7,19	7,38	7,57	7,69
RD %	87	90	92	94	96	98

Mo content:

2,5 %Mo

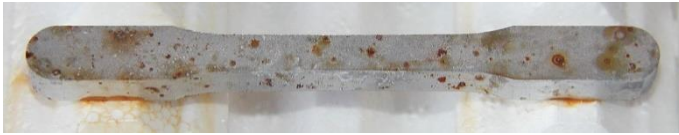
6,5 %Mo



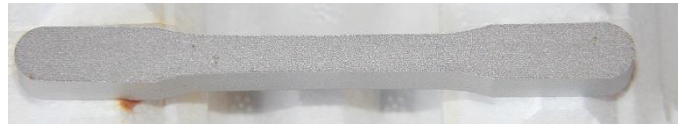
LPS – Stainless Steel

Corrosions test according to ASTM B117 [5% NaCl – 35 °C – 1 to 2 ml/h – 6,5 to 7,2 pH]:

The test with additives gave the best results after 288 hours:



SS100 standard



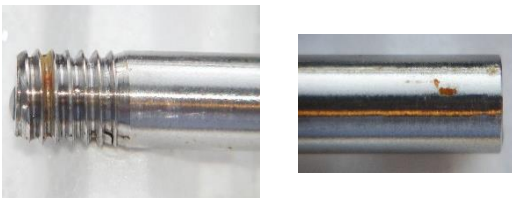
SS100 with additives



316 standard



316 with additives



Reference: 316 steel bar



Test preformed by Danfoss Industry Service



LPS – High Speed Steel

WEARDENS® – chemical composition:

	%C	%Mo	%W	%Cr	%V	%Fe	%Others
Min	0.9	4.5	5.0	3.5	2.5	Bal.	0.4
Max	1.5	10.0	7.0	4.5	3.5	Bal.	1.3

Results:

	WEARDENS® No.	Micro hardness [HV0,3]	Macro hardness [HV30]	Density [g/cm ³]
+ < Wear resistance >	4500	900	864	7,87
- < dimension stability > +	6500	887	866	7,98
	6515	886	871	7,99
	6535	890	857	8,01
	6555	965	896	8,04

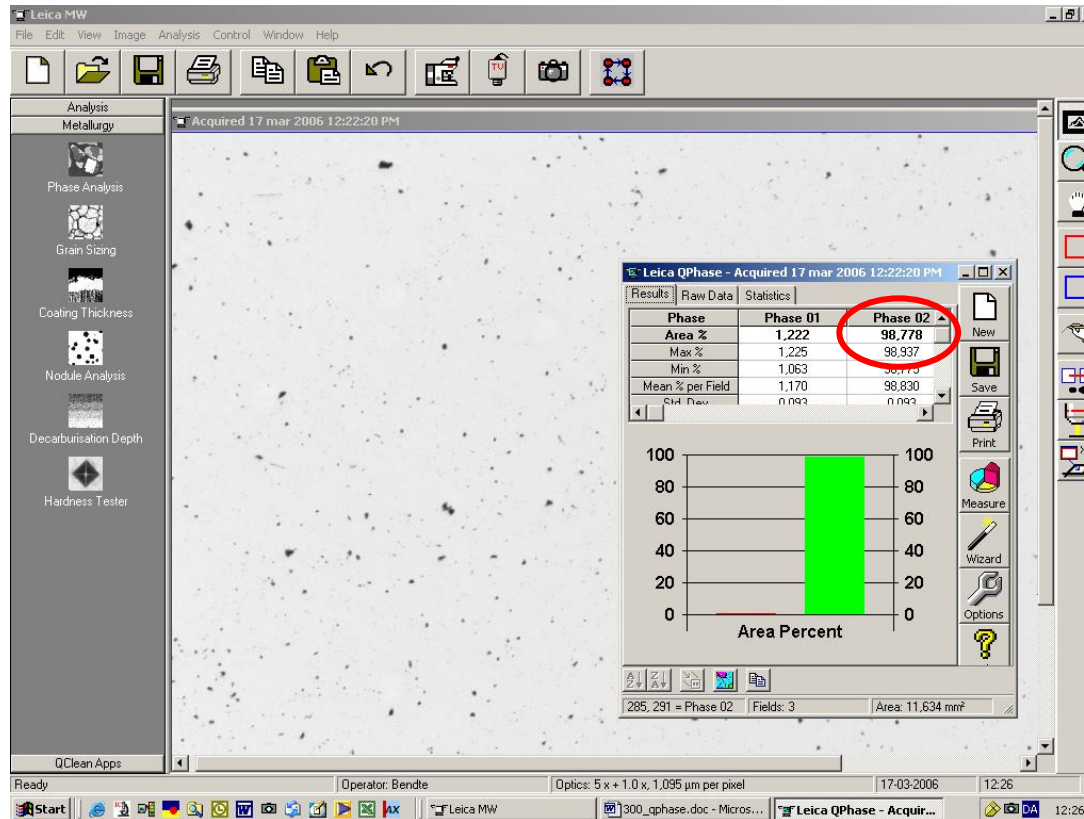
Theoretical density: 8,41 g/cm³

7,87 – 8,04 in density => RD 94% - 96%



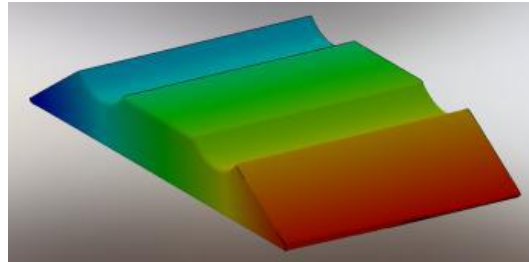
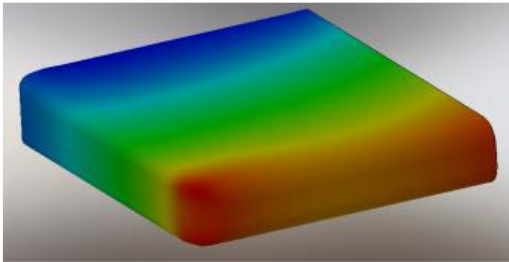
LPS – High Speed Steel

In practise density measured on Weardens 6500 shows RD of 98,8% using Leica Qphase.



LPS – High Speed Steel

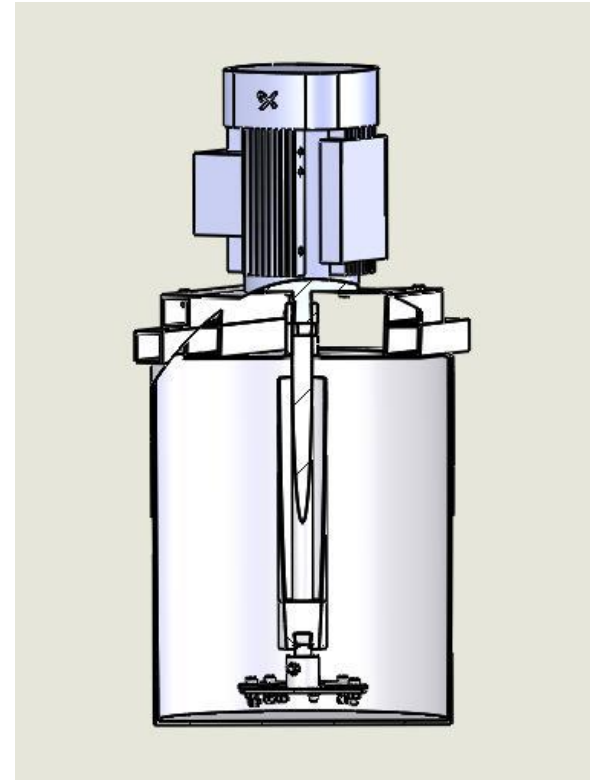
Wear test of Weardens compared to a massif knife for wood chip production:
(Wear test performed by students – Ingeniørhøjskolen Aarhus Universitet)



Left: Weardens sample – right: TKIII knife.

Tested in a slurry of:
Bark and wood chips
Pebbles / granite
Water

Testing time: 12 hours



LPS – High Speed Steel

Results:

	Weight before [g]	Weight after [g]	Δm [mg]	Δm [%]	Surface Area (Sa) [cm ²]	$\Delta m / Sa$ [mg/cm ²]
Weardens	129,246	128,820	426	0,329	2,841	149,9
TKIII	47,643	47,340	303	0,636	1,879	161,3

The Weardens material has better wear resistance - round 7% better in this test.

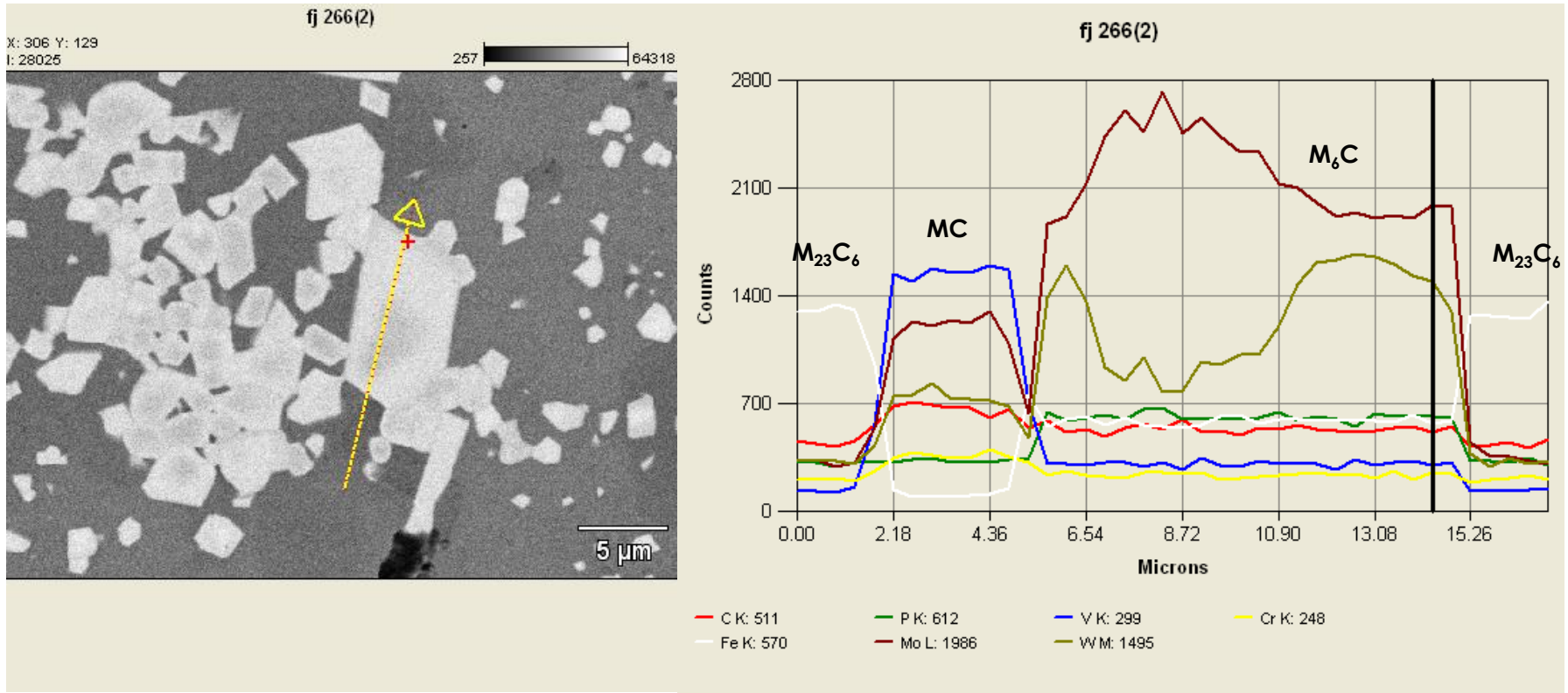
One of the conclusion in this report is that Weardens has 4,5% longer lifetime than TKIII.

Vi har fundet frem til, at Weardens har bedre slidegenskaber end TK III. Det er beregnet, at Weardens har 4,5 % længere levetid end TK III.



LPS – High Speed Steel

SEM analysis (performed by DTU/RISØ)



Through the cross section high Mo and W rich carbides are detected.



THANK YOU FOR YOUR ATTENTION!



FJ • INDUSTRIES