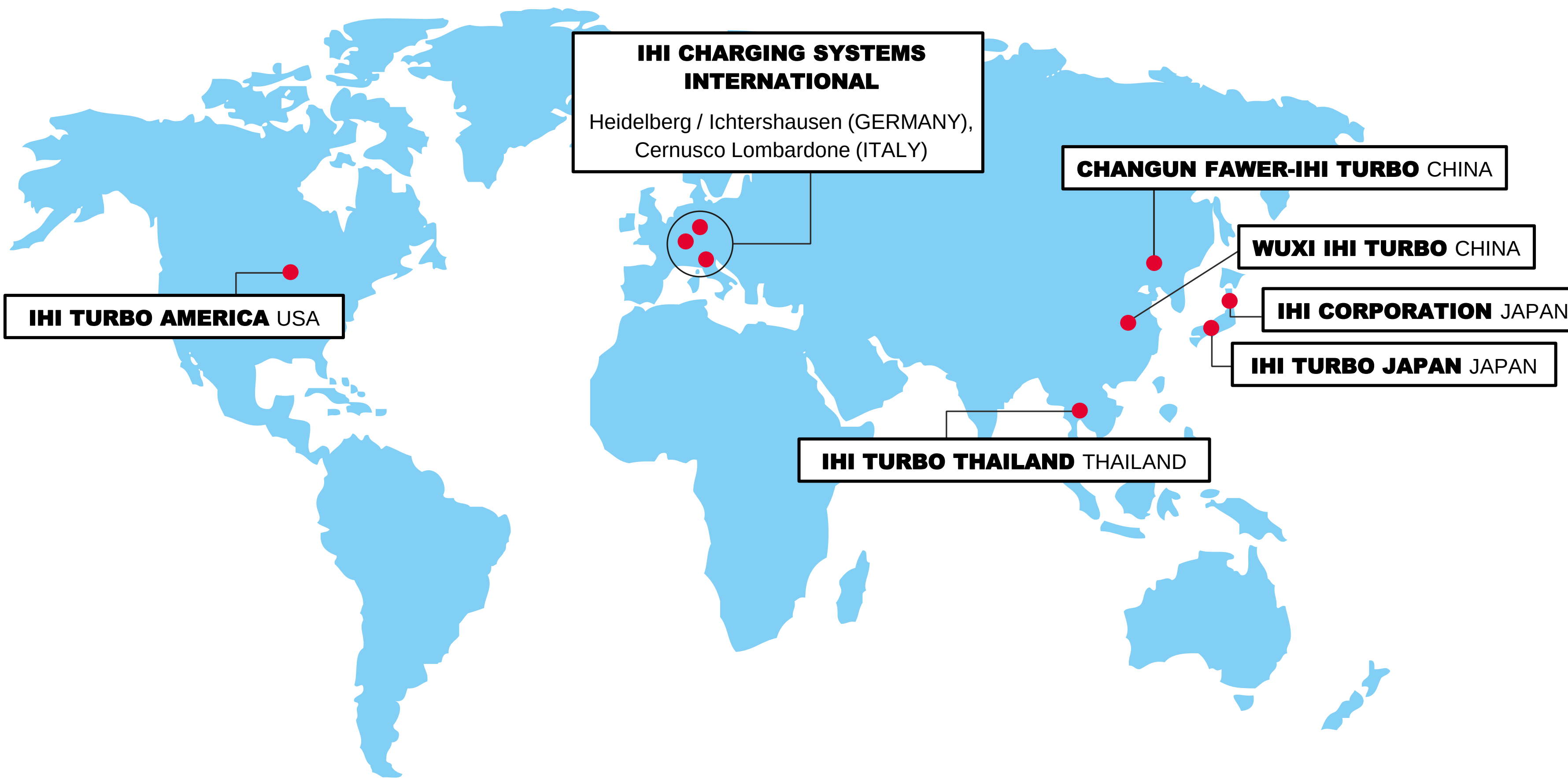
High Speed Balancing Mark Optimization

IHI

25.06.2020

IHI Corporation
IHI Charging Systems International GmbH
Martin Kreschel, Roberto DeSantis

IHI: Worldwide Operations



IHI: Engineering Center Heidelberg

ICSI is an established provider of charging systems in the European turbocharger segment. Millions of our systems are successfully used by almost all European automotive manufacturers.

With fast processing time and sophisticated production technologies, even during the prototype phase, we contribute to shortening development time and increasing project effectiveness.

Future orientation and the associated responsibility are an integral part of our corporate philosophy and are implemented every day by our employees across the entire process chain.

LOCATION

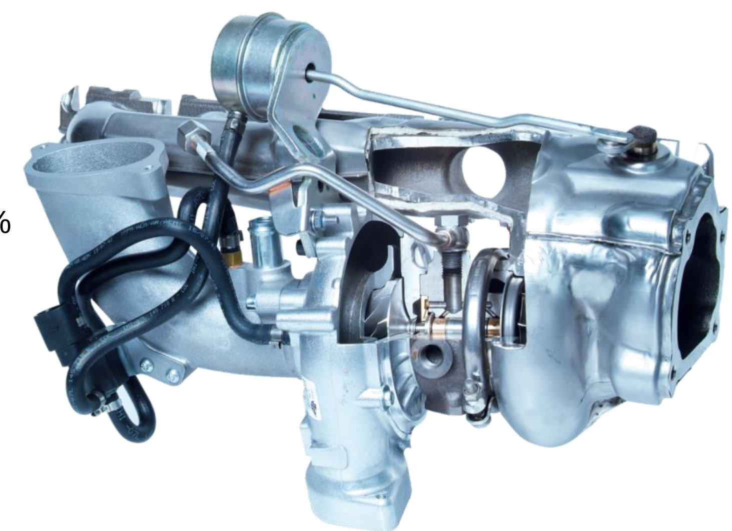
Heidelberg, Germany

ESTABLISHED

IHI Charging Systems International GmbH was founded in 2001 as a joint venture company between Daimler AG and IHI Corporation (Japan). Since March 2013, ICSI is a 100% subsidiary of IHI Corporation.

FUNCTIONS

Engineering center
Engine & T/C test center
Prototype shop
Project management of European customers



IHI: Manufacturing Footprints

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LOCATION	**Ichtershausen (Thuringia), Germany - Headquarter**	**Cernusco Lombardone (Lecco), Italy**
COMPANY	IHI Charging Systems Germany International GmbH 100% shares owned by ICSI GmbH	IHI Charging Systems International S.p.A. 100% shares owned by ICSI GmbH
ESTABLISHED	2008, opening ceremony in April 2009 Second production hall completed in October 2012	1995 as WARNER-ISHI Turbo 1998 IHI Turbo Italy S.p.A. 2001 IHI Charging Systems International S.p.A.
CAPACITY	> 2 million units/year	> 2 million units/year
FUNCTIONS	• Machining bearing housing • Machining compressor wheel • Welding turbine wheel & shaft • CS assembly and balancing • TC assembly • Testing • Prototype shop	• Machining bearing housing • CS assembly and balancing • TC assembly • Prototype shop

IHI: Turbocharger Design Methodology

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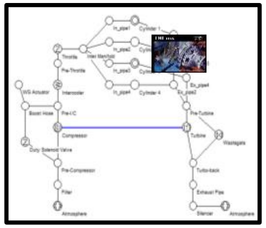
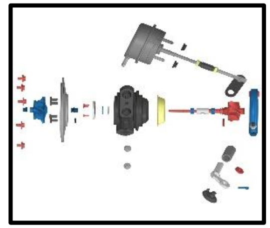


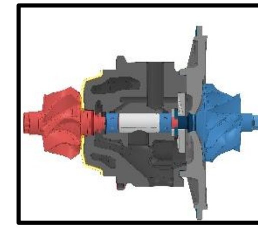
- 0D simulation (ITES in-house tool)
- TC frame size selection
- Turbine & compressor specification
- 1D simulation (GT-Power tool)

Matching TC/ICE



- Standard and customized components
- 3D design
- 2D drawings
- Materials

Design



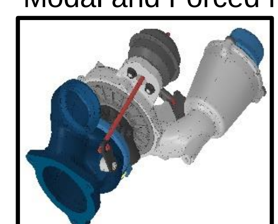
- FEA compressor & turbine wheel
- CW-shaft connection
- Rotordynamics
- Thrust force
- Oil & water core

Verification of center section

Customer

Verification of assembly

- CFD compressor & turbine stage
- FEA housings
- Thermo-mechanical fatigue of turbine housing
- Modal and Forced Response Analysis



Prototyping

- Machining center
- Inspection and metrology lab
- Prototyping/ assembly

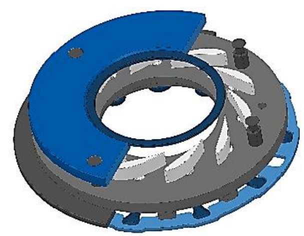
Validation/ Testing

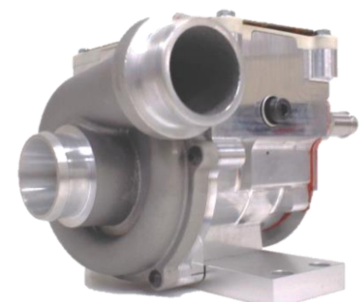
- Standard test procedures
- Cold-gas test benches
- Hot-gas test benches
- Engine test bench

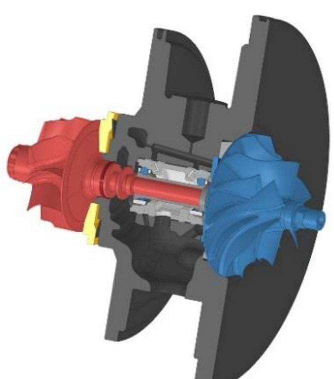
IHI: Technologies / Products for Today and Tomorrow

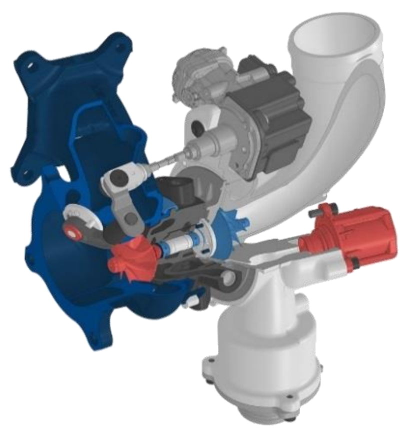
- Turbine housing with integrated manifold
- Turbine housing adapted to manifold integrated into cylinder head
- Ball bearing
- E-compressor
- E-assisted turbo

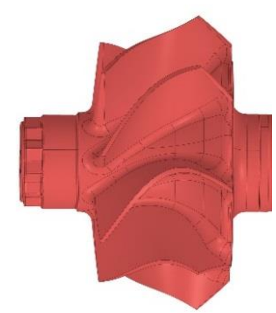
- Mixed-flow turbine
- Twin scroll turbine
- Double scroll turbine
- Variable turbine for gasoline engine application
- Electric waste gate regulation











IHI: Balancing Process

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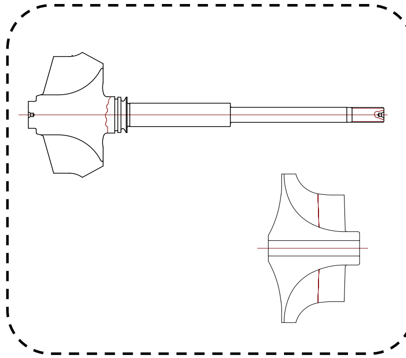

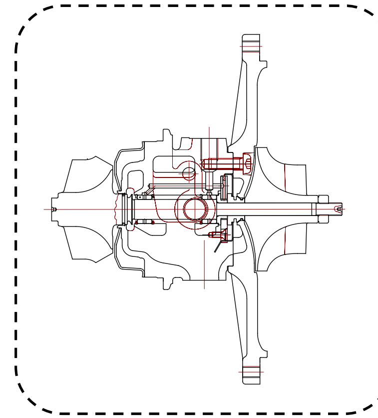

	Single component balancing	High Speed Balancing (HSB)
What	Turbine Wheel & Shaft Compressor Wheel	Centersection
Method	Rigid rotor	Flexible rotor
Aim	Reduction of initial unbalance of single components	Reduction of unbalance of rotor assembly
Measurement Speed	Single Speed between 4000 – 5000 RPM	Single speed or speed range within T/C speed range

IHI: Balancing Process

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1st calibration run without trial weights

Several calibration runs with different trial weights in balancing planes

→ Calculation of influence coefficients → Influence coefficients

Once for each rotor type

Measurement run → Calculation of rotor unbalance and correction unbalances

Correction unbalances

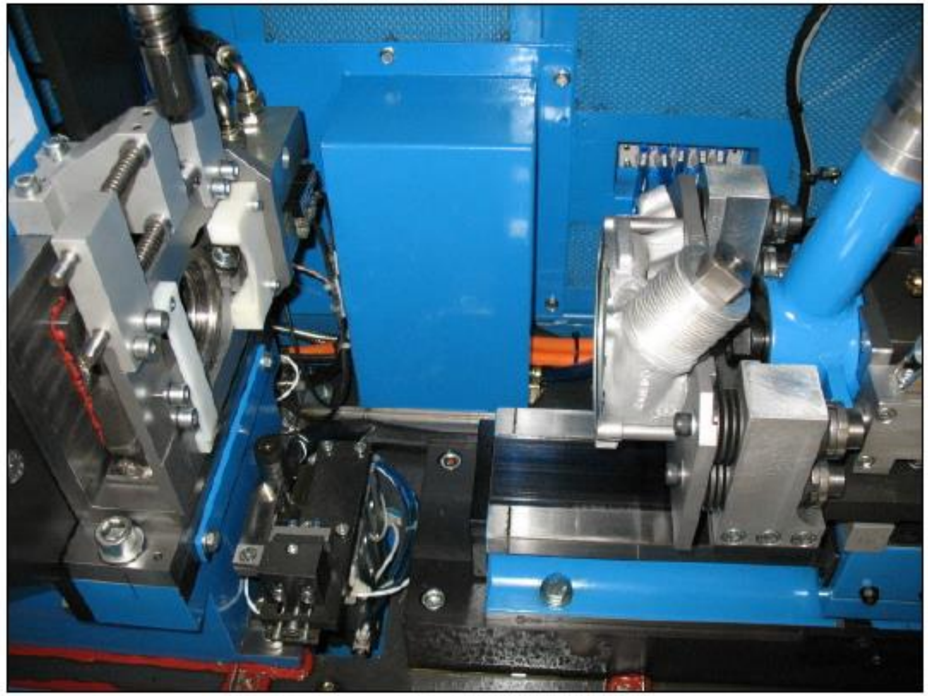
Lock Nut Plane

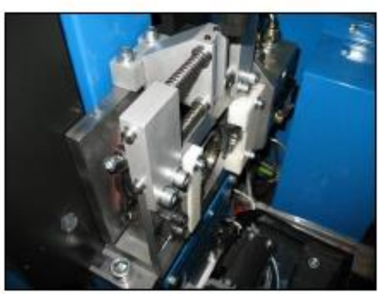
Sufficient balancing mass for a robust process

Compressor Wheel Plane

Target conflict between production requirements and stress reduction→ **Optimization needed**

IHI: Balancing Machine Overview





Mounting jig

TC clamped in jig

Acceleration sensor

Speed sensor

IHI: Balancing at Compressor Wheel Plane

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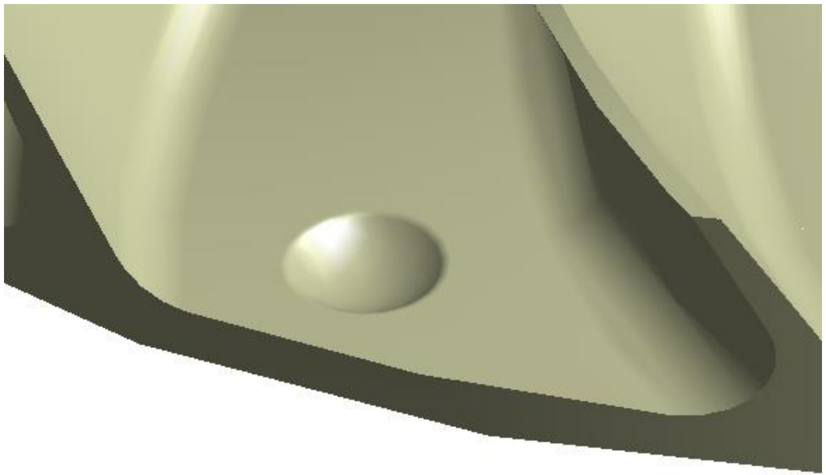
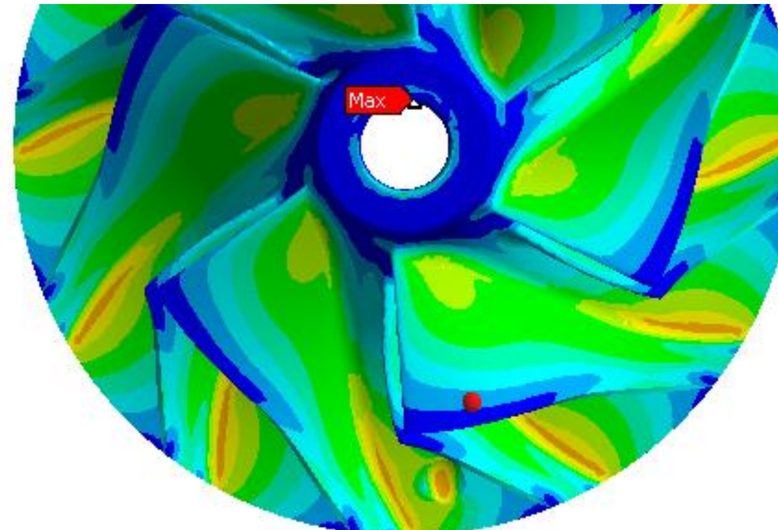
Balancing geometries

Stresses under centrifugal forces

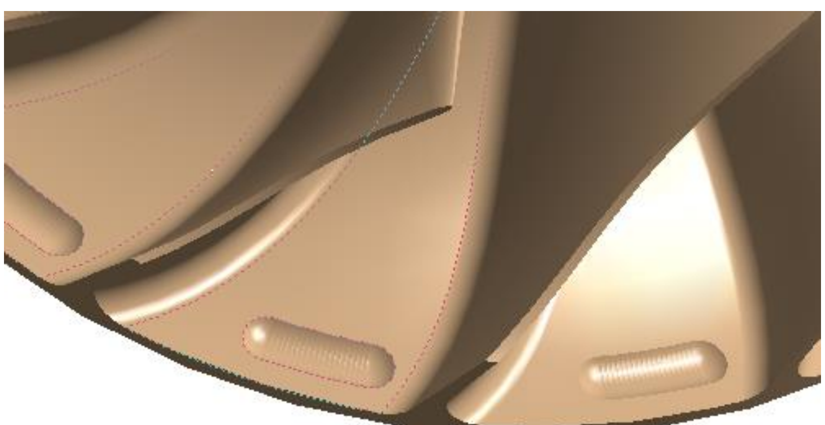
Point shape

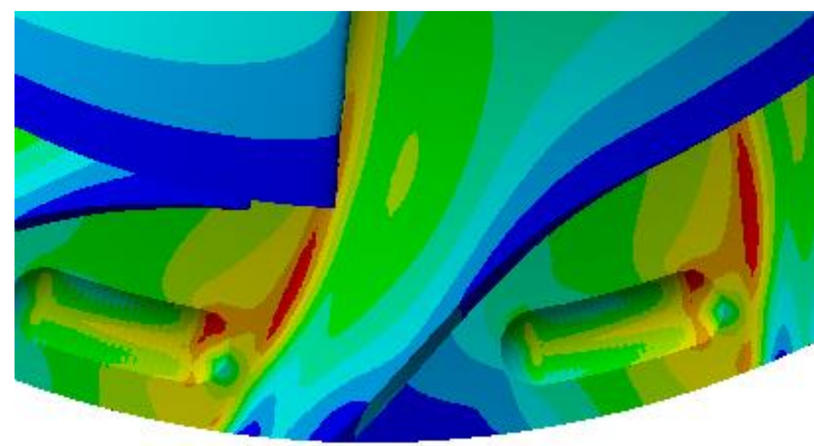




Thick Backdisc: Balancing removal mass: 25%

Banana shape





Thick Backdisc: Balancing removal mass: 100%

Thin Backdisc: Balancing removal mass: **15%**

New balancing mark design required!

IHI: HSB mark triangle shape

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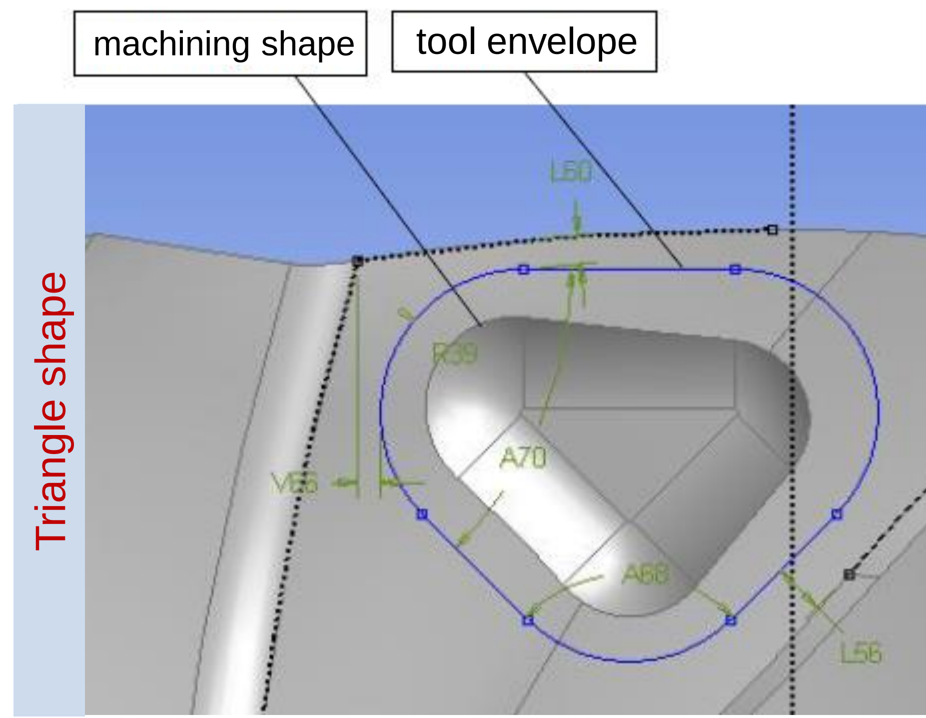
Shape optimization in 2017:

New compressor wheel geometry
- Optimized stresses
- Inertia reduction with thin backdisc → too small balancing mass removal capacity

New High Speed Balancing (HSB) mark required
- Development aim: maximizing balancing mark removal mass
- Side criteria: Stress criteria, production restrictions

Boundary conditions:

Minimum wall thickness	
Milling tool distance to blade	
Distance milling geometry to outer radius	
Milling tool diameter minimum	
Realization of geometry by HSB machine	Radially symmetrical
Stress borders	To be fulfilled



Realizable mass removal approx 62,5%
Low acoustic borders on HSB → higher HSB scrap rate
→ **increase of balancing mass** required from production

IHI: HSB mark triangle shape

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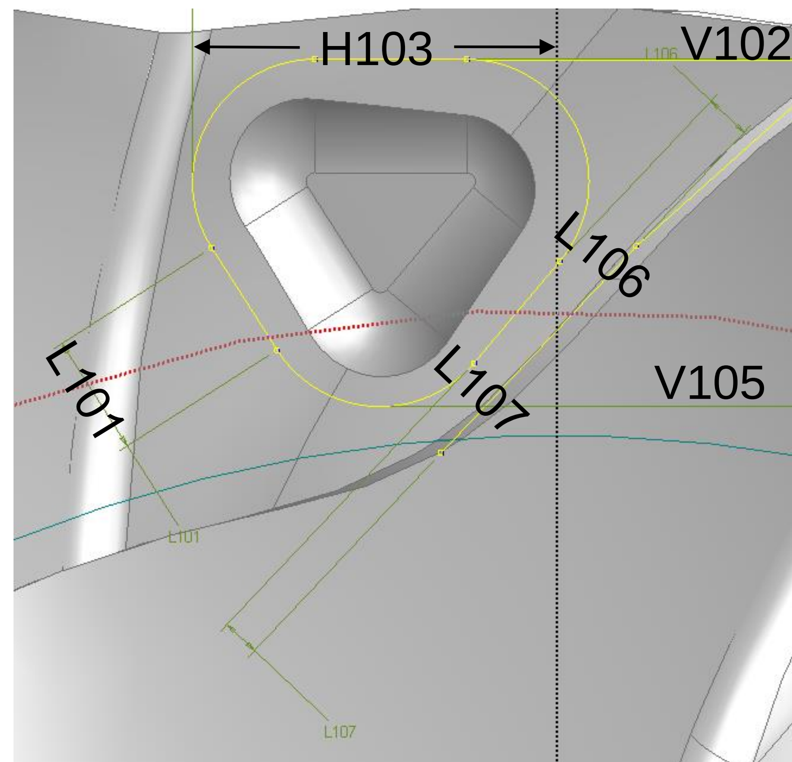
New optimization in 2019/2020:

Change of boundary conditions

- Stronger acoustic HSB borders require higher HSB mass removal to keep scrap rate low
- Radially symmetrical geometry no longer a requirement → more DOF for shape of balancing mark

New parametrization:

Parameter	restriction
Depth milling tool	maximum
H103 – upper width	maximum
L101 – left length	
L106 – upper distance tool to blade	minimum
L107 – lower distance tool to blade	minimum
V102 – max radius balancing mark	
V105 – min radius balancing mark	



IHI: HSB mark triangle shape – Workbench Model

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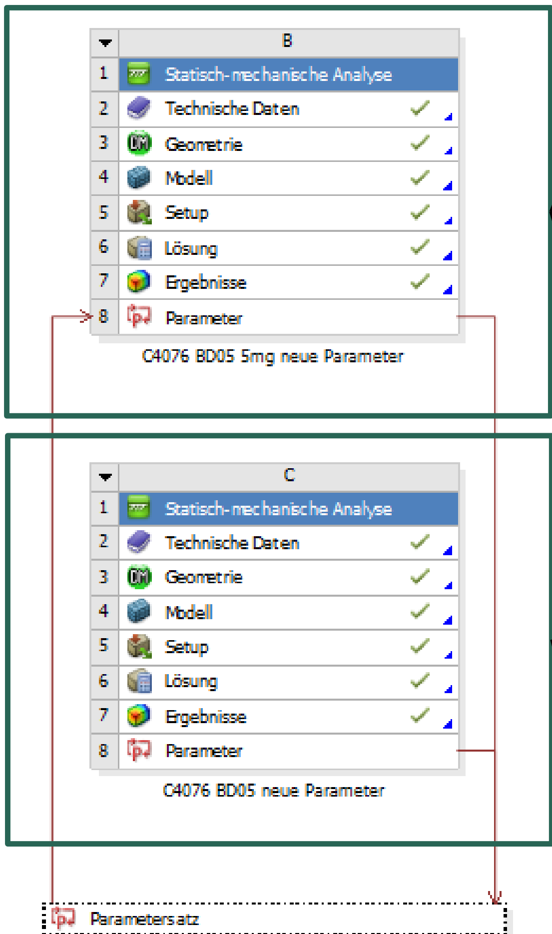
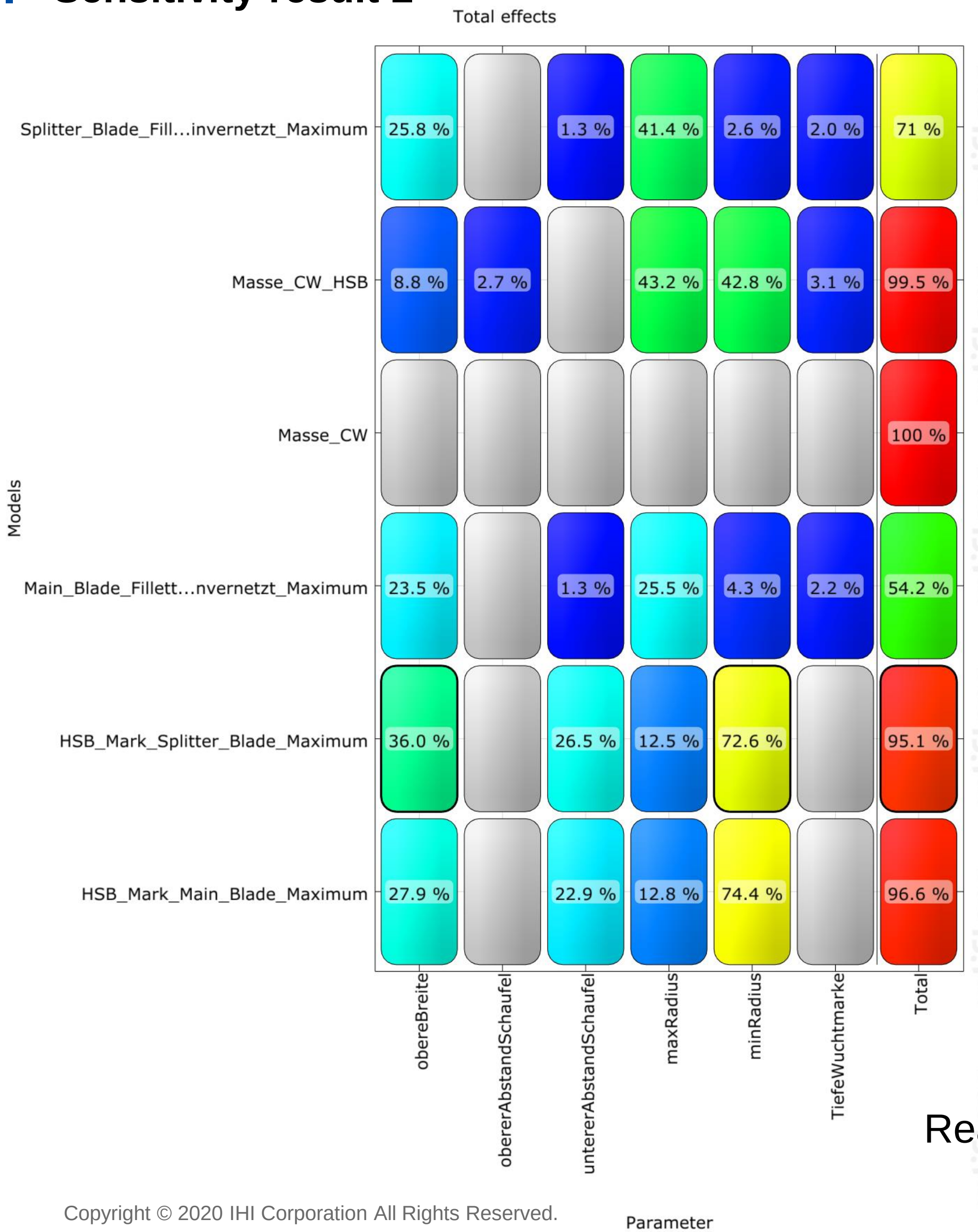
Workbench model:

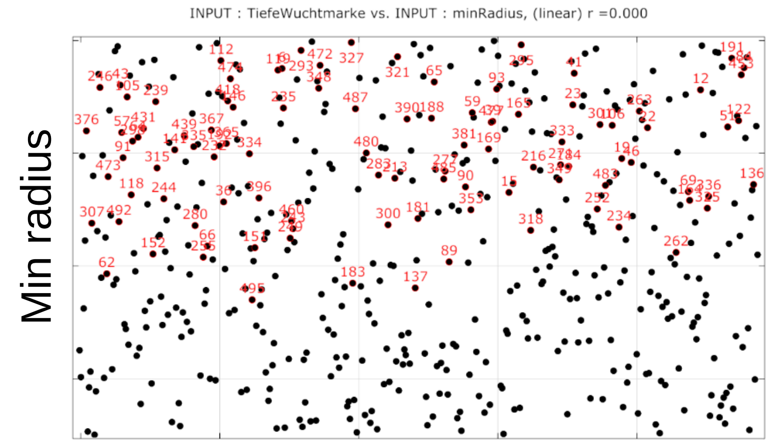


Eingabeparameter	Input parameter
P9	minDurchmesser
P10	maxDurchmesser
P11	obereBreite
P13	linkeLänge
P14	obererAbstandSchaufel
P15	untererAbstandSchaufel
P16	TiefeWuchtmarke
Neuer Eingabeparameter	Neuer Name
Ausgabeparameter	Output parameter
P4	
P17	HSB Mark 2 Maximum
P18	Fillet 1 Maximum
P19	Fillet 2 Maximum
P8 Reference mass	
Neuer Ausgabeparameter	
Diagramme	

IHI: HSB mark triangle shape – Sensitivity

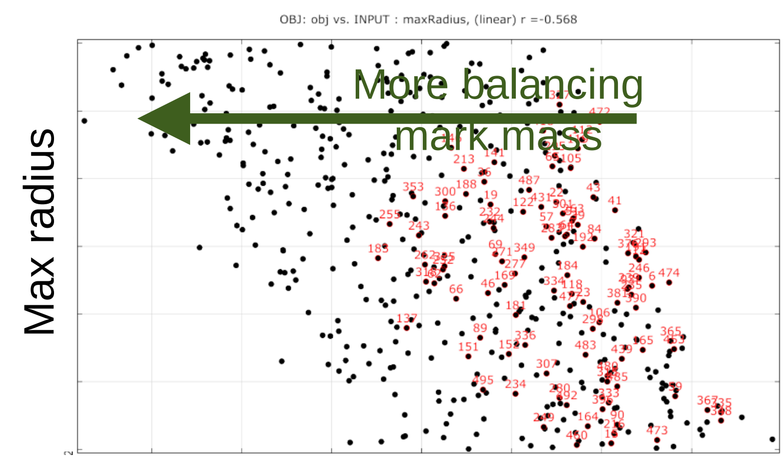
Sensitivity result 2





Depth balancing mark

Feasible designs



Obj: balancing mark mass

Realizable mass removal approx 105%.

IHI: HSB mark triangle shape – Optimization

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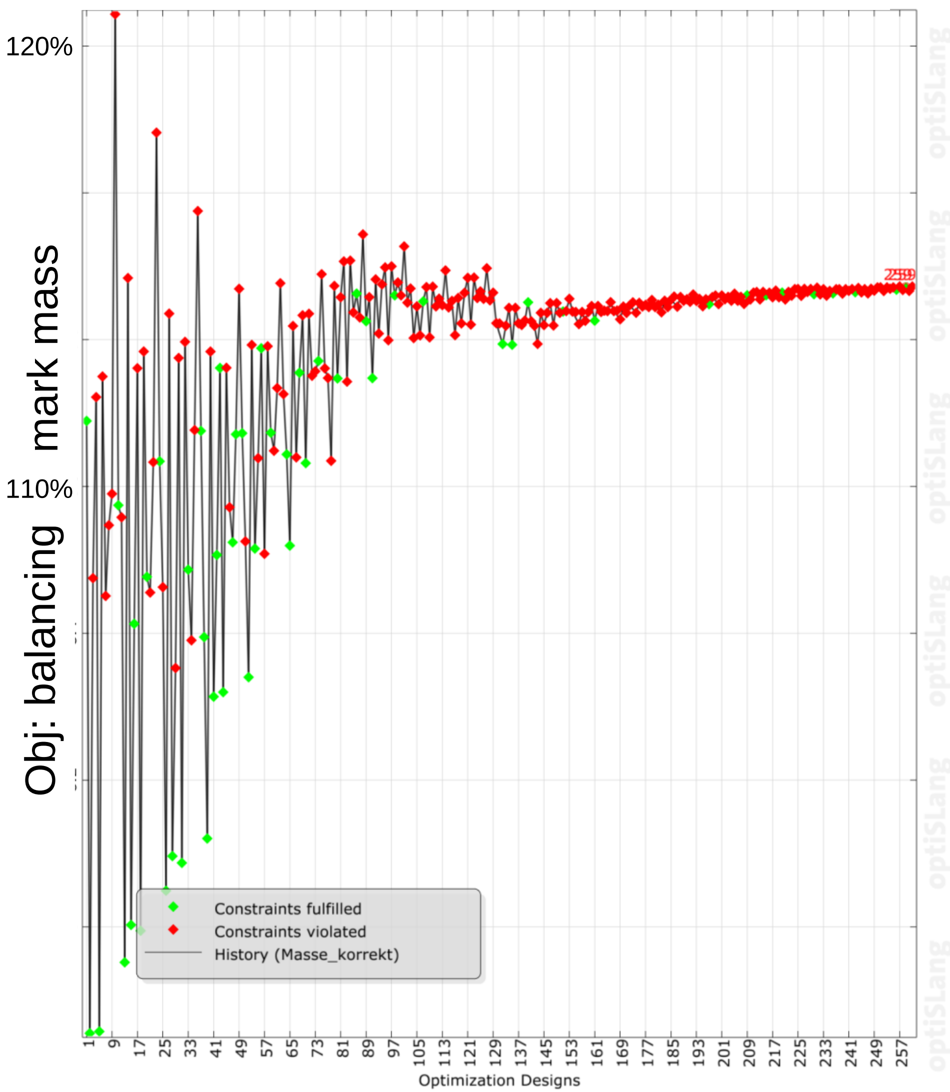
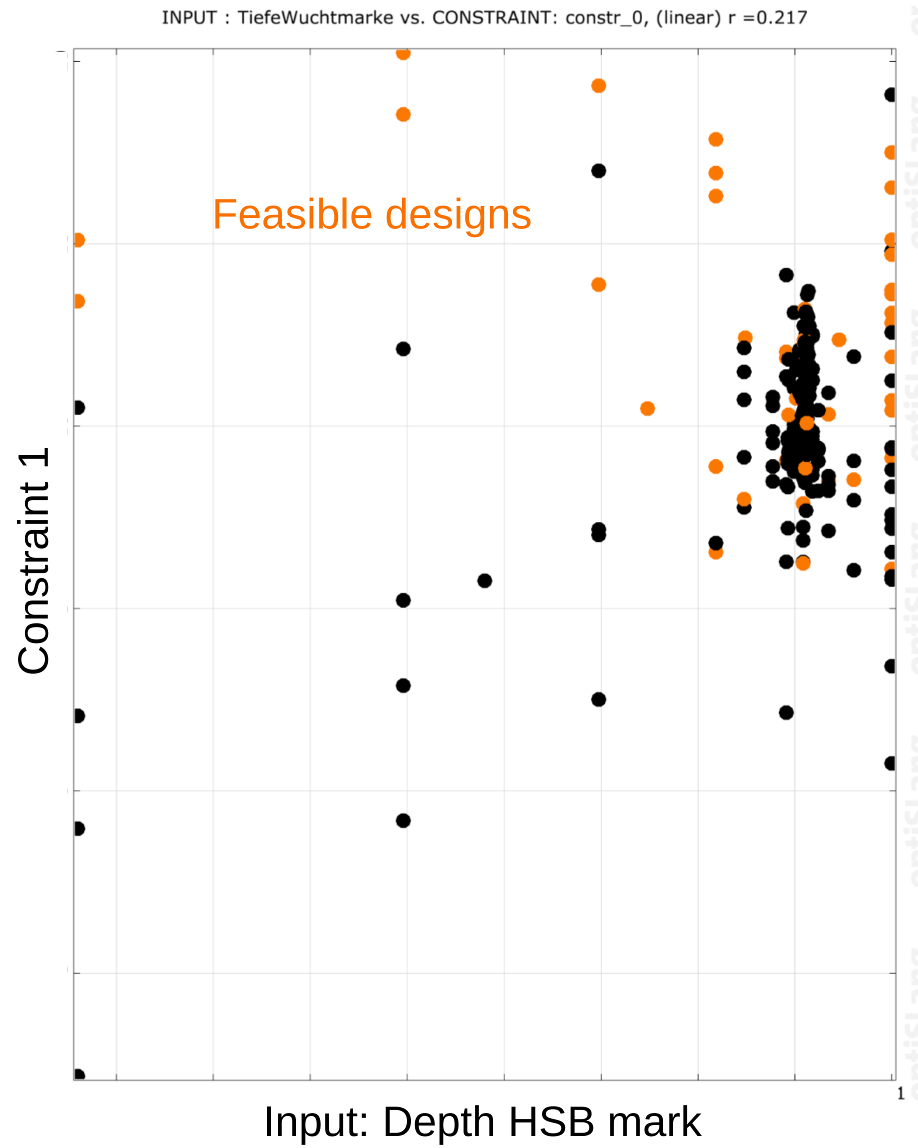
Direct optimization (ARSM):

Obj: balancing mark mass





Realizable mass removal approx 114%.

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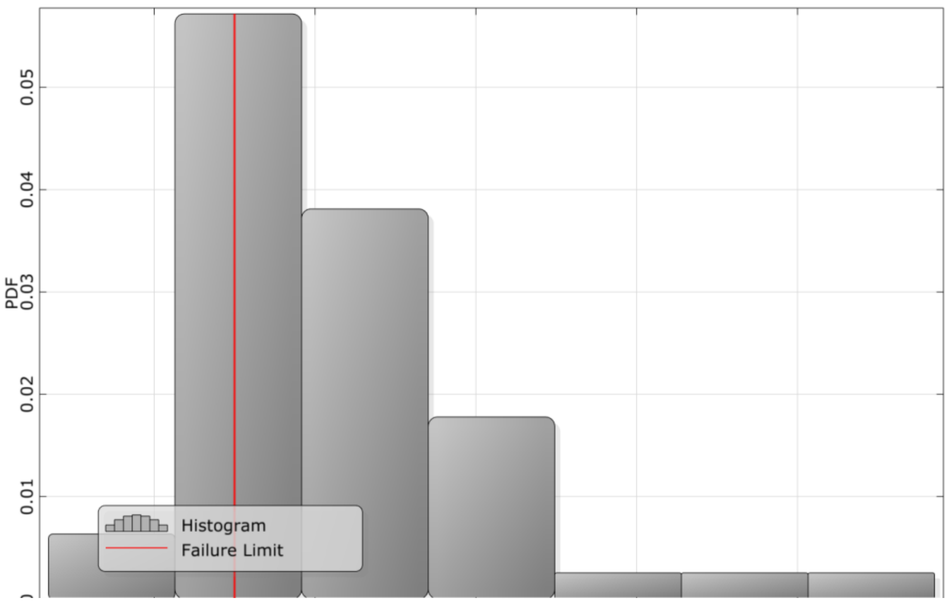
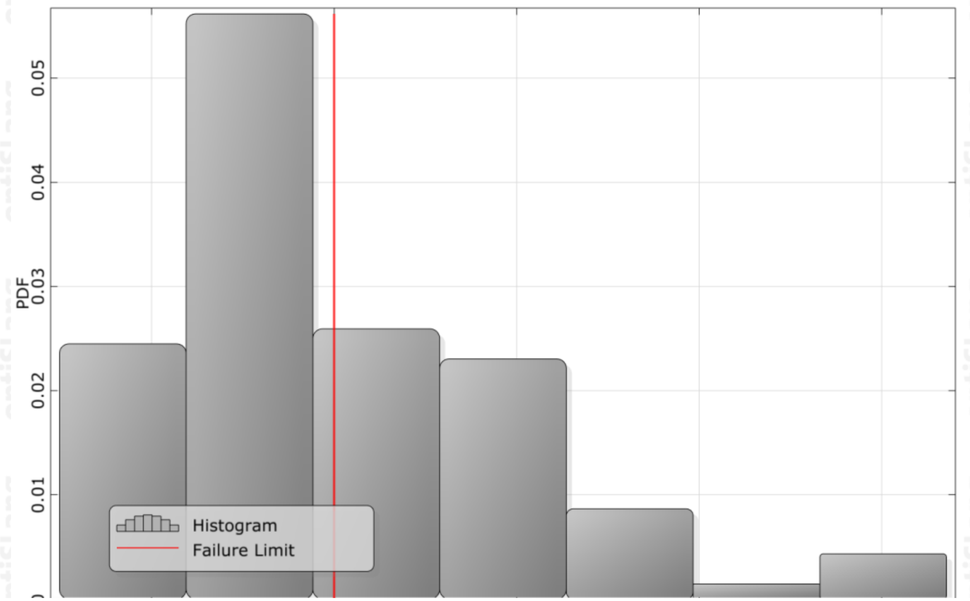
Robustness:

Stress HSB mark main blade



Stress HSB mark splitter blade



With normal distributed input values,
too many objectives above criterion.

Robustness shows increase in mass removal up to 120%, but with improvement potential for robustness.
→ Lower stress limits for optimization to find more robust optimized design.

IHI: HSB Balancing Mark Optimization - Conclusion

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Low balancing mass removal yields in higher balancing scrap rate
→ Increase in balancing mass removal required

Sensitivity, Optimization & Robustness study directly integrated in Workbench model

- Sensitivity shows increase in mass removal up to 105%
- Optimization shows increase in mass removal up to 114%
- Robustness shows increase in mass removal up to 120%, but with improvement potential – with loss of balancing mass removal

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Realize your dreams