SHEET METAL FORMING IN THE ERA OF INDUSTRY 4.0

USING DATA AND SIMULATIONS TO IMPROVE UNDERSTANDING, PREDICTABILITY AND PERFORMANCE

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AUTOMOTIVE MANUFACTURING

link

AUTOMOTIVE MANUFACTURING

Link

1927, Volvo PV 4

Link

2019, Volvo V60

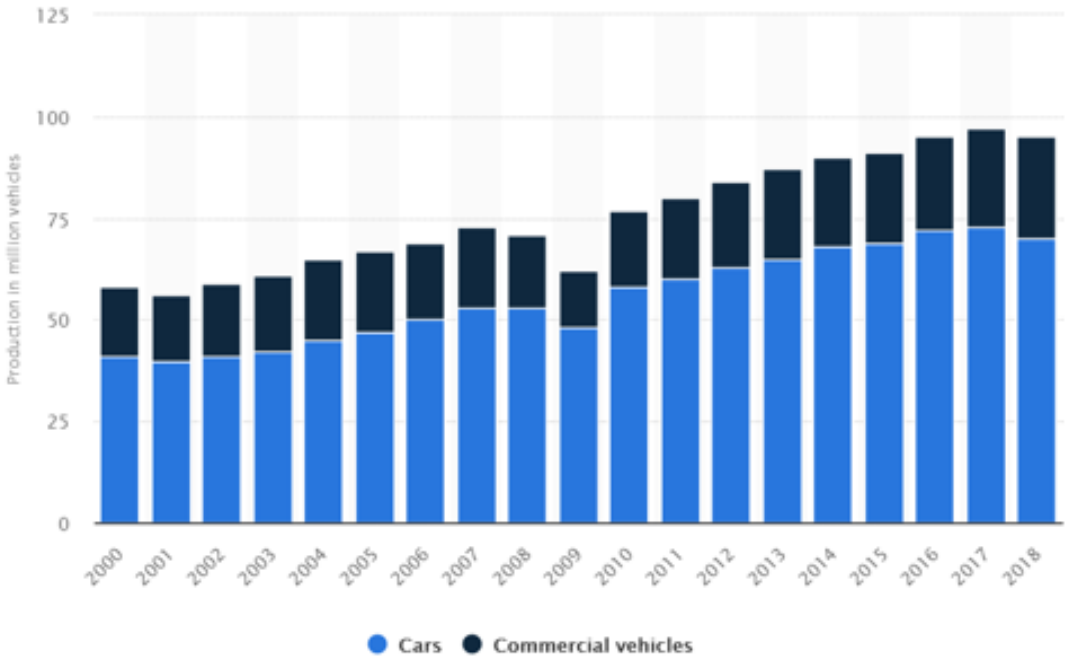
AUTOMOTIVE MANUFACTURING

Manufacturing goals vs Customers demands

link

AUTOMOTIVE MANUFACTURING

Worldwide automobile production 2000-2018 (in million vehicles)



Mini Coopers [Link]

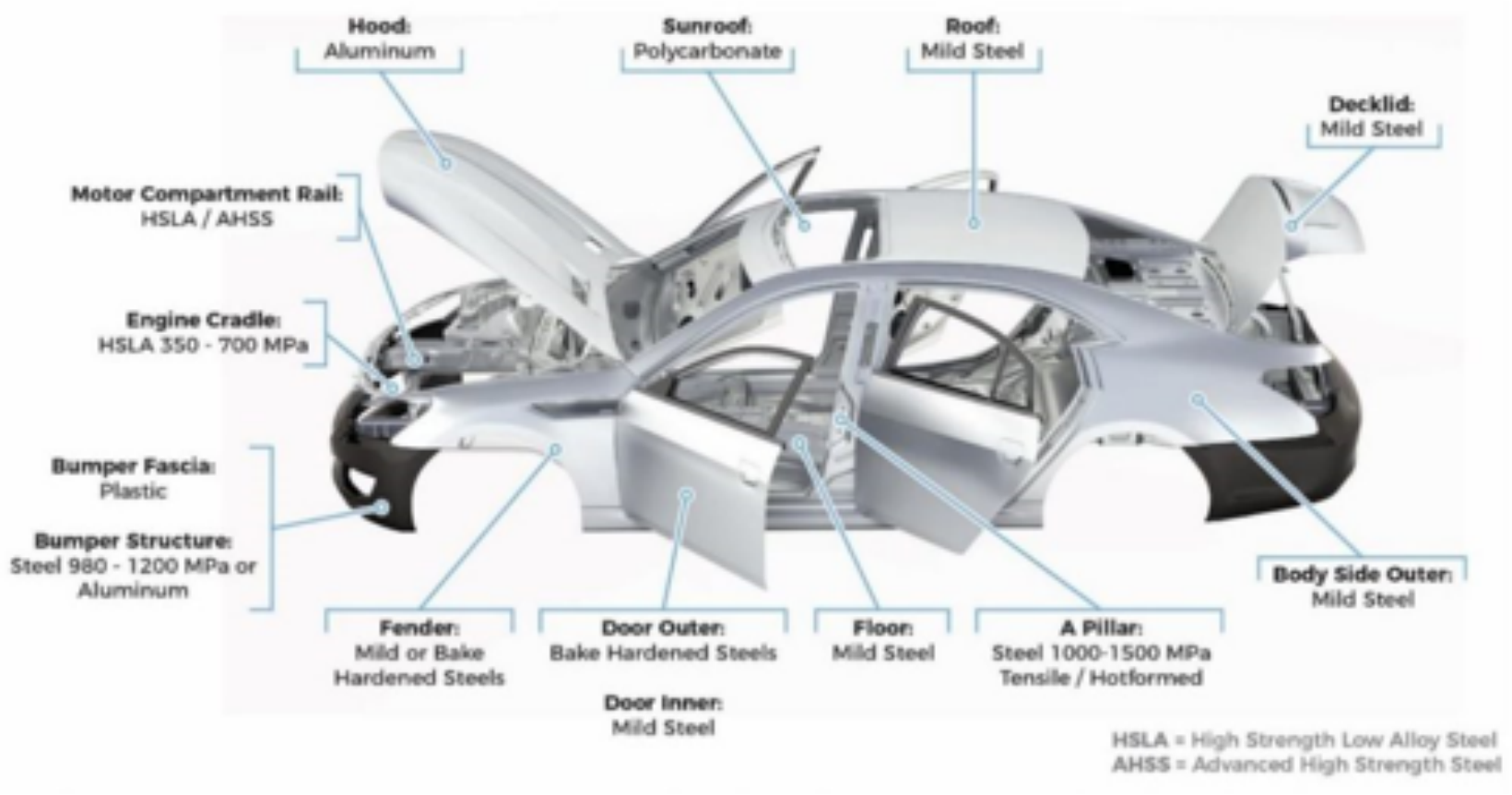
AUTOMOTIVE MANUFACTURING

Industries

- Rethink strategies
- New ways to improve process
- Zero-defect manufacturing, first-time right production-popularity
- Last decade-manufacturing process data collection
- Trend augmented further by Industry 4.0, 2011

PRESSURE
to
DO MORE
in
LESS TIME
at
LOWER COSTS

SHEET METAL FORMING (SMF)



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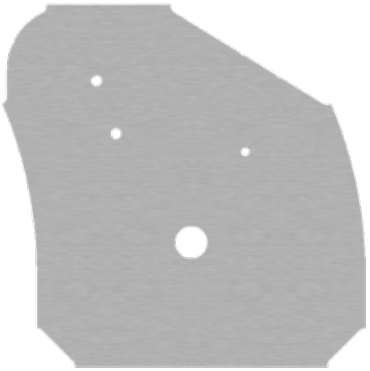
SHEET METAL FORMING (SMF)

Sheet metal coils

Blanking line



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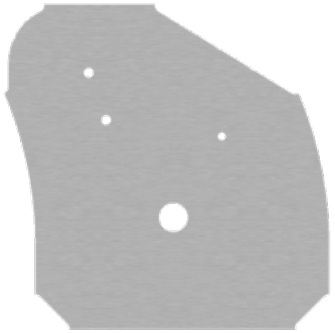
SHEET METAL FORMING (SMF)



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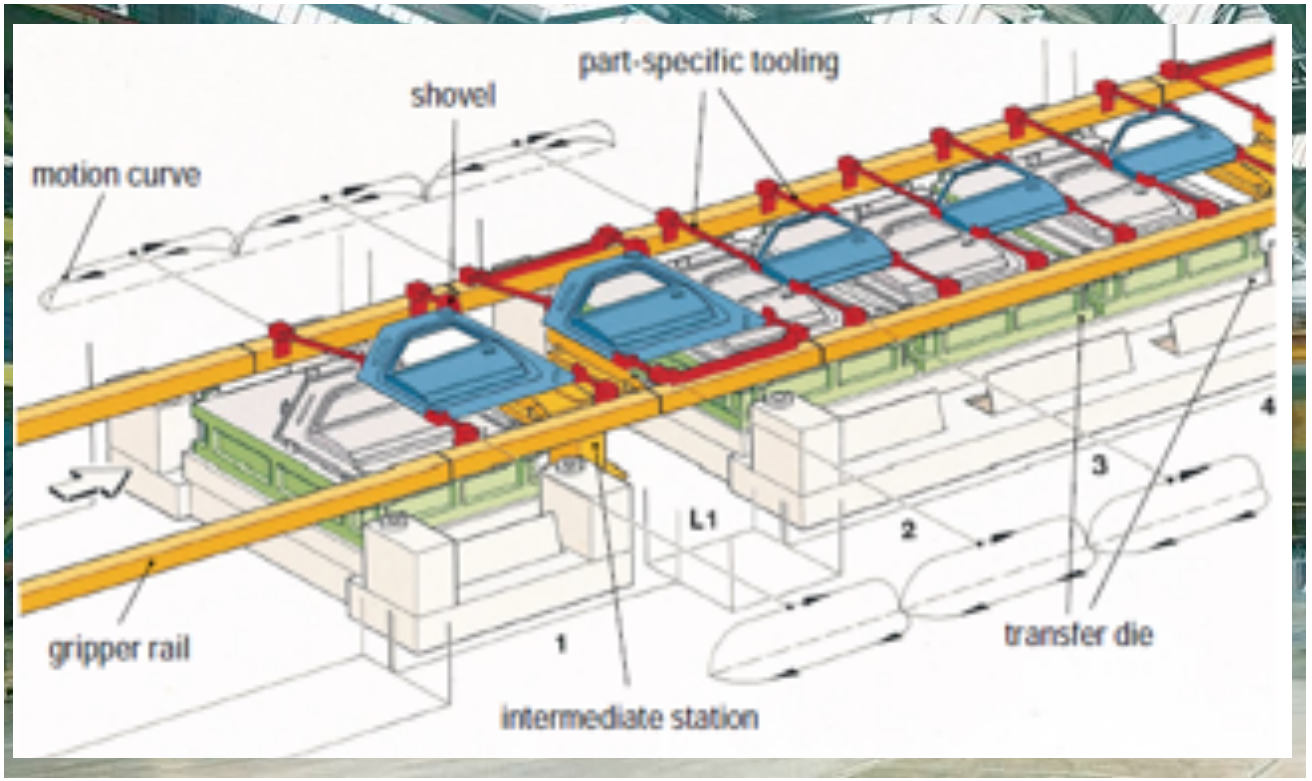
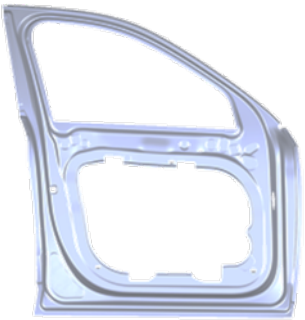


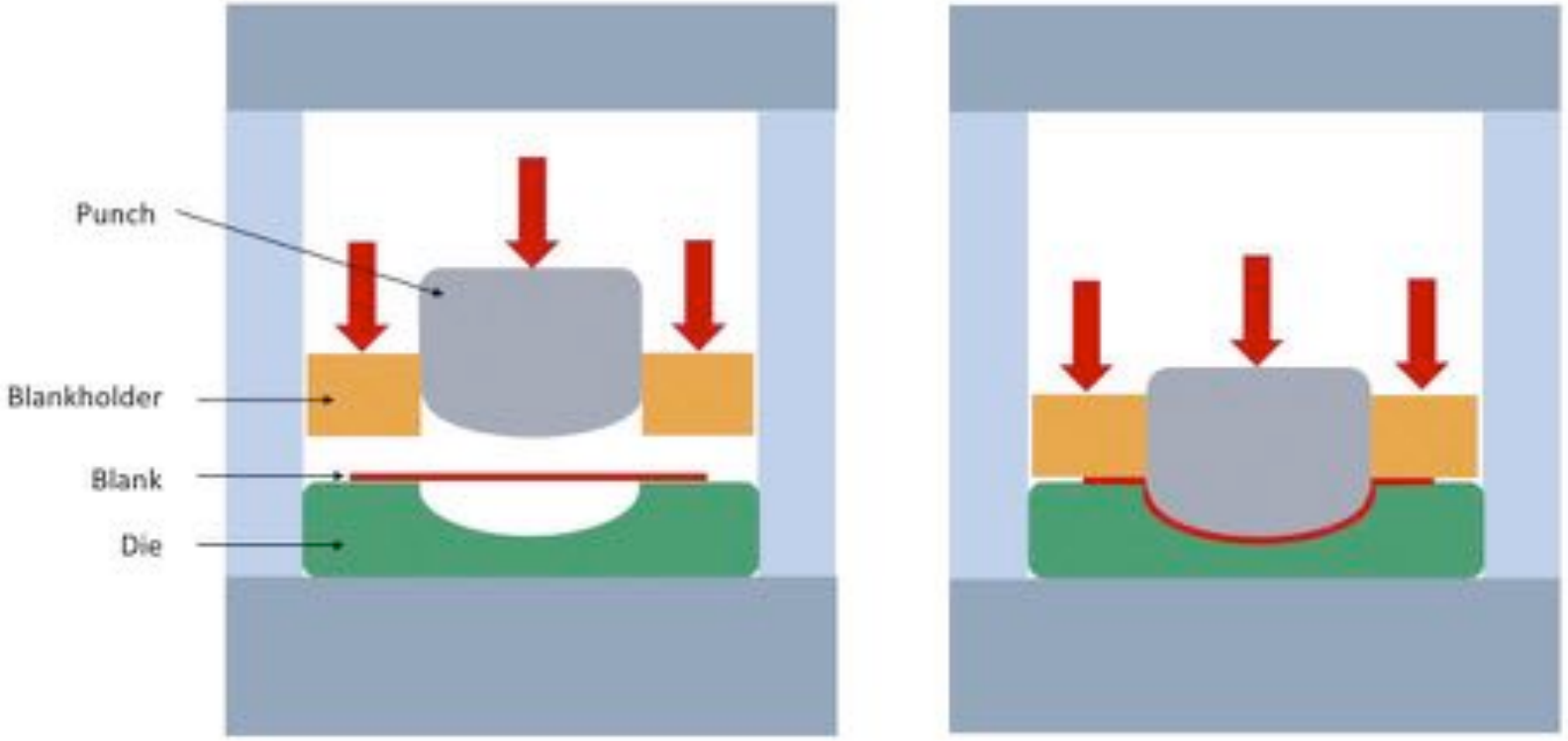
Press line



Final part

SHEET METAL FORMING (SMF)

SMF: transforms a piece of sheet metal into desired shape



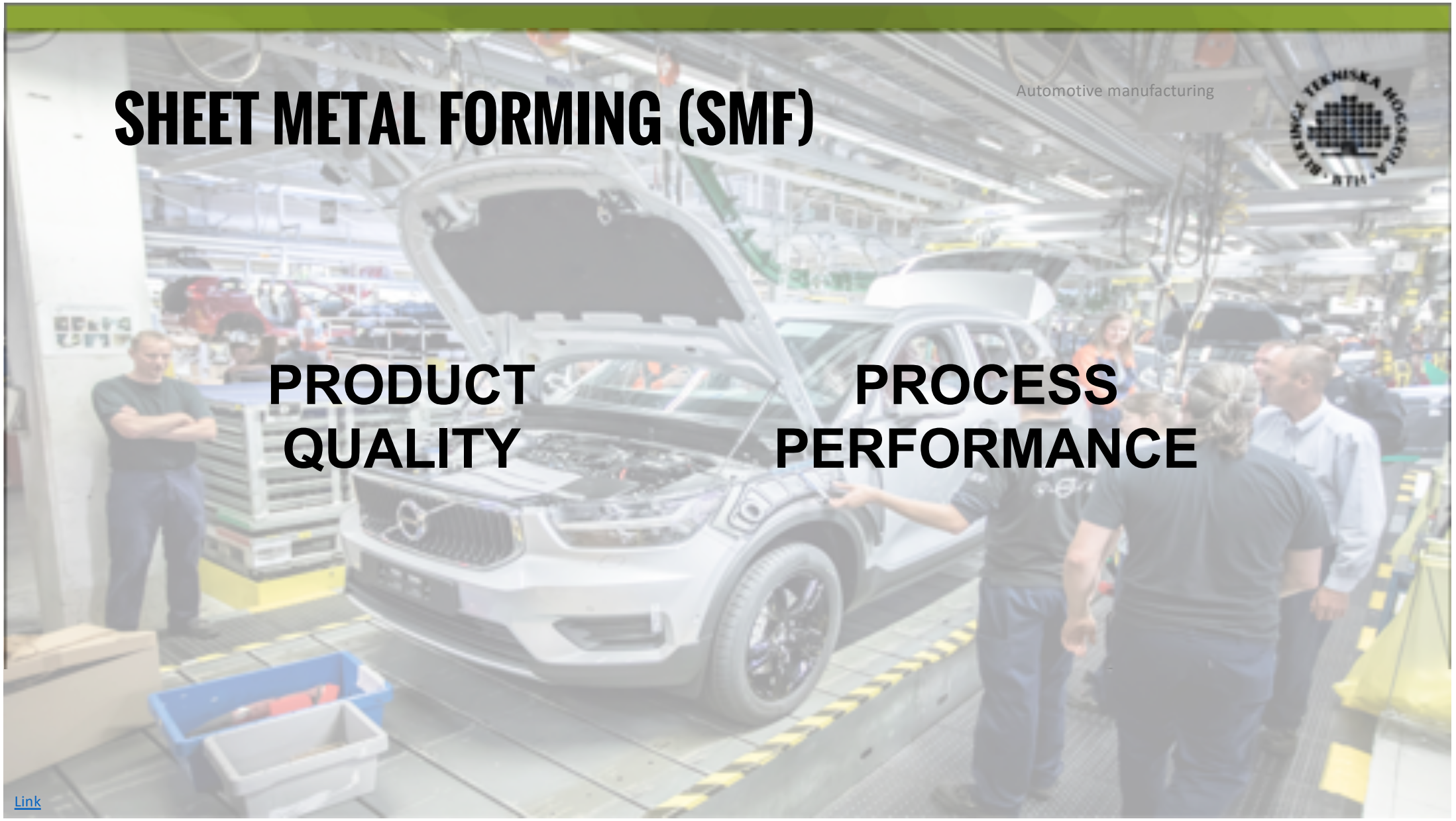
SMF IN ACTION

Major Forming Step

SHEET METAL FORMING (SMF)

SHEET METAL FORMING (SMF)

Automotive manufacturing



PRODUCT QUALITY

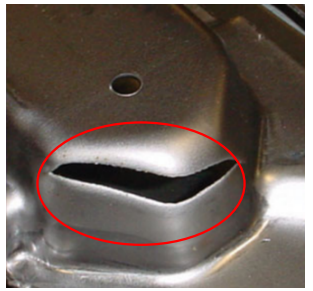
PROCESS PERFORMANCE

Link

SHEET METAL FORMING (SMF)

- Challenging:
  - Varying production conditions.
  - Complex physical phenomena.
  - Multiple variables.
- Issues: springback, wrinkles, fractures.

Springback (Link)



Tearing (Link)

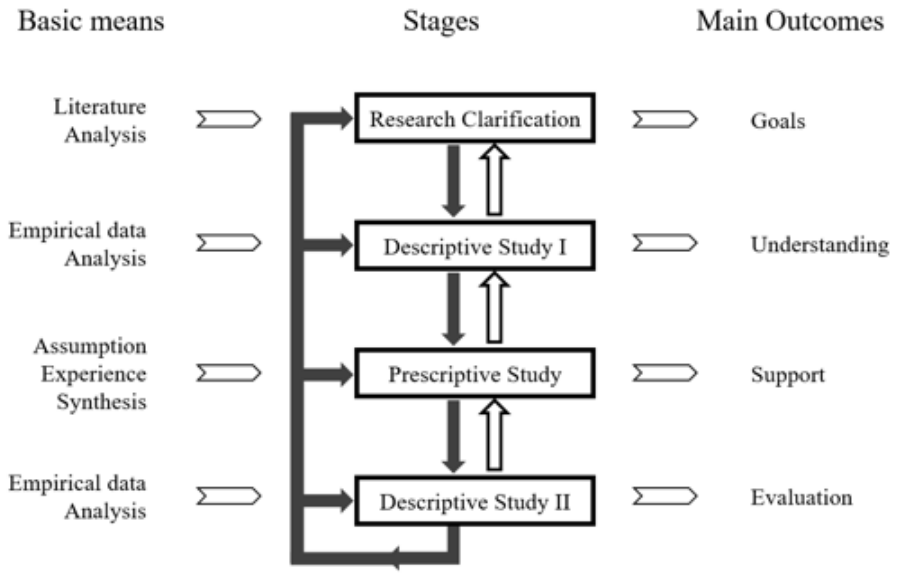
Wrinkles (Link)

AIM & RQ

- Challenges and opportunities within SMF.
- In-line measured data and simulations can improve SMF understanding, predictability, performance.

How can in-line measured data combined with process simulations aid understanding of sheet metal forming process?

RESEARCH METHODLOGY



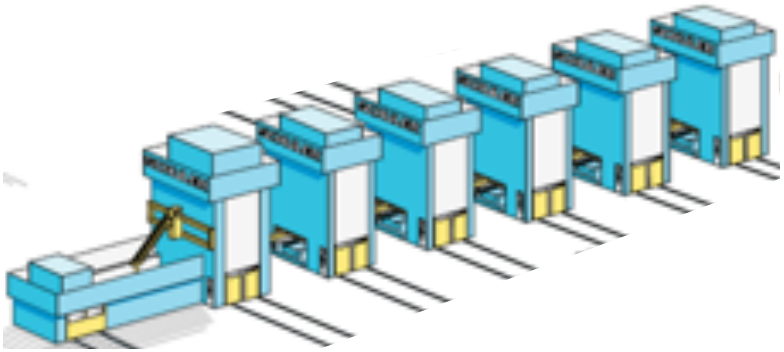
DRM basic framework (adapted from Blessing and Chakrabarty, 2009

Why DRM?

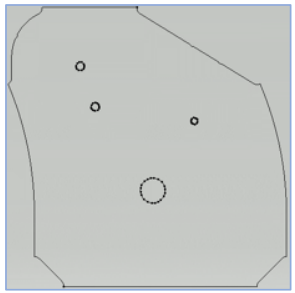
- Supports both *understanding* and *improvement*
- Provides tools: as-is / to-be situations.

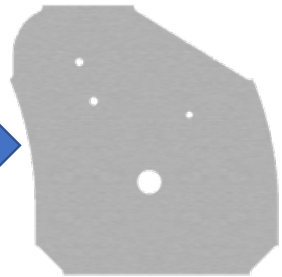
RESEARCH CASE

Volvo XC 90 Press-line

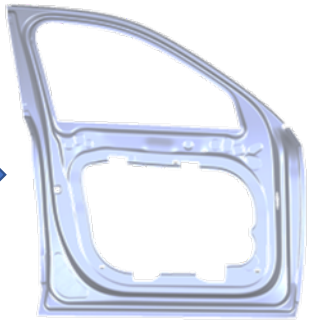


Volvo XC 90 front door-inner

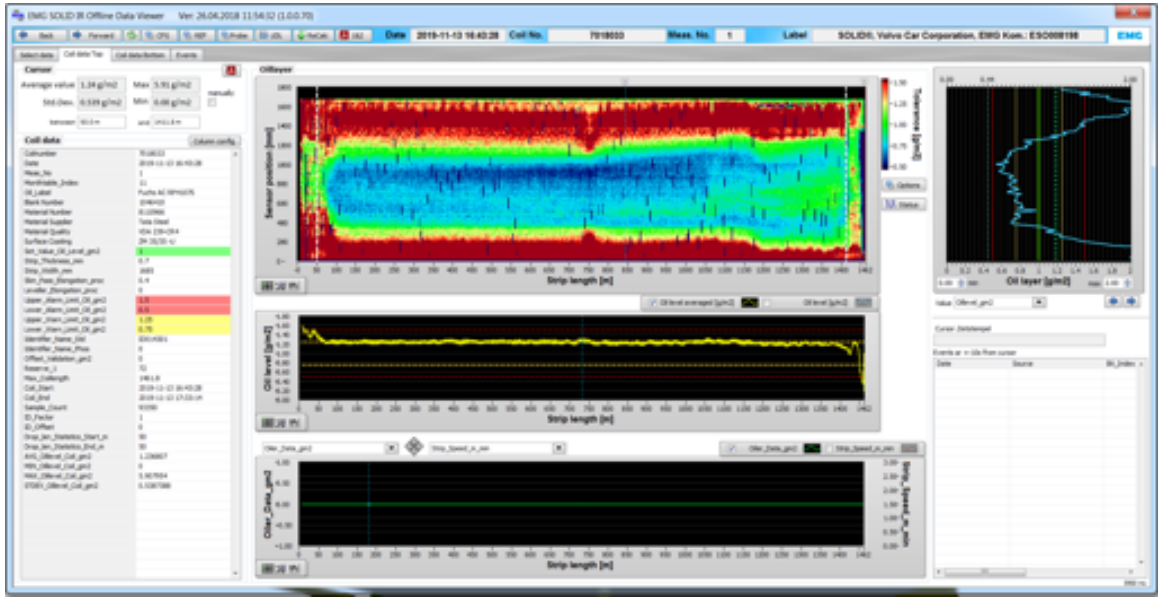




Major forming step



INSPECTION



Lubrication

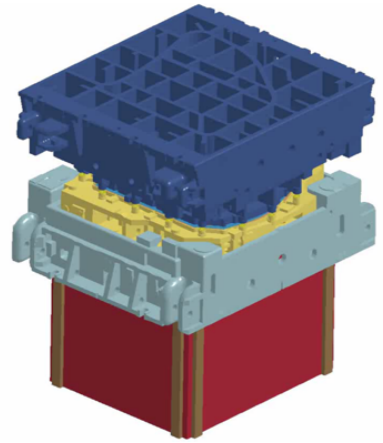
Amount, Type, Distribution

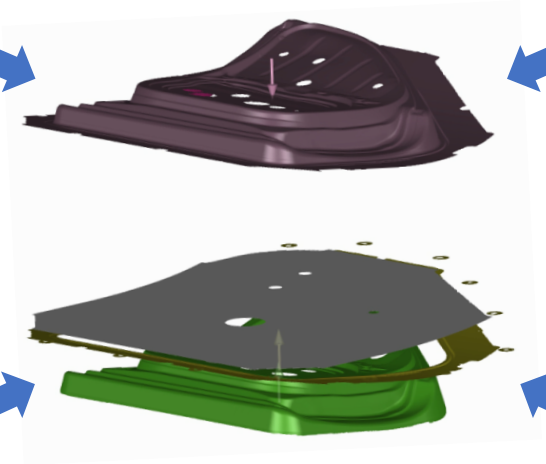
- Issues: wrinkles, fracture, springback.
- Cause: varying tribology, input (material properties, thickness, temperature, stroke rates, tool deformations…..
- Dealt by experts: tool force, temperature drop, alter surface, replace tool.
- Costly, halt production, no guarantee, generate new errors
- Equipment to measure tribology conditions.
- Unsure of effect.
- Major challenge: right combination of process settings.
- Lack of knowledge of interdependencies and influences of parameters.
- Simulation-based investigation- understand further.

link

SIMULATION MODEL

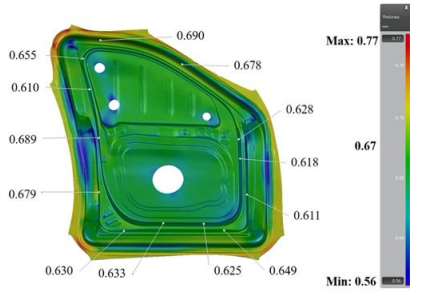
Elastic press and die deformations



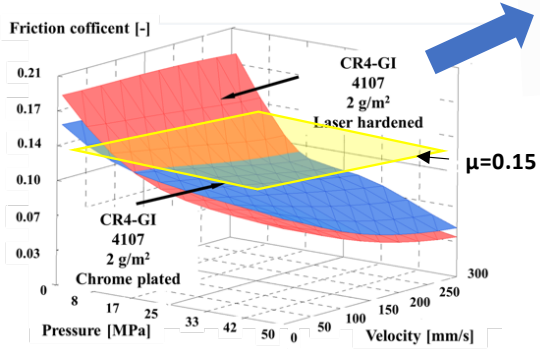


Material model

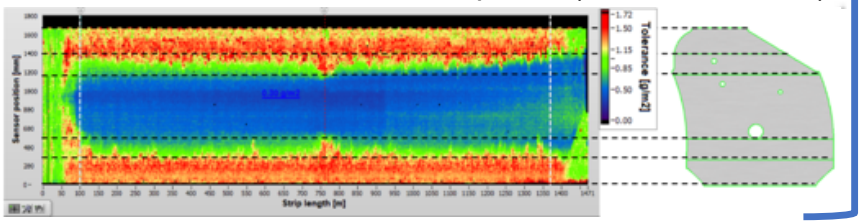
Validation

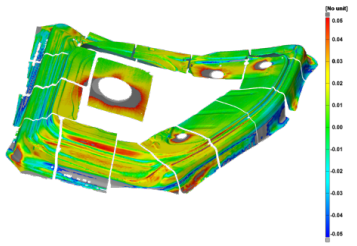


Dynamic friction model

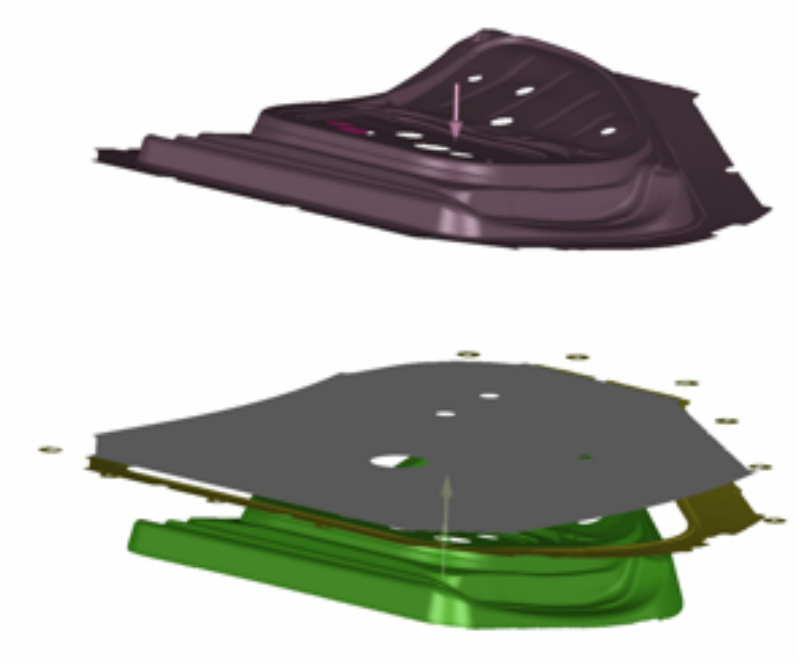


Lubrication profile (measured in-line)

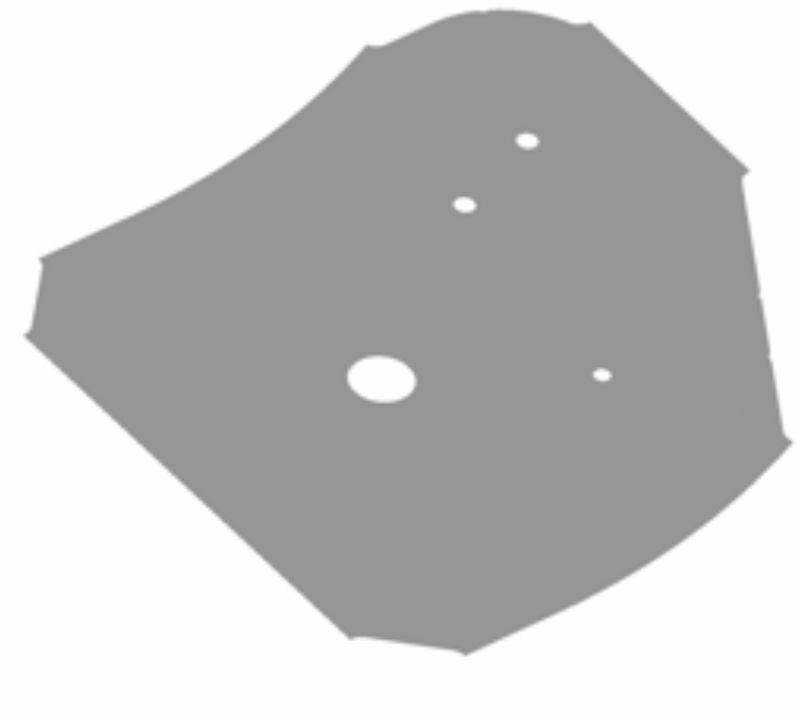




SIMULATION ANIMATION



Played in real-time (same rate as in production)



Played in slow-motion (to visualize forming operation)

SIMULATION BASED INVESTIGATION

- Systematic investigation- AutoForm Sigma
- Design variables
  - Lubrication amount
  - Material properties ($R, R_m, R_{p0.2}$)
  - Blankholder force
- Design of Experiment (DOE): Latin hypercube

Configuration 1

material property variation ($R, R_m, R_{p0.2}$)

Configuration 2

lubrication amount variation

Design variables / Configurations	Material coating	Material Scatter	No. of sections	Blankholder Force (Tonne)		Lubricant (g/m^2)	
				Nominal	Range	Nominal	Range
Config 1	GI	Yes	1	150	130-300	2.0	1.0-3.0
Config 2	GI	No	5	150	130-300	1.0 1.5 2.0	1.0-2.0 1.5-2.5 2.0-3.0

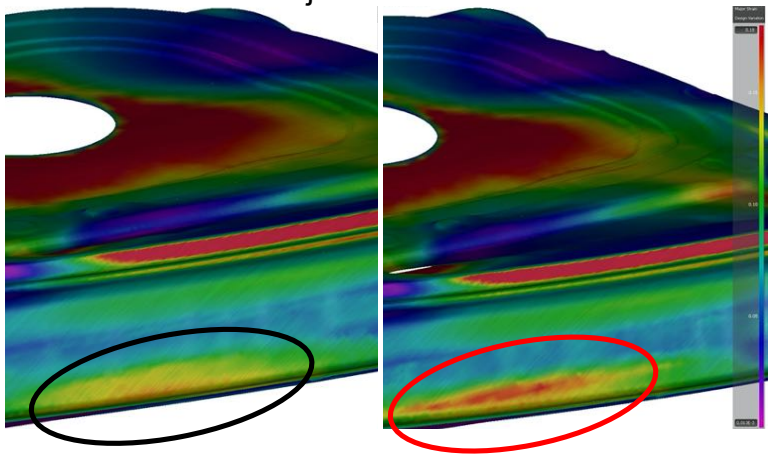
- Discretization based on Latin-Hypercube approach
- Triangular elastic-plastic shell elements
- Initial mesh size-20 mm
- 5-integration points over sheet thickness.

SIMULATION BASED INVESTIGATION RESULTS

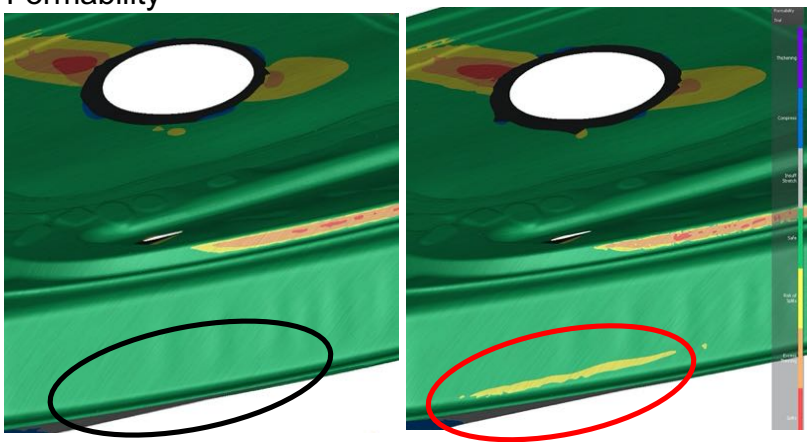
- Modelled lubrication profile influenced predicted quality.
- Model accuracy.
- Allowed exploration.

Potential: improve understanding parameter correlations and effect on predicted part quality.

Variation of blank major strain

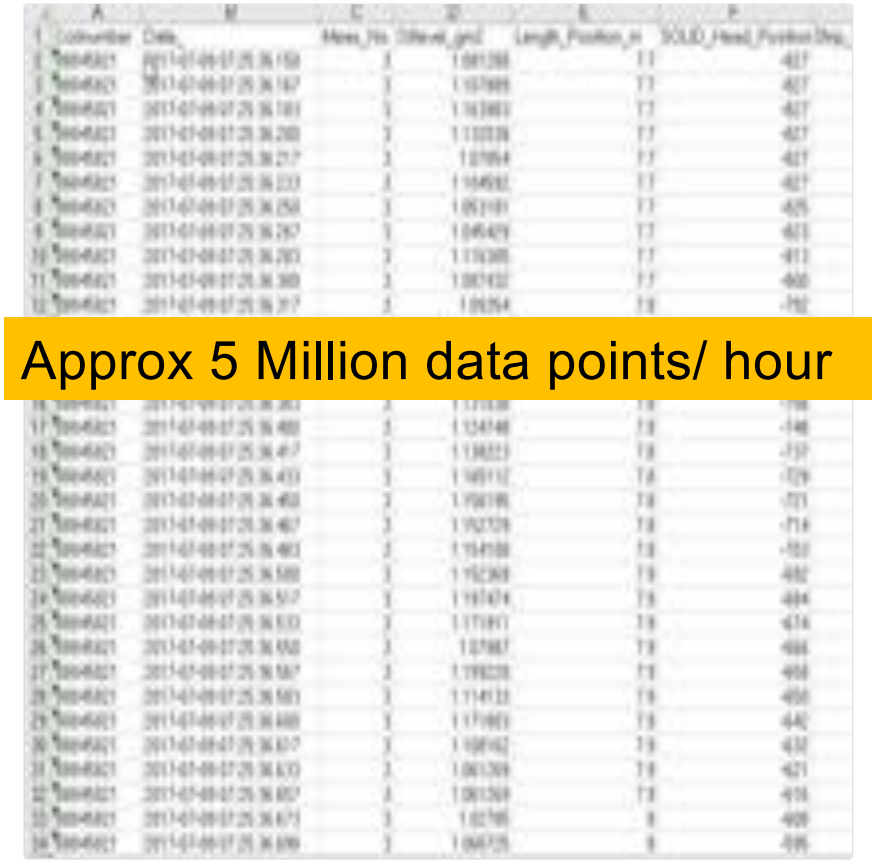


Formability



INCORPORATING DATA WITHIN SIMULATION

- Challenging & tedious.
- Data processing and configuration tasks required
- Limited features within CAE softwares
- Further study: to address this issue

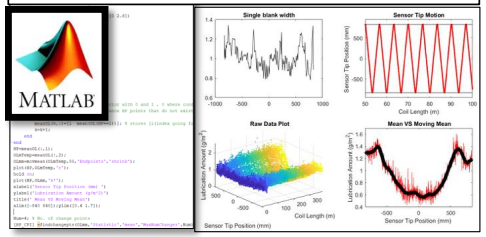


Approx 5 Million data points/ hour

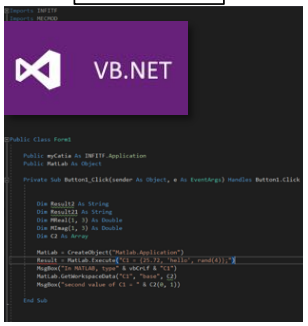
AUTOMATED STRATEGY

Client 1

Data Processing Module



Server

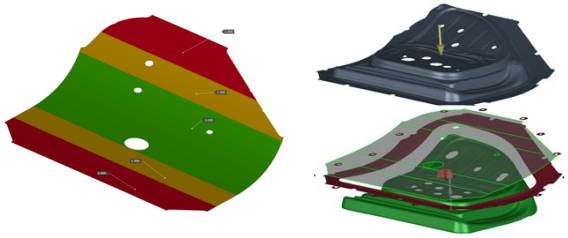


Client 2

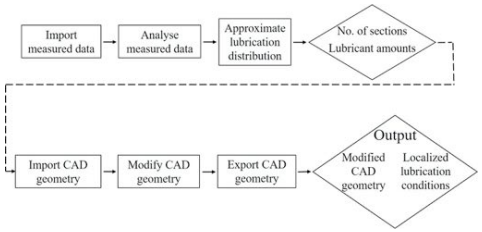
Data Configuration

SMF Simulation Software

AUTOFORM
Forming Reality



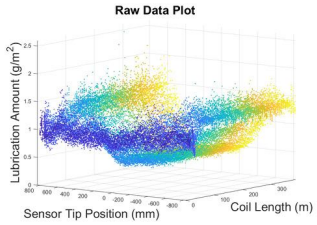
AUTOMATED STRATEGY

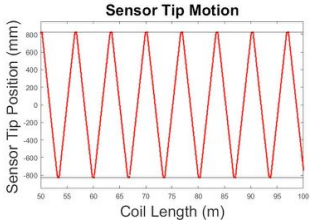


- Import Data
- Sorting/Analysis
- Approximate values
- Remove Outliers
- Determine sections
- Lubricant amounts
- Modify CAD geometry
- Assign lubricant values

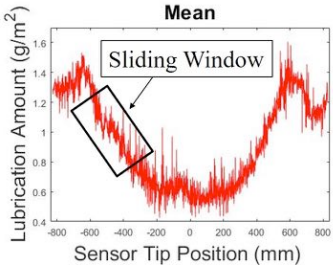
Data Processing

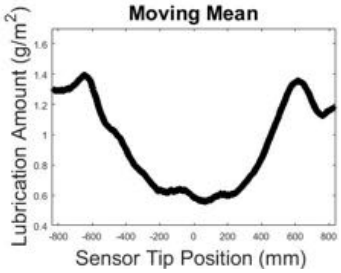
Import, plot data, analyze trends





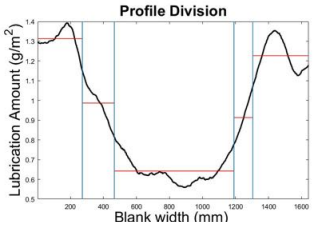
Sort data, approximate, remove outliers



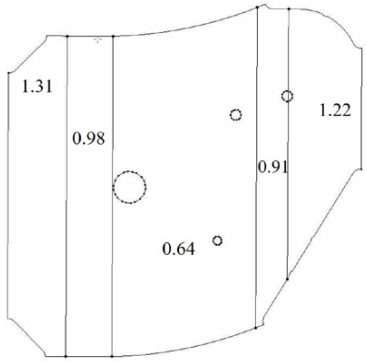


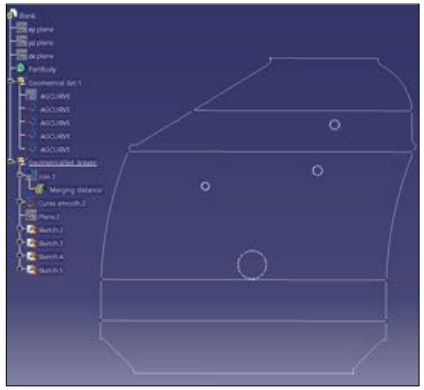
Find abrupt changes, plot graph, output locations

	Oil_Level	Width
Section 1	1.3126	271
Section 2	0.98597	194
Section 3	0.64252	725
Section 4	0.9146	114
Section 5	1.2269	338

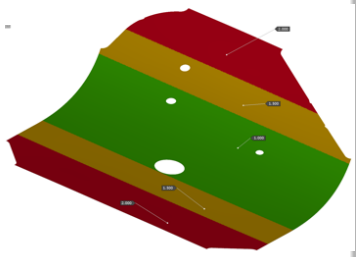


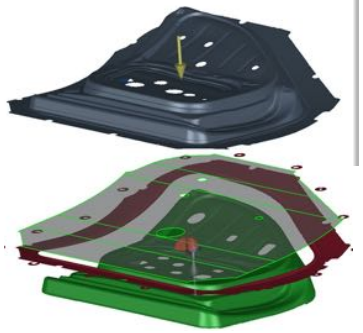
Data Configuration





Data Incorporation



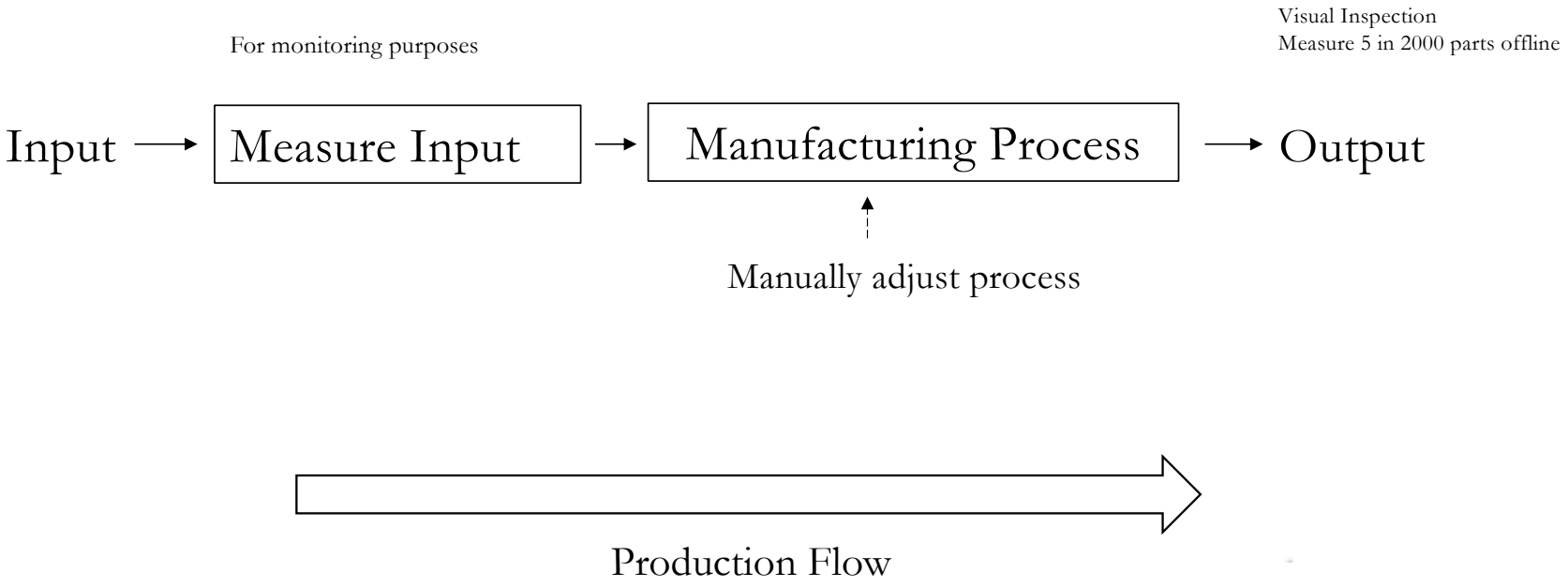


AUTOMATED STRATEGY RESULTS

- Automation: reduced overall modelling effort.
- Necessary for large datasets

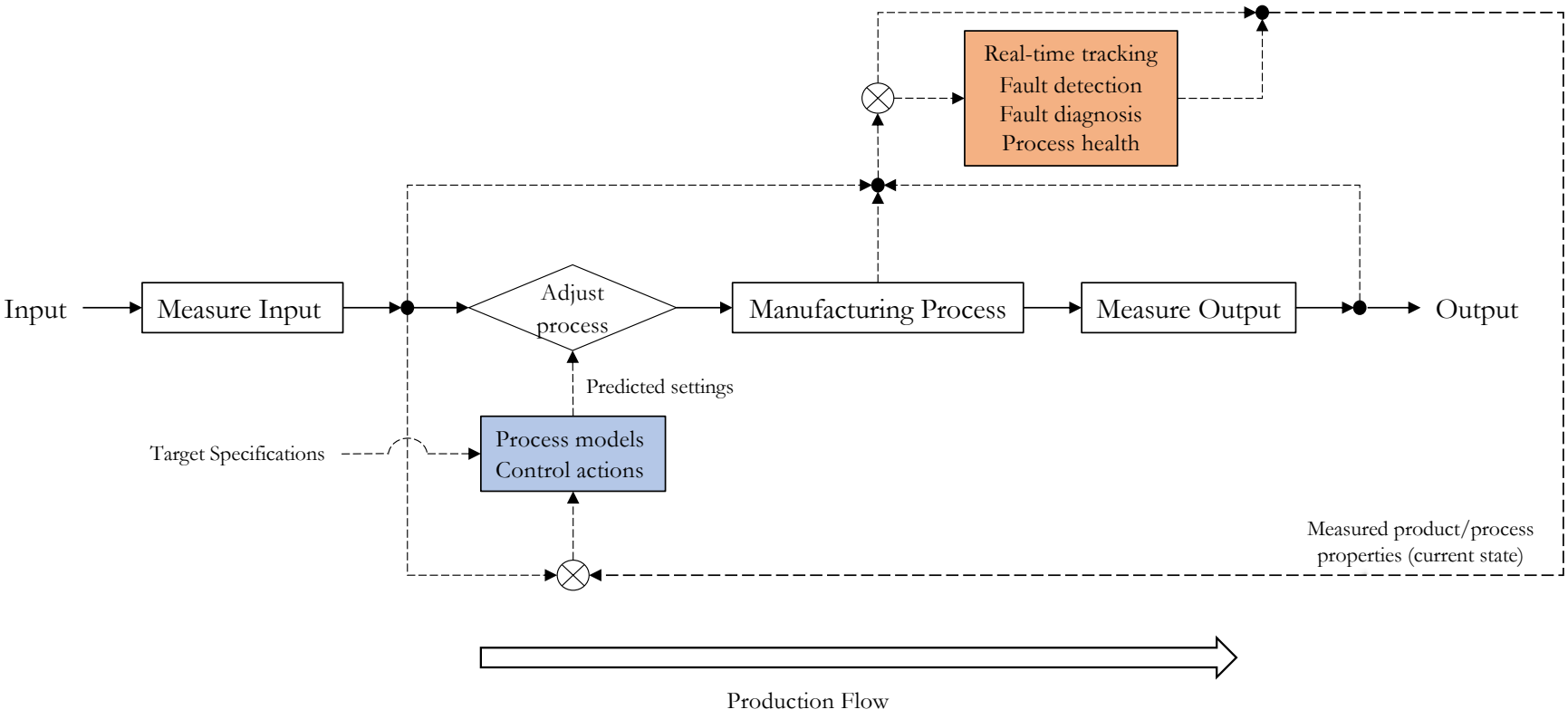
Potential to improve understanding and predictability of SMF. However, applicability of results-additional challenges-further study.

CURRENT PROCEDURE



HYBRID APPROACH

Proposed framework implements a hybrid data-and-model-based approach



CONCLUSIONS

- Phenomenological to structured investigation.
- In-line measured data and simulations- potential improve SMF understanding, predictability.
- Facilitated by accurate simulation models, systematic investigations and an automated strategy.
- To use improved undersstaning-framework-hybrid approach-disturbances in reality, process behaviour knowledge.

FUTURE WORKS

- Further validation, implementation, test of framework.
- Results applicability to other part's production.
- Results applicability to SMF in other domains.
- Highly interesting: Design products for smart manufacturing.

Data will talk to you if you're willing to listen.

- Jim Bergeson

Acknowledgements: Supervisors, Dr. Mats Sigvant, Knowledge Foundation, Tillväxtverket and ERUF, Company Partners

THANK YOU