Evaluation of tribosystems for sheet metal forming

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Publication date:
2019

Document Version
Peer reviewed version

Citation (APA):
Moghadam, M., Üstünyagiz, E., & Nielsen, C. V. (2019). *Evaluation of tribosystems for sheet metal forming*. Abstract from Techtank Conference, Olofström, Sweden.

Evaluation of tribosystems for sheet metal forming

Marcel Moghadam, Esmeray Üstünyagiz, Chris Valentin Nielsen (cvni@mek.dtu.dk)

Department of Mechanical Engineering, Technical University of Denmark

Summary:

Focus on phasing out environmentally hazardous lubricants has led to extensive experimental testing of tribosystems. Multi-stroke testing is used to evaluate resistance towards lubricant film breakdown. The presentation includes industrial examples of evaluation for deep drawing and ironing based on the simulative tests: bending under tension, strip reduction and drawbead testing. Production conditions are determined by physical measurements and numerical simulations and replicated in laboratory testing. Lubricant film breakdown is evaluated based on measured forces, torque, roughness and visual inspection of tool surfaces. Parameter studies in the laboratory are used to give feedback to the production for improvement of tool life or replacement of the tribosystem. The presentation also includes results for severing processes, where four-ball testing and high-temperature pin-on-disc testing are used to evaluate the lubricant ability to bond to the tool and workpiece surfaces. The temperature range at which the lubricant additives are activated is revealed for each lubricant, and a clear distinction of the performance of the different lubricants for a specific punching process is made by comparing the process temperature to the temperature range of activated additives.

Marcel Moghadam, Esmeray Üstüniagiz and Chris Valentin Nielsen

Evaluation of tribosystems for sheet metal forming

Department of Mechanical Engineering
Technical University of Denmark

Environmentally benign tribosystems for sheet metal forming

REACH

(**R**egistration, **E**valuation, **A**uthorization, and **R**estriction of **C**hemicals)

- Improved protection of human and environmental health
- Restricted use of hazardous chemicals:
  - Acute toxicity
  - Irritants
  - Sensitization
  - Carcinogenicity
  - Genotoxicity
  - Aquatic toxicity
  - Bioaccumulation
- Waste reduction and process optimization for prolonged tool and lubricant life

Two types of evaluations of lubricants

1. Off-line testing of tribosystems with conditions close to production conditions

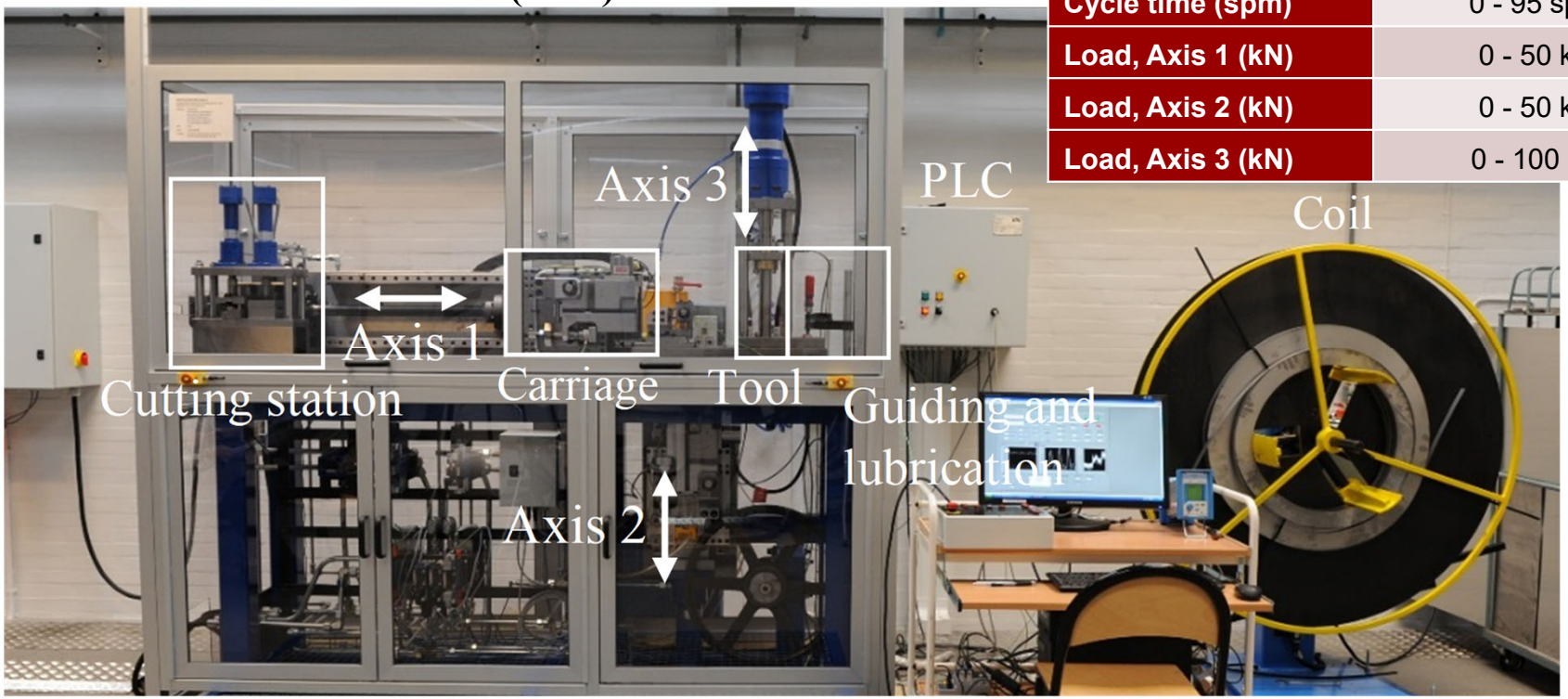
2. Physical and chemical evaluation of lubricant ability to bond to tool and workpiece surfaces

Off-line testing of tribosystems with conditions close to production conditions

Off-line testing of tribosystems with conditions close to production conditions

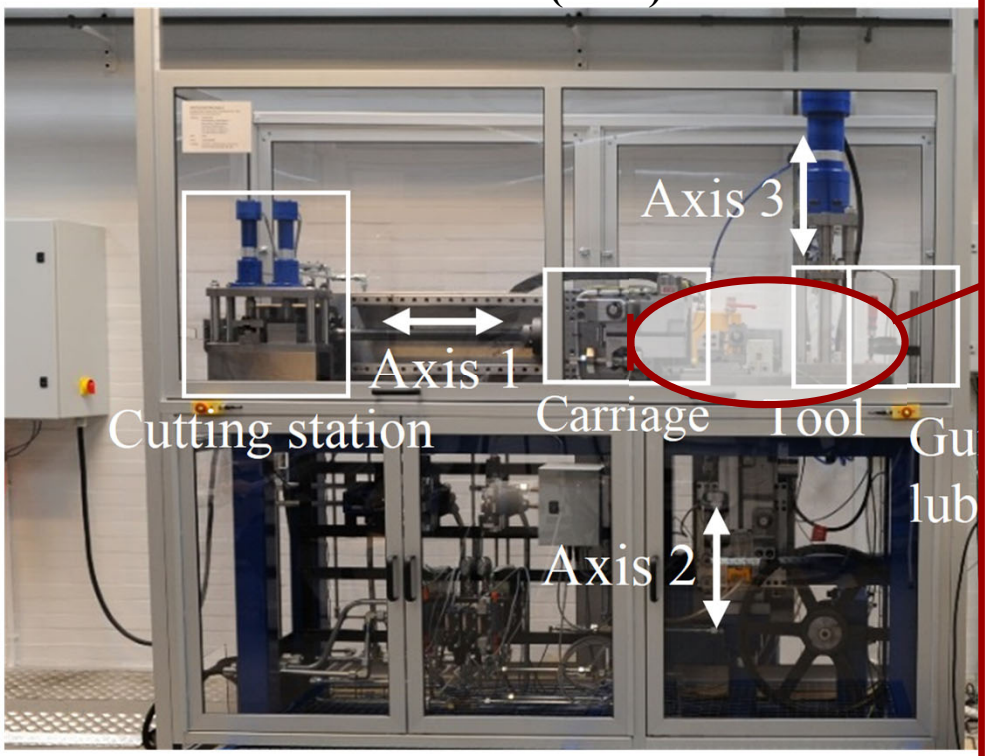
Sliding length	**0 - 500 mm**
Sliding speed (mm/s)	0 - 150 mm/s
Cycle time (spm)	0 - 95 spm
Load, Axis 1 (kN)	0 - 50 kN
Load, Axis 2 (kN)	0 - 50 kN
Load, Axis 3 (kN)	0 - 100 kN

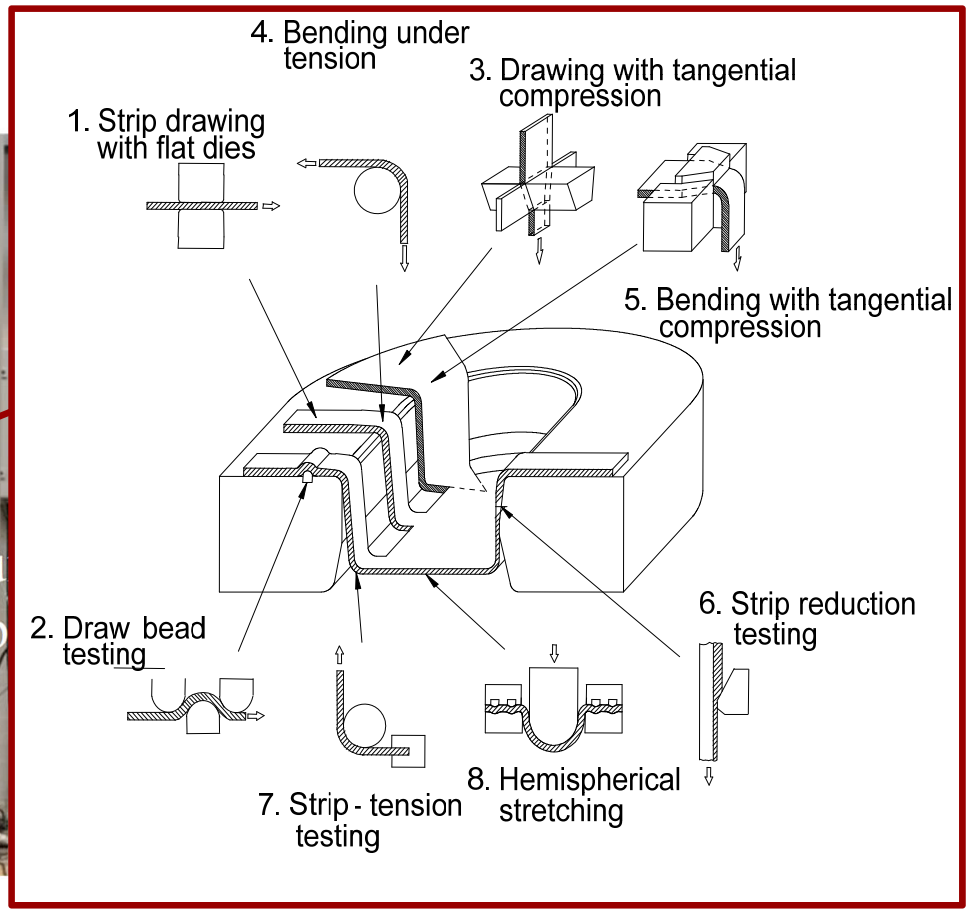
Universal Sheet Tribo-tester (UST)



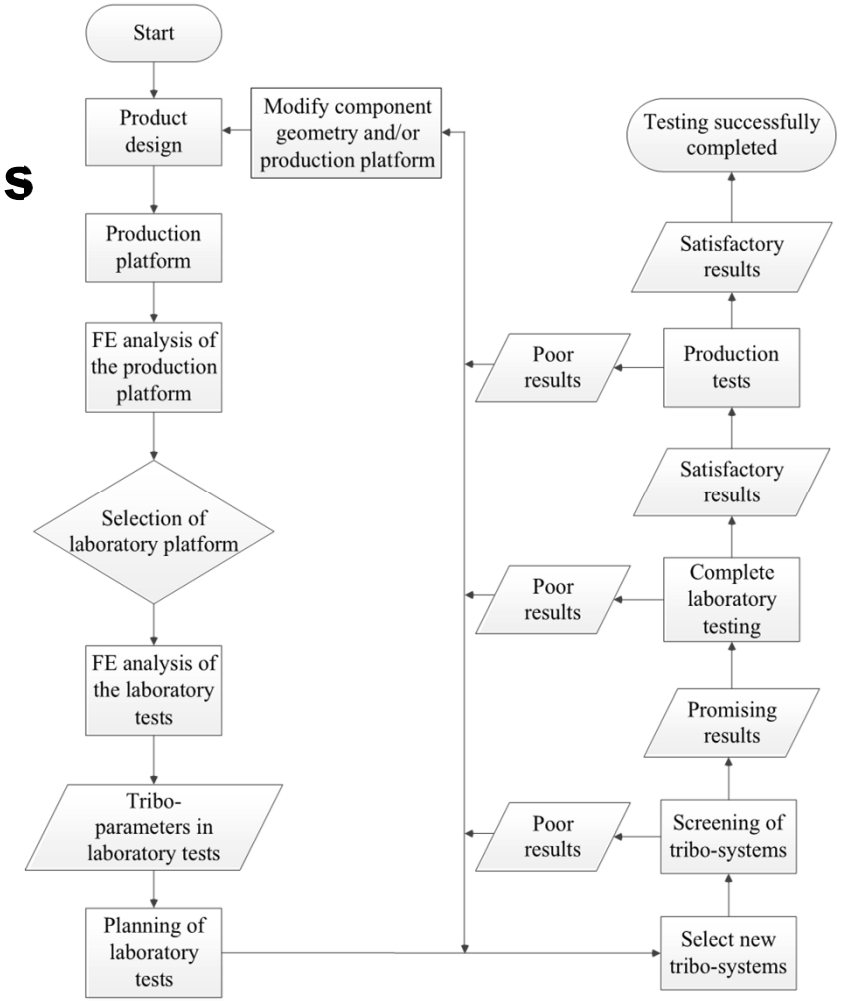
Off-line testing of tribosystems with conditions close to production conditions

Universal Sheet Tribo-tester (UST)





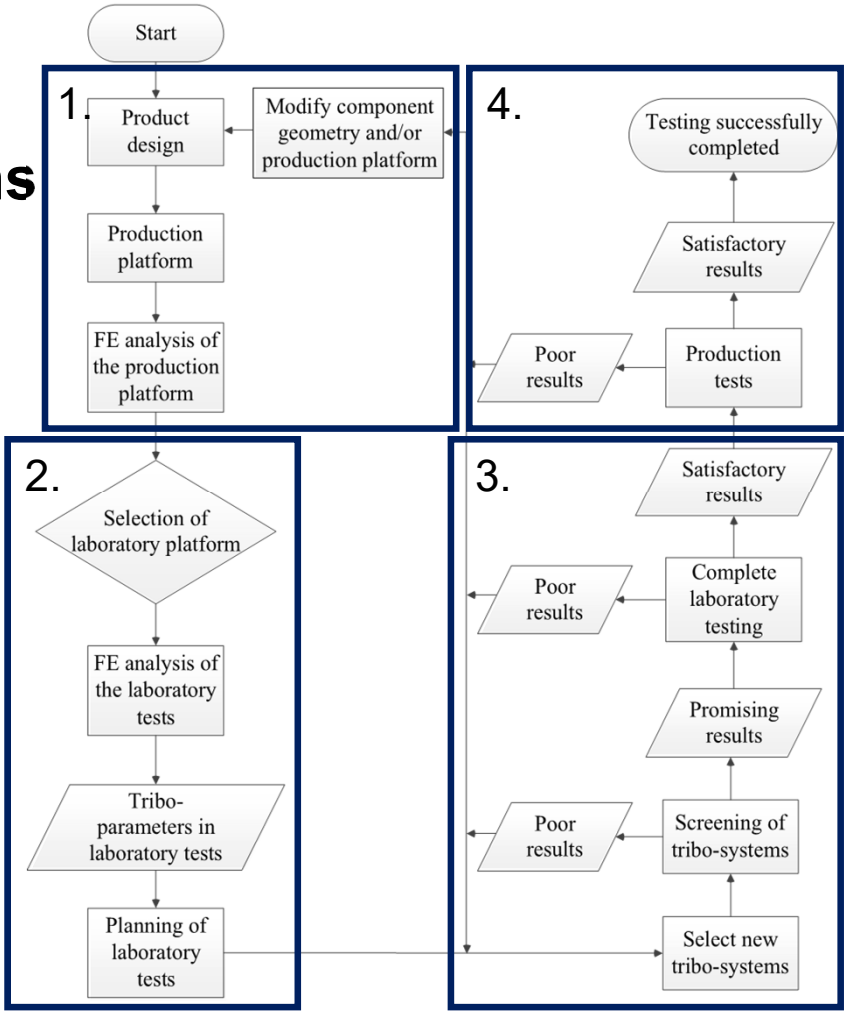
Off-line testing of tribosystems with conditions close to production conditions



Bay, N., Ceron, E. (2014): Off-line testing of tribo-systems for sheet metal forming production. Advanced Materials Research 966-967.

Off-line testing of tribosystems with conditions close to production conditions

1. Evaluation of production platform
2. Preparing laboratory test
3. Laboratory testing
4. Production testing



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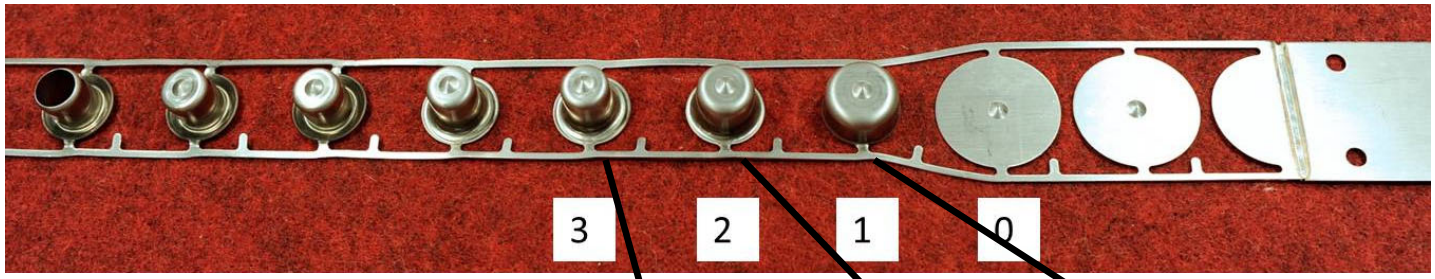
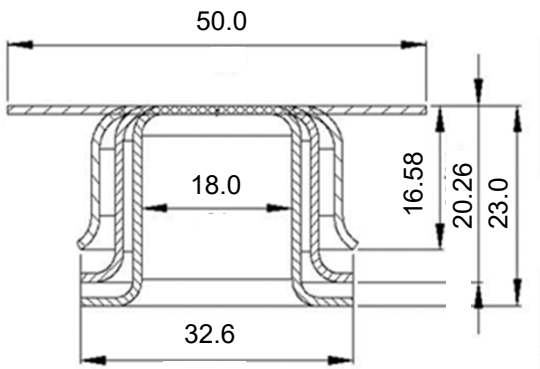
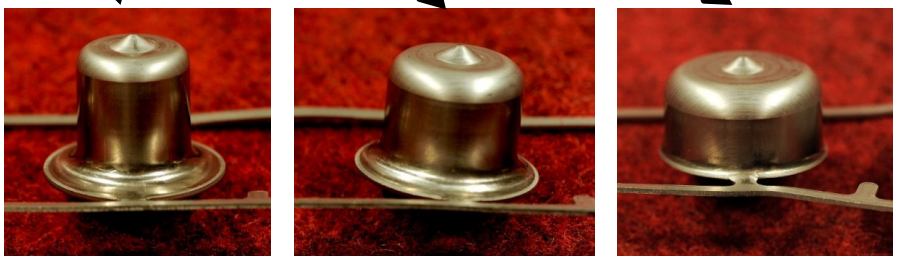
Industrial case involving deep drawing: Grundfos A/S

1. Evaluation of production platform



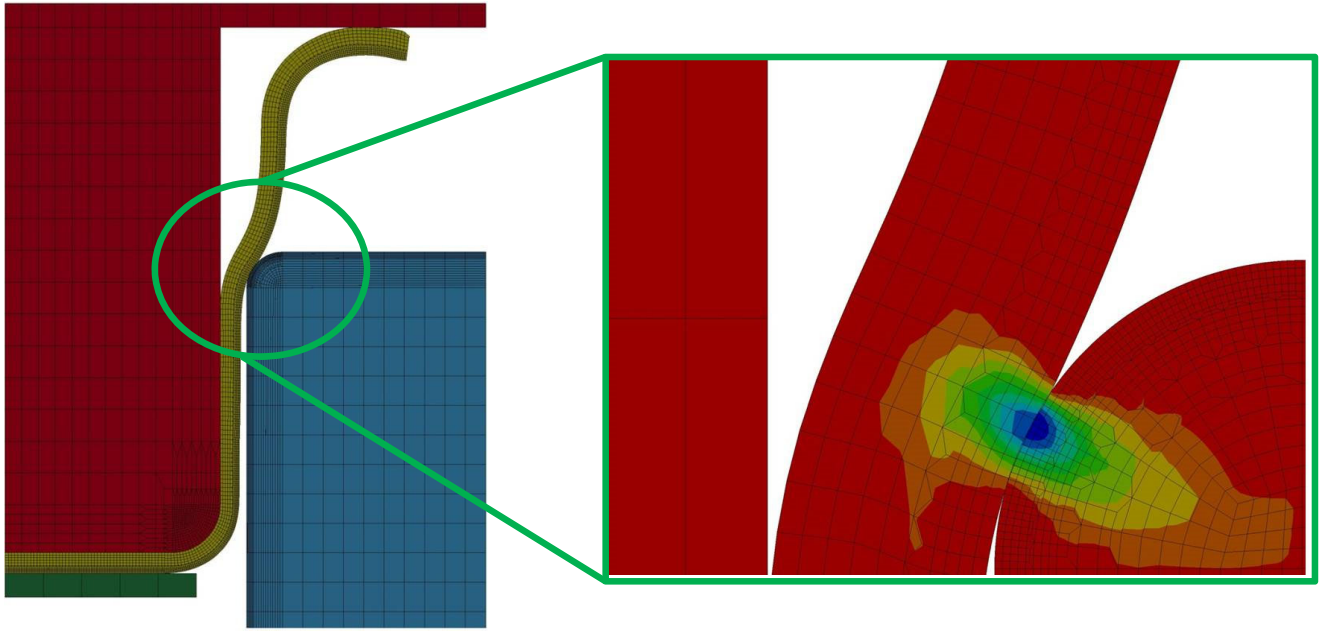




Ceron, E. (2014): New Tribo-systems for Sheet Metal Forming of Advanced High Strength and Stainless steels. PhD Thesis. Technical University of Denmark.

Industrial case involving deep drawing: Grundfos A/S

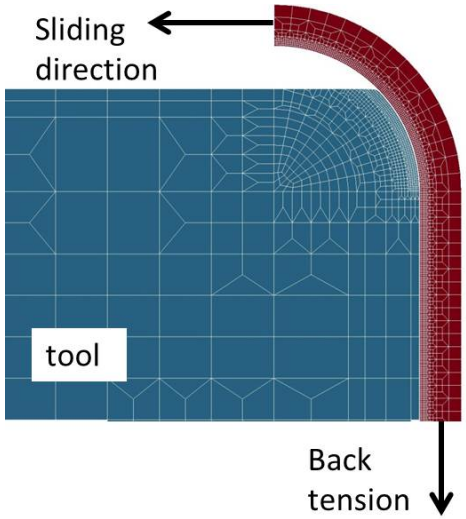
1. Evaluation of production platform

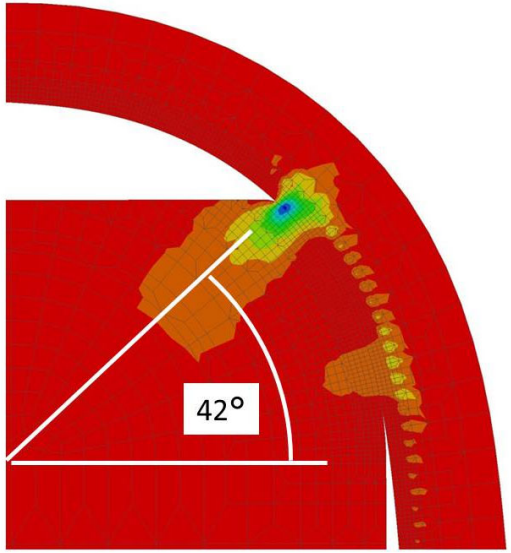


Ceron, E., Olsson, M., Bay, N. (2014): Lubricant film breakdown and material pick-up in sheet forming of advanced high strength steels and stainless steels when using environmental friendly lubricants. Advanced Materials Resarch 966-967.

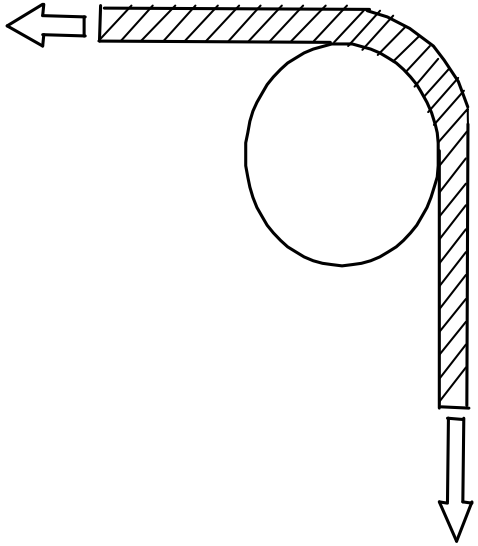
Industrial case involving deep drawing: Grundfos A/S

2. Preparing laboratory test





BUT



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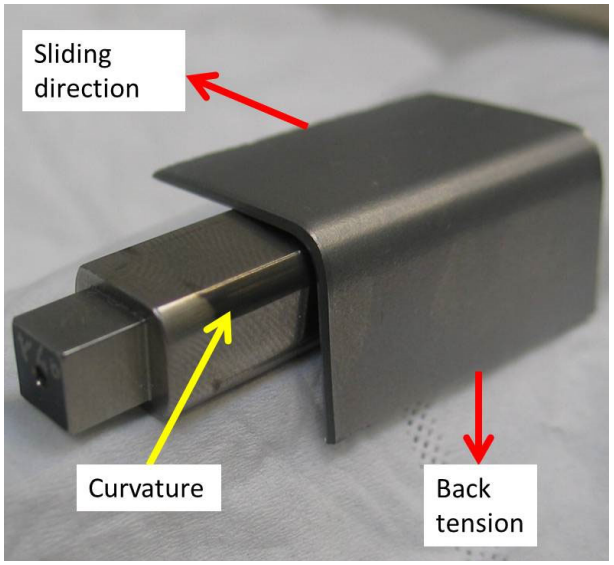
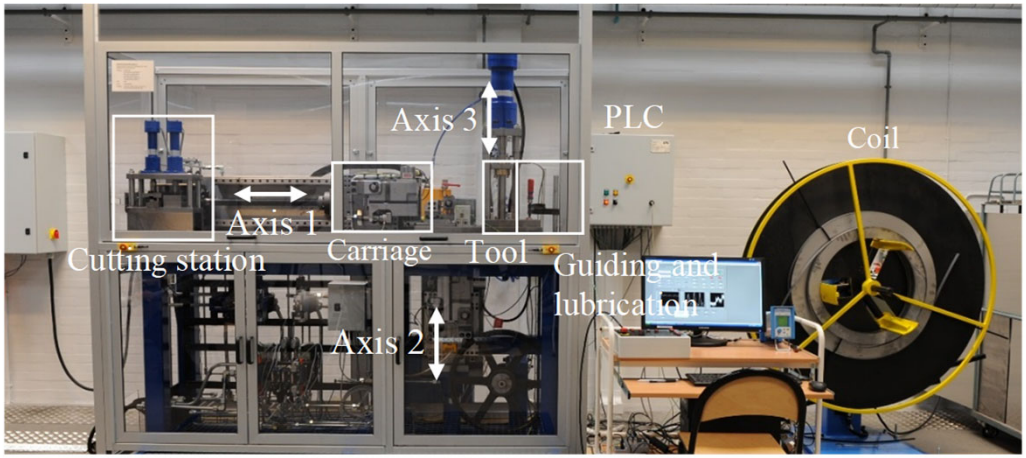
Industrial case involving deep drawing: Grundfos A/S

3. Laboratory testing





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Industrial case involving deep drawing: Grundfos A/S

4. Production testing
   a) EN 1.4301, Rh
   b) DP 800, F1
   c) DP 800 test die 3
   d) DP 800, F2

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Industrial case involving deep drawing: Grundfos A/S

Comparison of laboratory testing and production testing
(1500 strokes with 40 strokes/min)

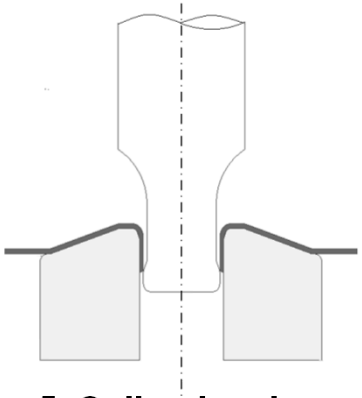
	Tribosystem OK
	Tribosystem sometimes failed, sometimes not
	Tribosystem failed

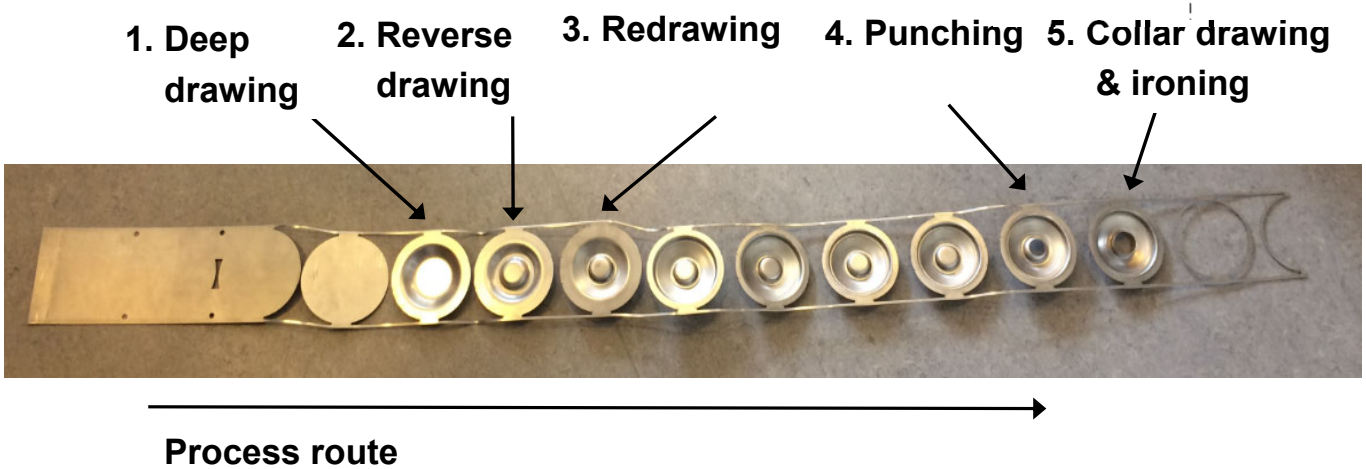
	Workpiece material					
Lubricant	EN 1.4301		EN 1.4162		DP 800	
	V4E	V40	V4E	V40	V4E	V40
Anticorital 3802-39 S					Lab	Lab
					Prod	Prod
Anticorital PLS 100 T					Lab	Lab
					Prod	Prod
Rhenus SU 166 A	Lab	Lab	Lab	Lab		
	Prod	Prod	Prod	Prod		

Ceron, E. (2014): New Tribo-systems for Sheet Metal Forming of Advanced High Strength and Stainless steels. PhD Thesis. Technical University of Denmark.

Industrial case involving ironing: Grundfos A/S

Stainless steel bearing plate for pump hydraulics





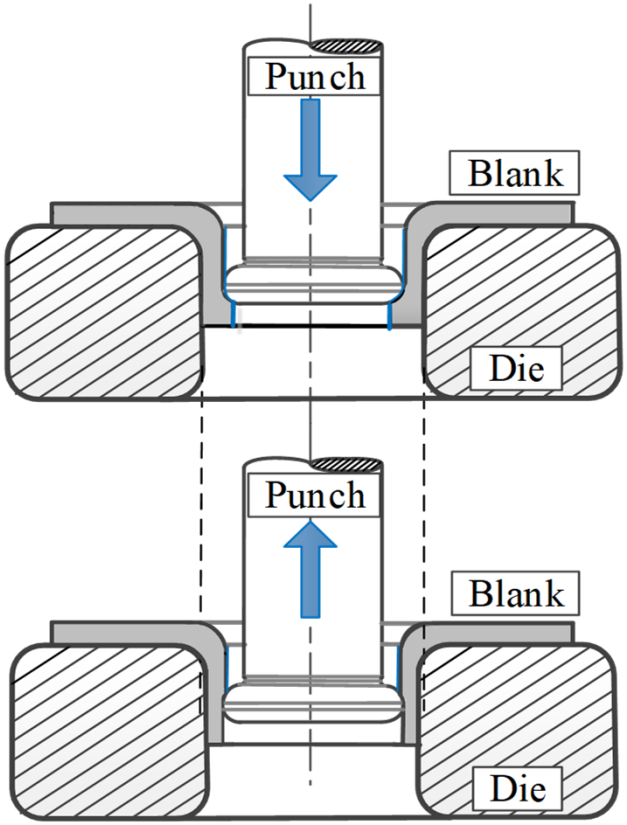
Üstünyagiz, E., Sulaiman, M.H., Christiansen, P., Nielsen, C.V., Bay, N. (2018): A Study on DLC Tool Coating for Deep Drawing and Ironing of Stainless Steel. Key Engineering Materials 767, 181-188.

Industrial case involving ironing: Grundfos A/S

Galling leading to scoring of workpiece surface

Strip material: EN 1.4301

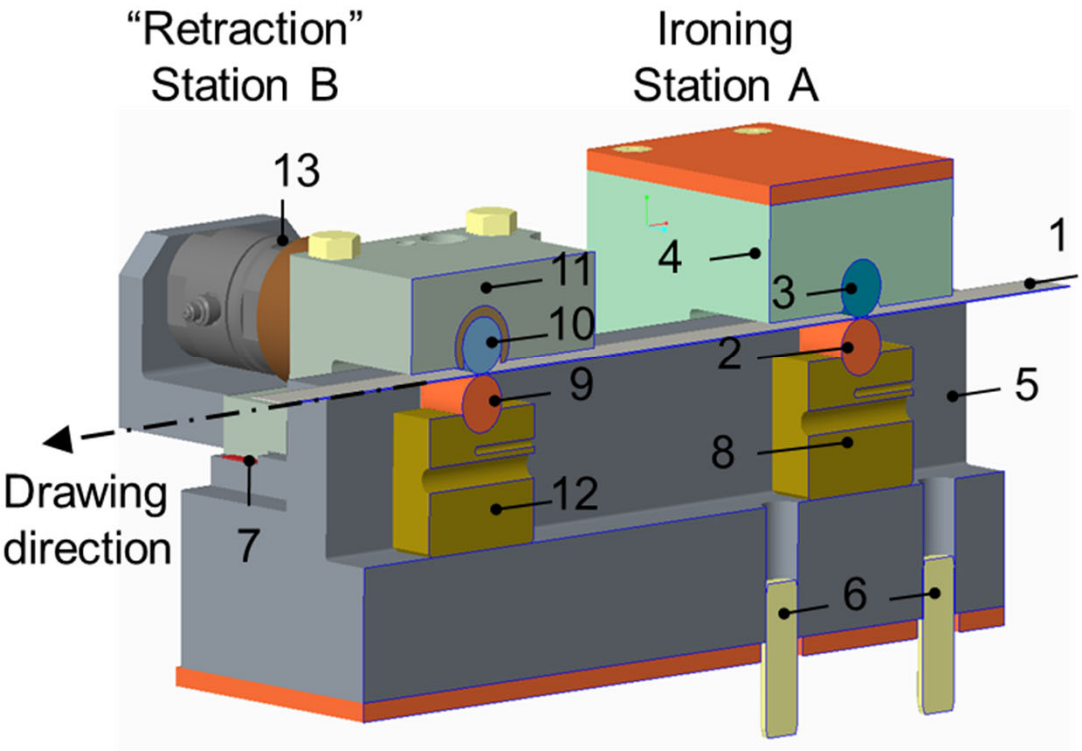
Lubricant: Rhenus 722086

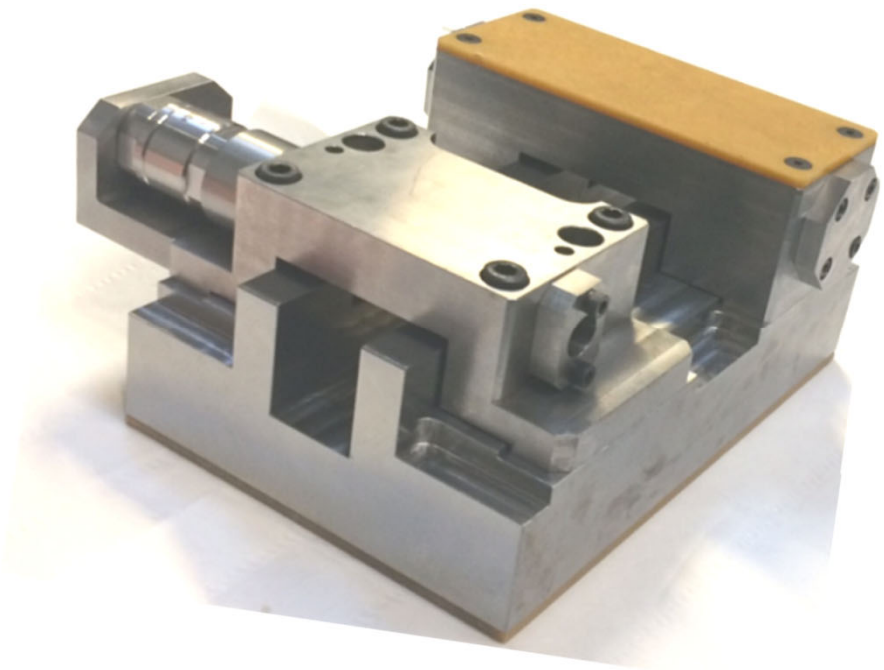


Strip reduction

Üstünyagiz, E., Sulaiman, M.H., Christiansen, P., Nielsen, C.V., Bay, N. (2018): A Study on DLC Tool Coating for Deep Drawing and Ironing of Stainless Steel. Key Engineering Materials 767, 181-188.

Industrial case involving ironing: Grundfos A/S





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Industrial case study:
Emission gas recirculation (EGR) component

Material: Steel 1.4301, 1.5mm sheet thickness.

Lubricant: Castrol Iloform BWN 205.

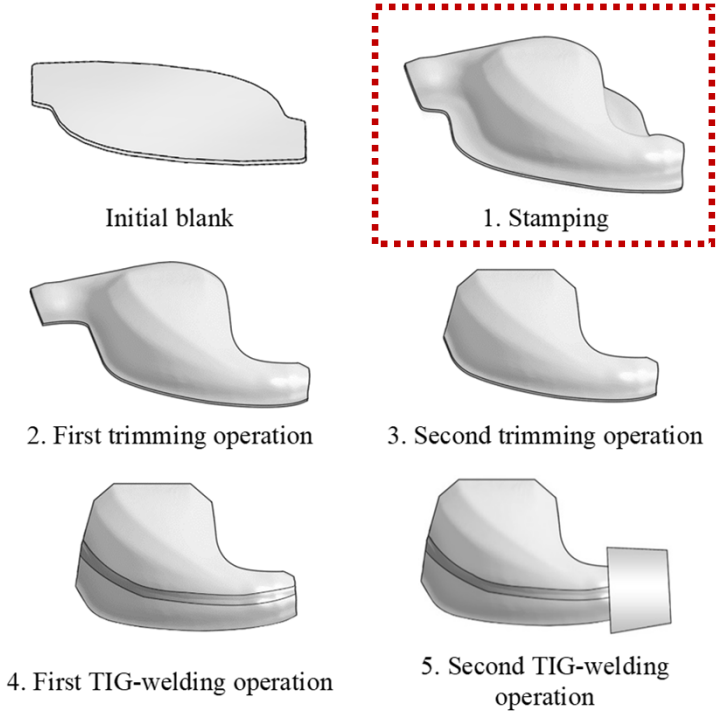
Production method: 1-step stamping operation

Onset of galling at approximately 200 strokes.

Die material: Sleipner, hardened to 60 HRC, polished to an average roughness of approximately 0,05µm.

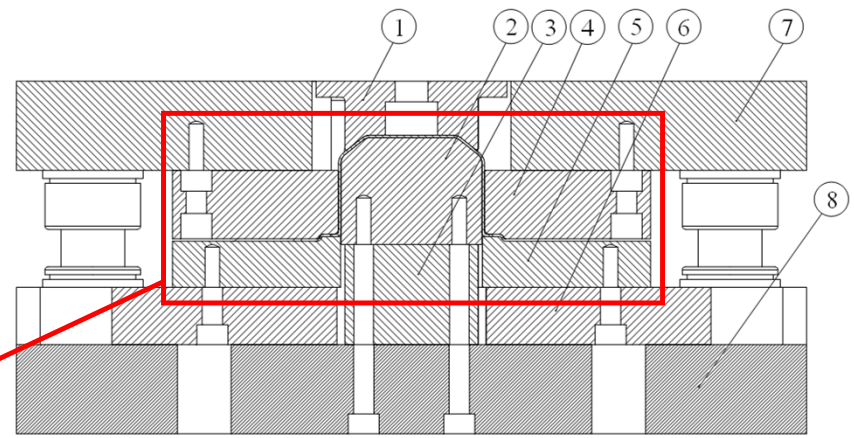
Possible defects: Fracture, wrinkling, wear on drawbeads

Goal of investigation: Evaluation of the applicability of non-chlorinated lubricants



Moghadam, M. (2019): Limits of lubrication in severe stamping operations. PhD Thesis. Technical University of Denmark.

Industrial case study:
Emission gas recirculation (EGR) component

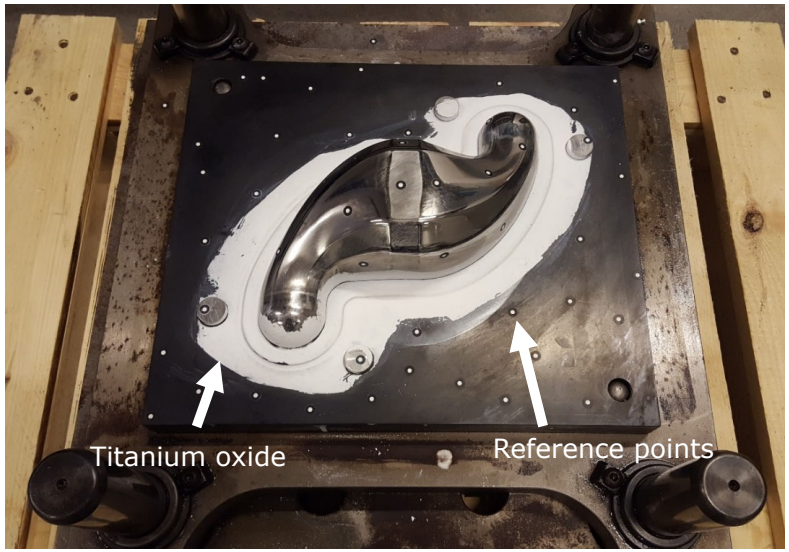


1. Counter-holder/ejector
2. Draw punch
3. Punch holder
4. Forming die
5. Blank holder
6. Draw cushion
7. Top plate
8. Press bed

Moghadam, M. (2019): Limits of lubrication in severe stamping operations. PhD Thesis. Technical University of Denmark.

Industrial case study:
Emission gas recirculation (EGR) component

ATOS Triple Scan
MV560 lens setup
3mm reference points



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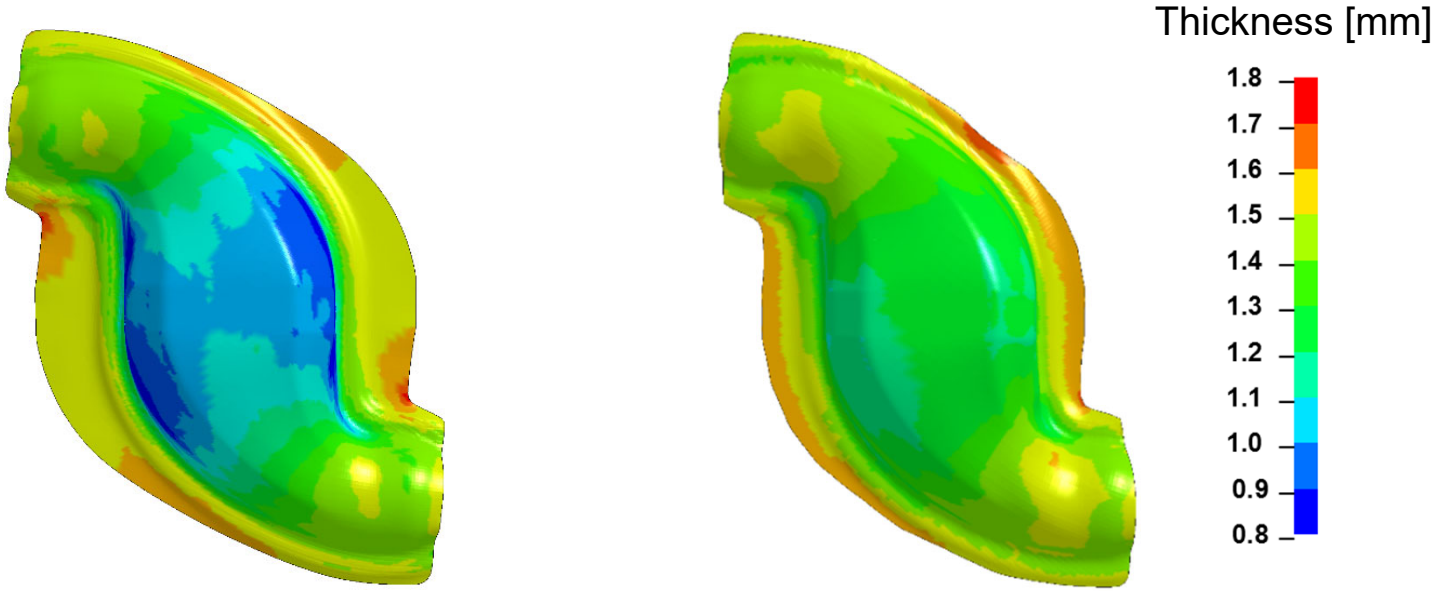

Initial drawbead geometry

Drawbead geometry after die tryout

20-30% reduction in thickness for automotive components

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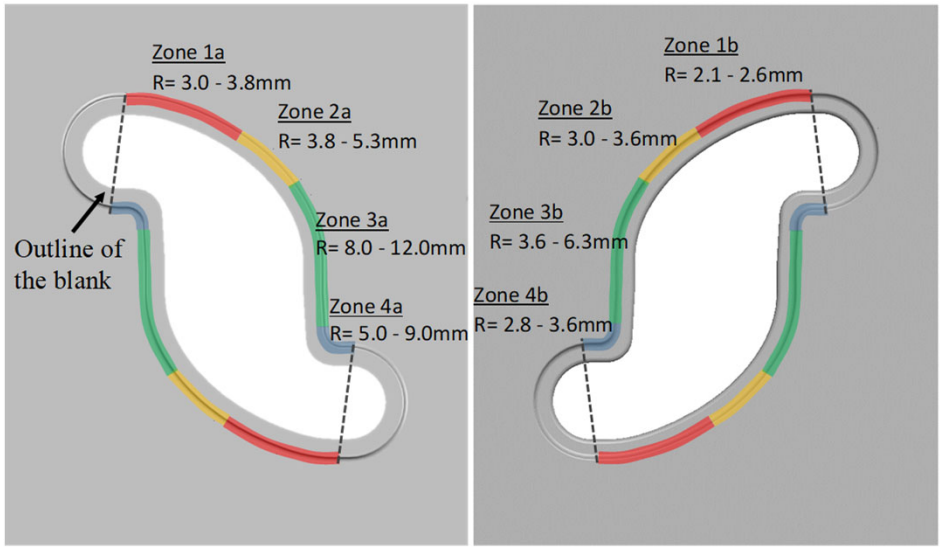
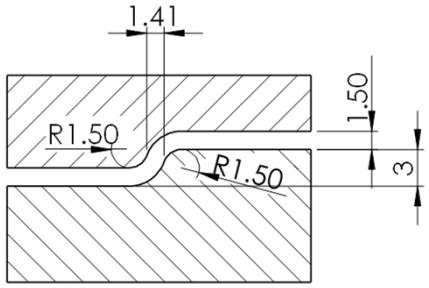
Technical University of Denmark.

Industrial case study:
Emission gas recirculation (EGR) component

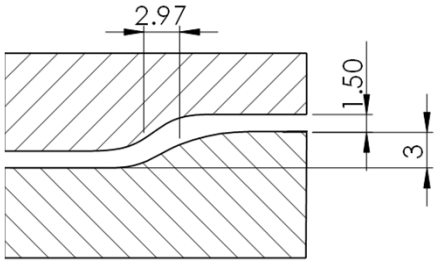


Blank holder

Forming die



Zone 3 before die tryout



Zone 3 after die tryout

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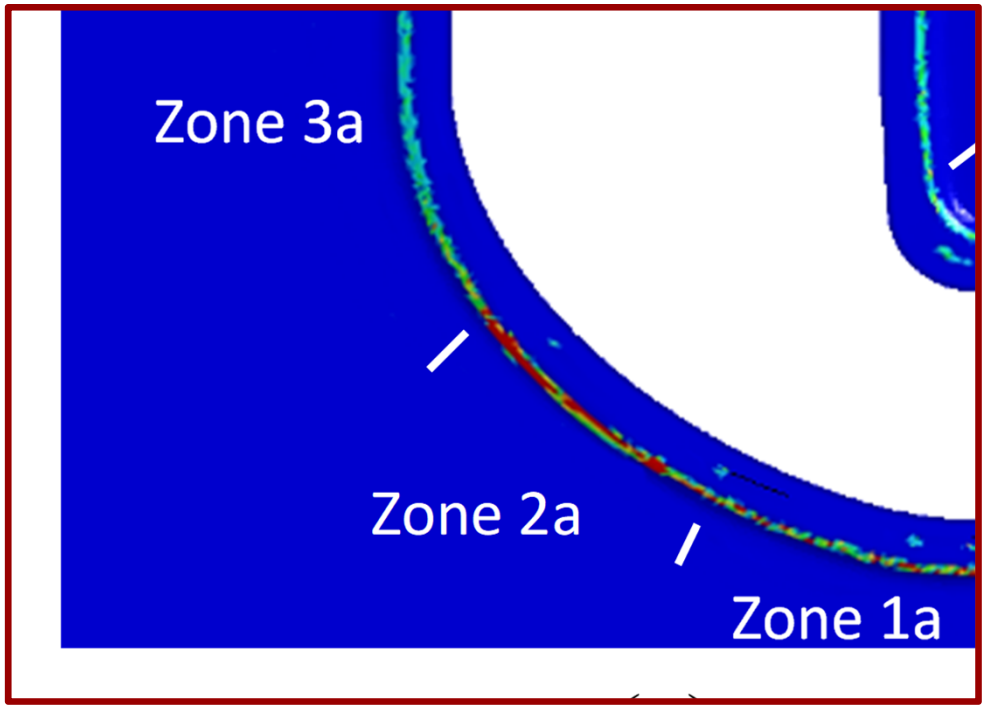
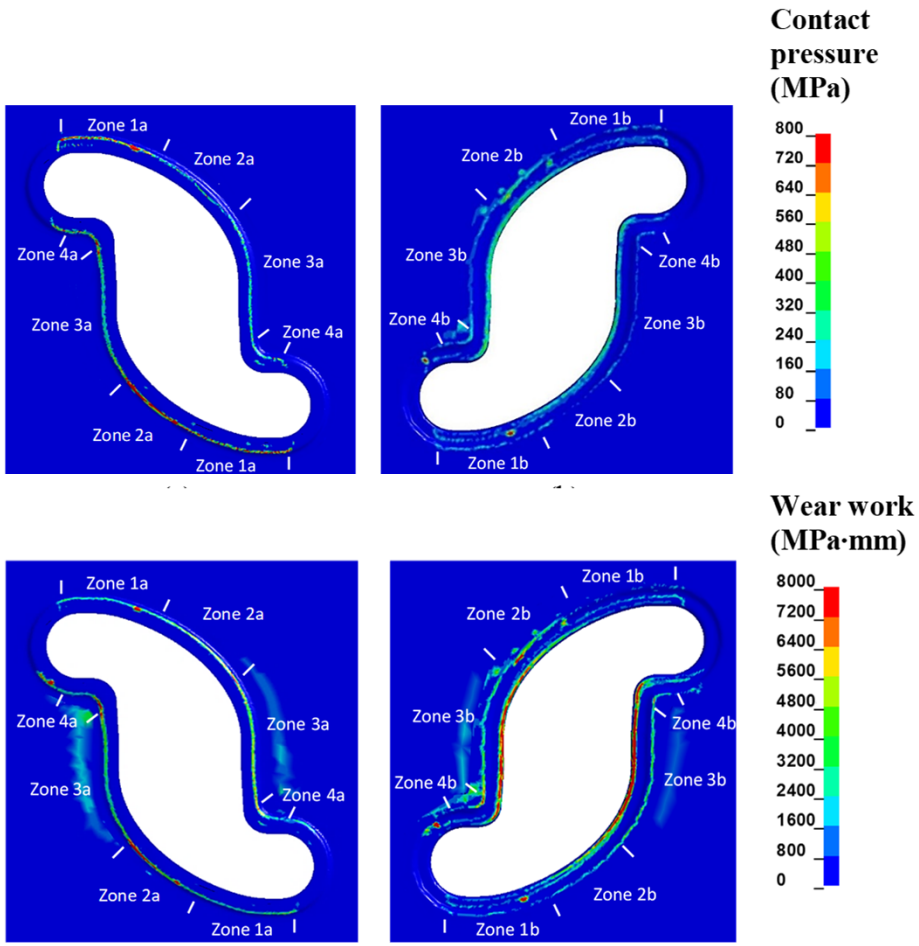
Industrial case study: EGR component





Blank holder

Forming die

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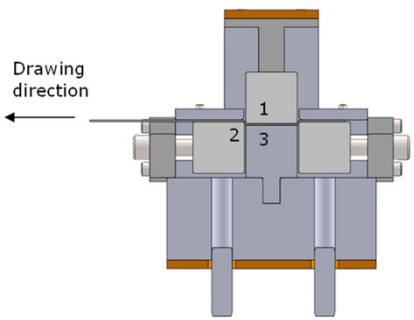
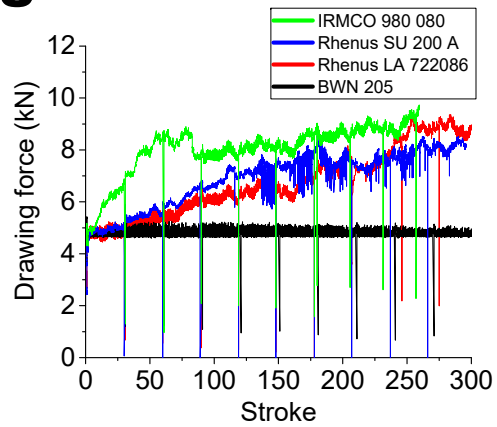
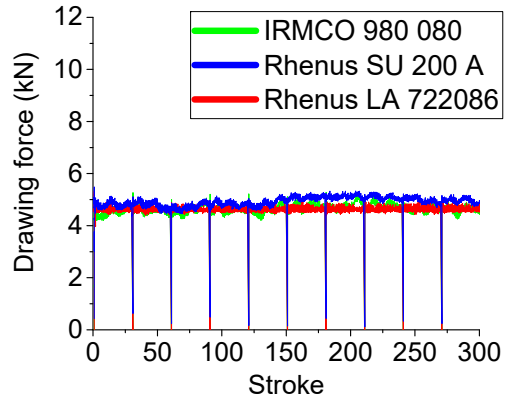
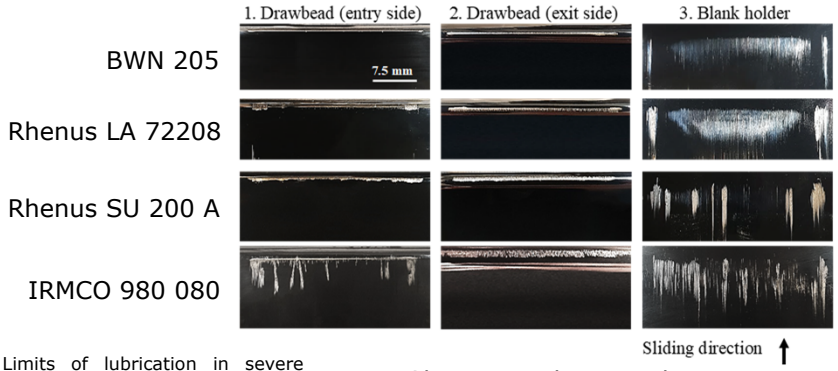
Industrial case study:
Emission gas recirculation (EGR) component

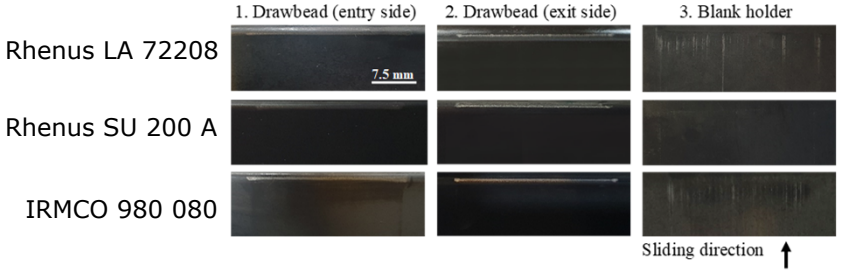








Sleipner tool material

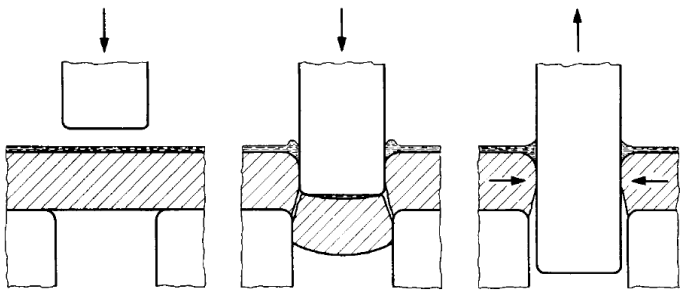


Sleipner tool material with Tenifer® QPQ surface treatment

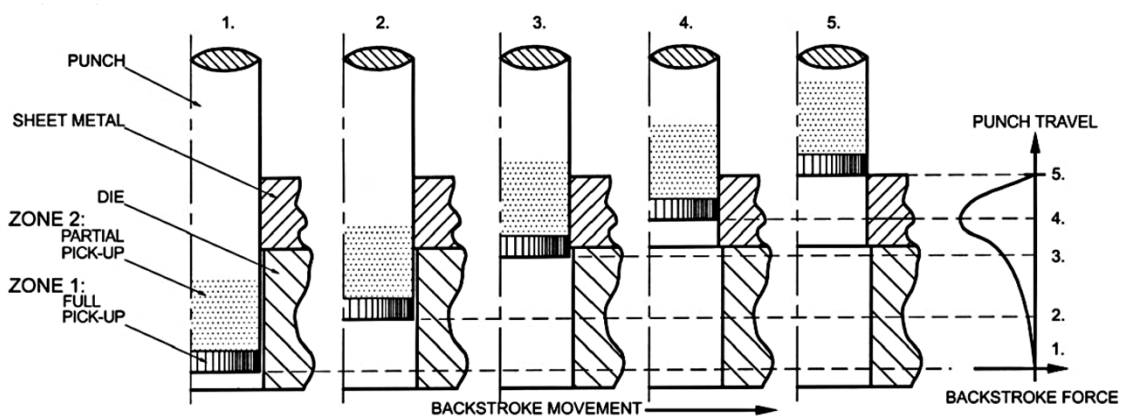
Moghadam, M. (2019): Limits of lubrication in severe stamping operations. PhD Thesis. Technical University of Denmark.

Physical and chemical evaluation of lubricant ability to bond to tool and workpiece surfaces

Wear and lubrication in punching and blanking operations



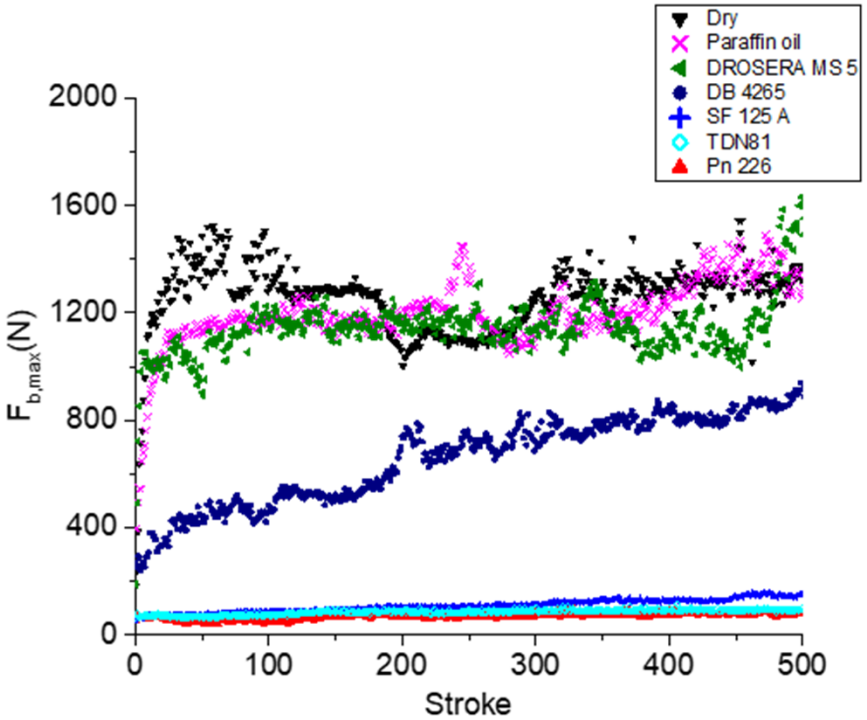
Mang, T., Dresel, W. (2007): Lubricants and Lubrication. John Wiley and Sons.



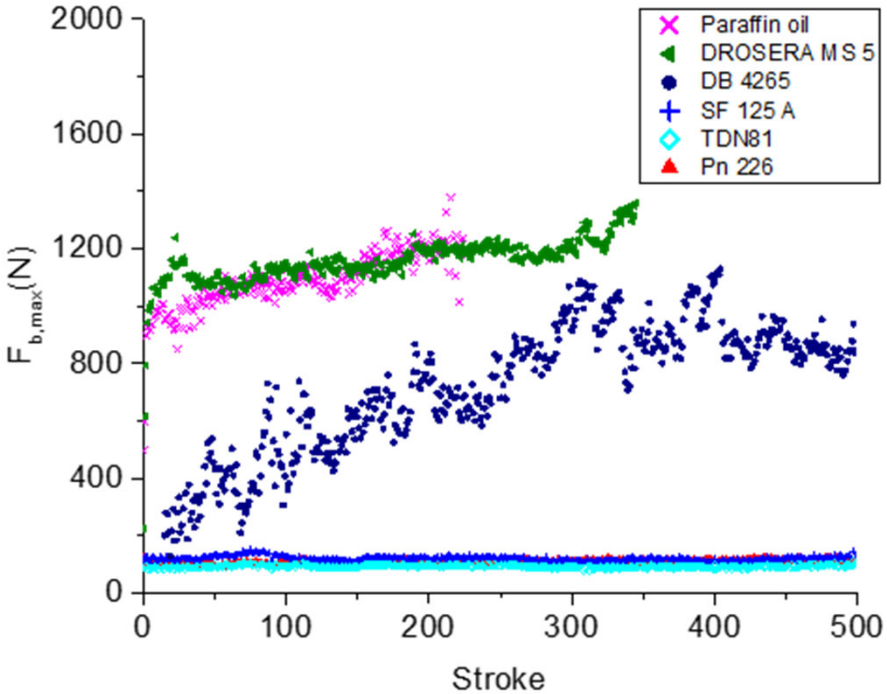
Olsson, D.D., Bay, N., Andreasen, J.L. (2002): Analysis of Pick-Up Development in Punching. Cirp Annals 51, 185-190.

Wear and lubrication in punching and blanking operations

Roller lubricators



Lubrication channels



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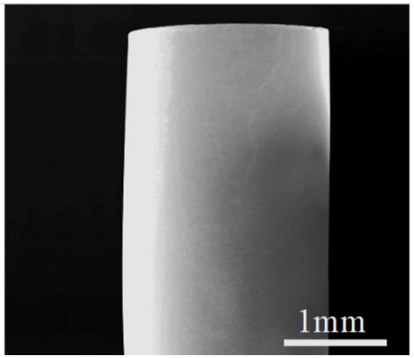
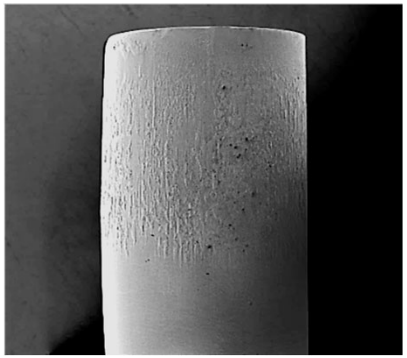
Wear and lubrication in punching and blanking operations



New punch



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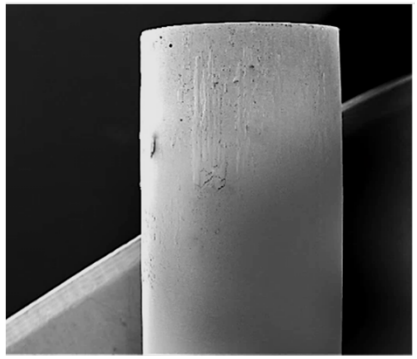
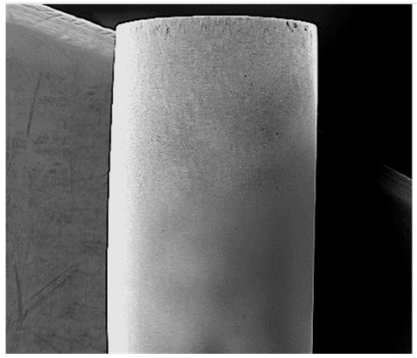


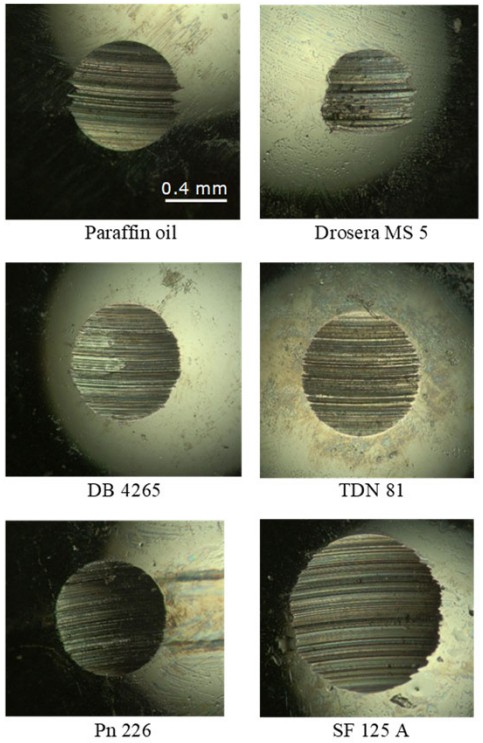
Drosera MS 5

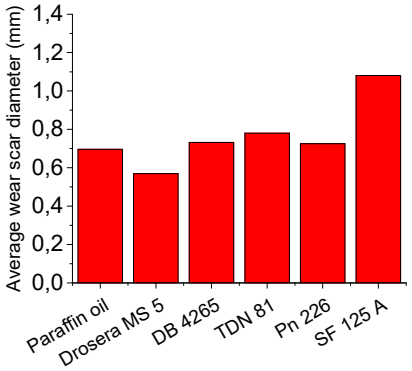


Pn226

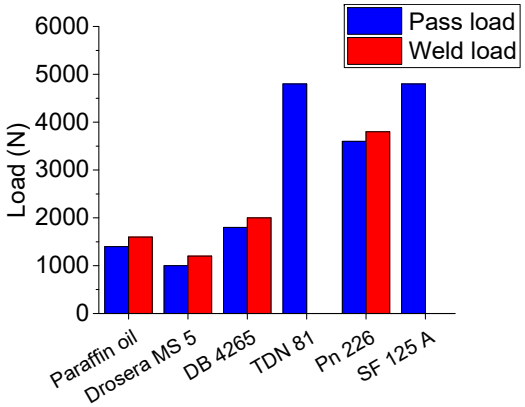
Moghadam, M., Villa, M., Moreau, P., Dubois, A., Dubar, L., Nielsen, C.V., Bay, N. (2020): Analysis of lubricant performance in punching and blanking. Tribology International 141, doi:10.1016/j.triboint.2019.105949.

Wear behavior and load bearing capacity





Test material	Ø12.7mm, 100Cr6
Test duration	60 min.
Rotational speed	1420 RPM
Test load	300 N



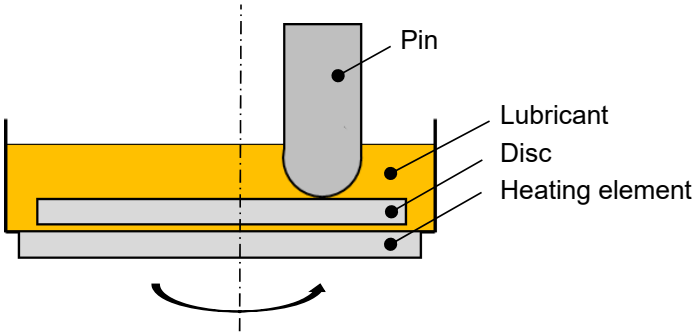
Test material	Ø12.7mm, 100Cr6
Test duration	1 min.
Rotational speed	1420 RPM
Test load	Increased incrementally until welding is achieved

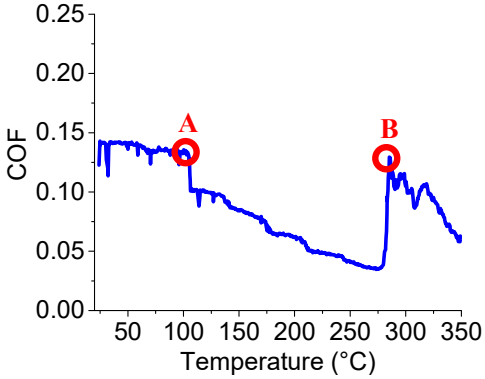
Moghadam, M., Villa, M., Moreau, P., Dubois, A., Dubar, L., Nielsen, C.V., Bay, N. (2020): Analysis of lubricant performance in punching and blanking. Tribology International 141, doi:10.1016/j.triboint.2019.105949.

High-temperature pin-on-disc test

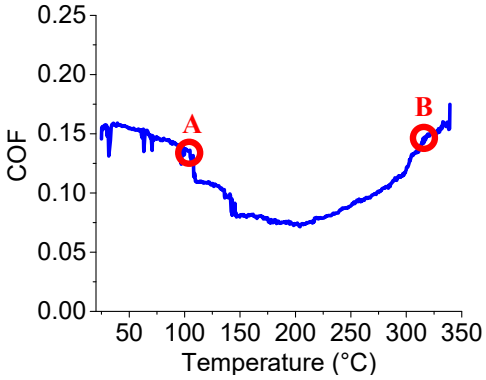
Bruker Universal Mechanical Tester Tribolab™

Disc material	AISI M3:2, hardened to 64 HRC
Surface roughness	Ra = 0.08 µm
Test load	16 N
Rotational velocity	0.2 mm/s
Heating rate	6 °C/min

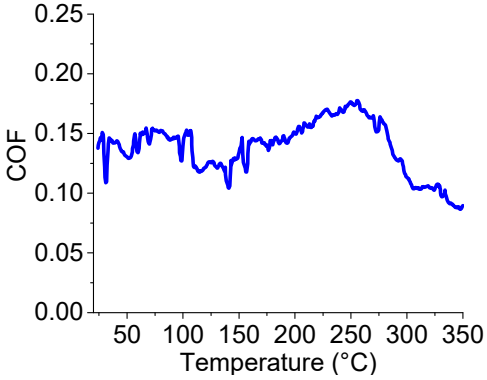




Pn 226



Drosera MS 5



Paraffin oil

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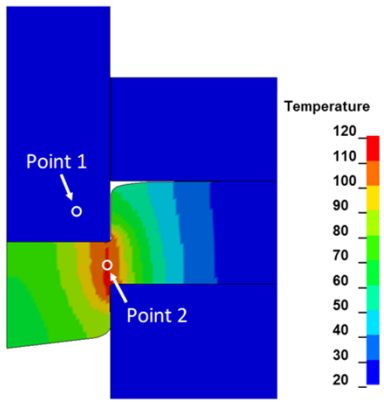
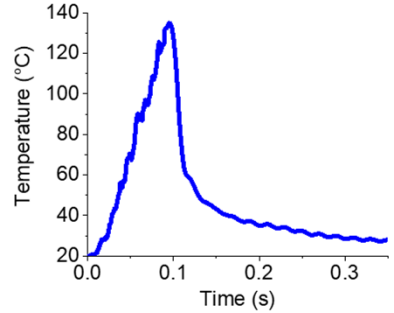
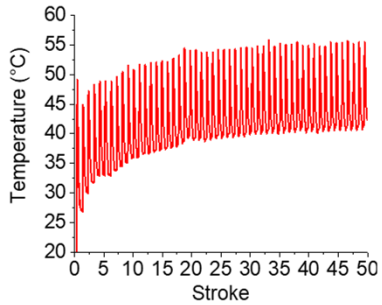
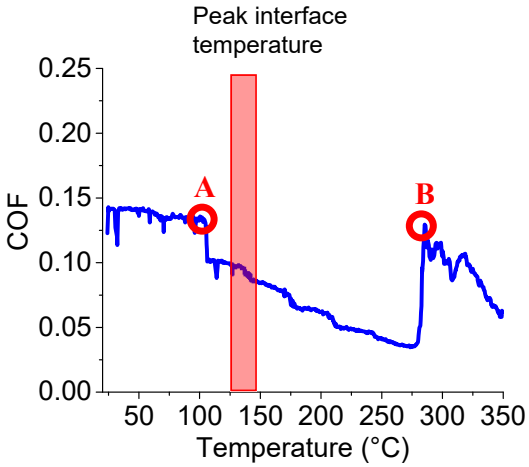
Temperature development during testing









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