JOINING 4.0

SELFPIERCE RIVETING BY CYBER-PHYSICAL SYSTEM

JOINING SUB-PLATFORM - 6th General Assembly

D. Landgrebe, R. Mauermann, M. Jäckel, T. Falk

Fraunhofer IWU

© Fraunhofer IWU

CONTENTS

1. Self-pierce riveting with semi-tubular rivet (SPR-ST)
2. Simulation model and verification
3. Sensitivity analyses
4. Improving flexibility of SPR-ST
5. Cyber physical systems to improve SPR-ST
6. Conclusion

© Fraunhofer IWU

CONTENTS

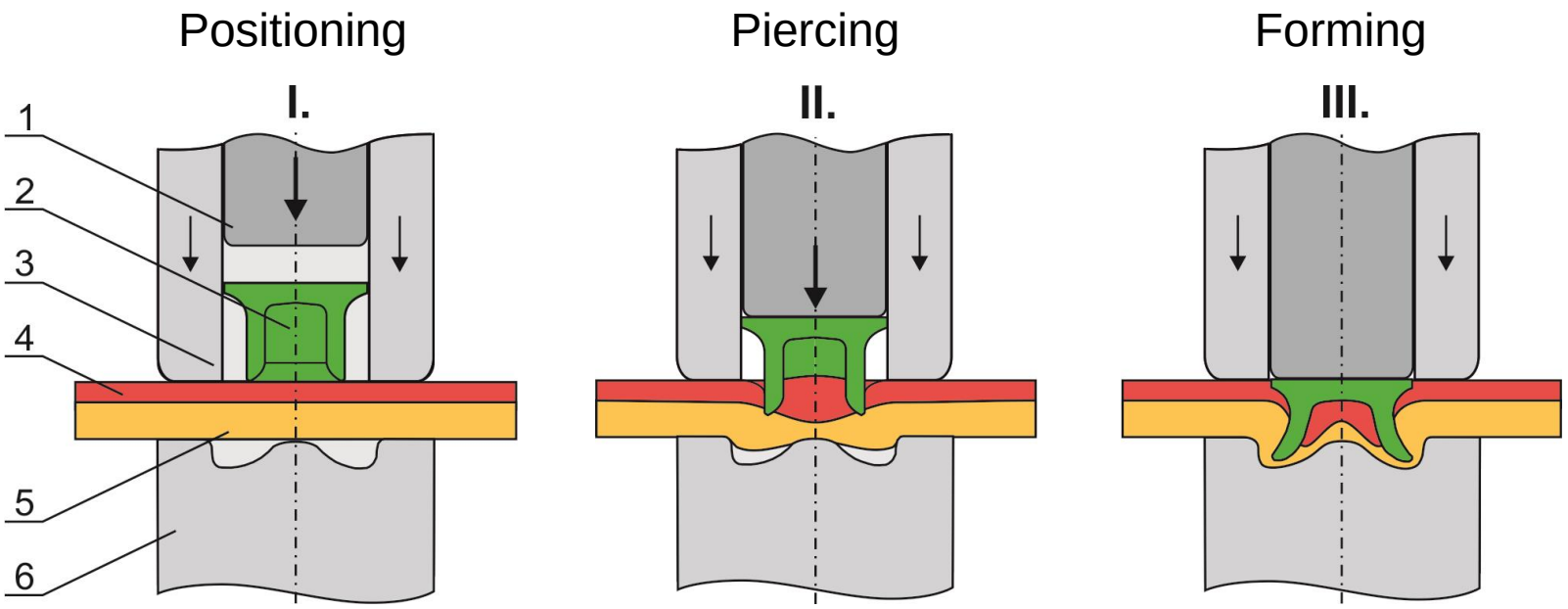
1. Self-pierce riveting with semi-tubular rivet (SPR-ST)
2. Simulation model and verification
3. Sensitivity analyzes
4. Improving flexibility of SPR-ST
5. Cyber physical systems to improve SPR-ST
6. Conclusion

© Fraunhofer IWU

Fraunhofer IWU

1. Self-pierce riveting with semi-tubular rivet (SPR-ST)

- Joining process in three steps

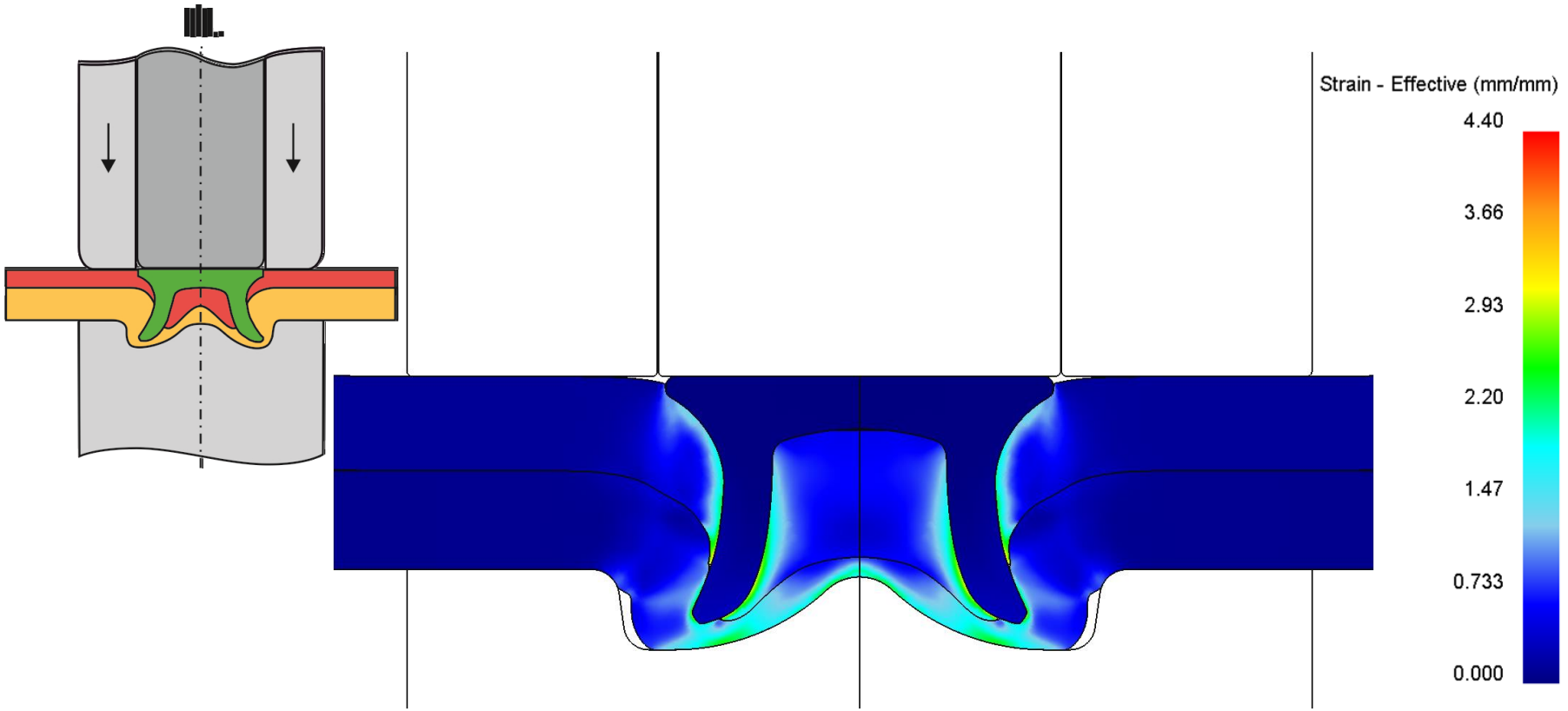


1. Punch
2. Semi-tubular rivet
3. Blank holder
4. Punch-side sheet metal
5. Die-side sheet metal
6. Die

© Fraunhofer IWU

1. Self-pierce riveting with semi-tubular rivet (SPR-ST)

- Animation of SPR-ST



© Fraunhofer IWU

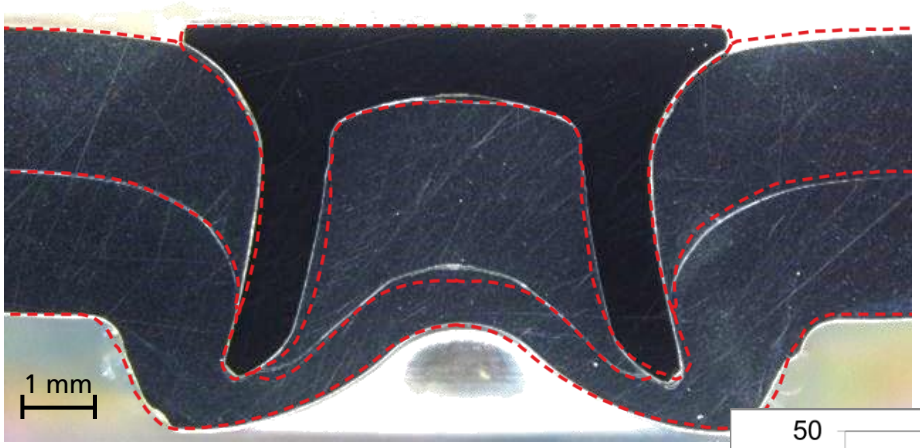
CONTENTS

1. Self-pierce riveting with semi-tubular rivet (SPR-ST)
2. Simulation model and verification
3. Sensitivity analyzes
4. Improving flexibility of SPR-ST
5. Cyber physical systems to improve SPR-ST
6. Conclusion

© Fraunhofer IWU

Fraunhofer IWU

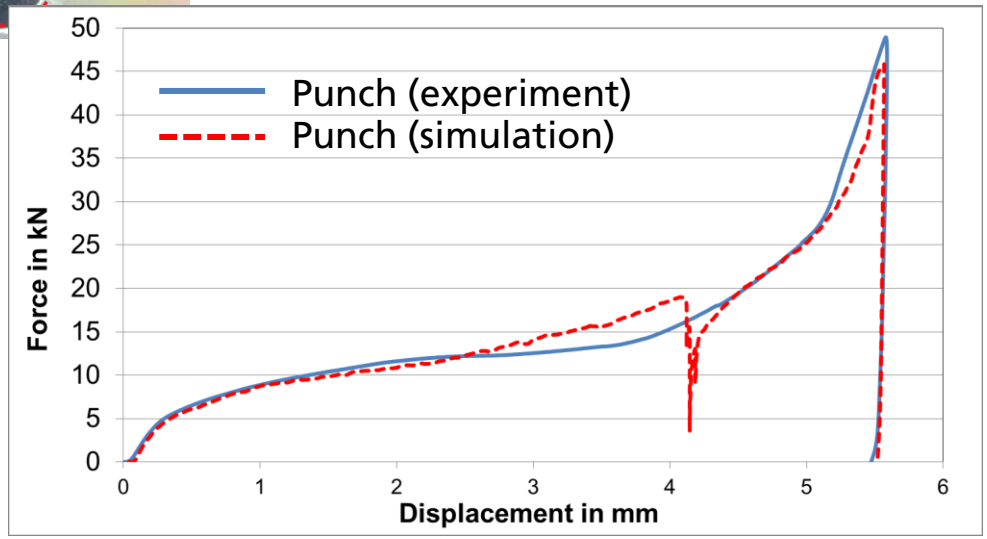
2. Simulation model and verification



- Verification of
  EN AW-6016 T4 (t = 2.0 mm) in
  EN AW-6016 T4 (t = 2.0 mm) with
  standard steel rivet C 5.3 mm x 5.5 mm

- Good agreement of experiment and simulation (cross section and joining force)

→ Simulation model can be used for following sensitivity analyzes



© Fraunhofer IWU

Fraunhofer IWU

CONTENTS

1. Self-pierce riveting with semi-tubular rivet (SPR-ST)
2. Simulation model and verification
3. Sensitivity analyzes
4. Improving flexibility of SPR-ST
5. Cyber physical systems to improve SPR-ST
6. Conclusion

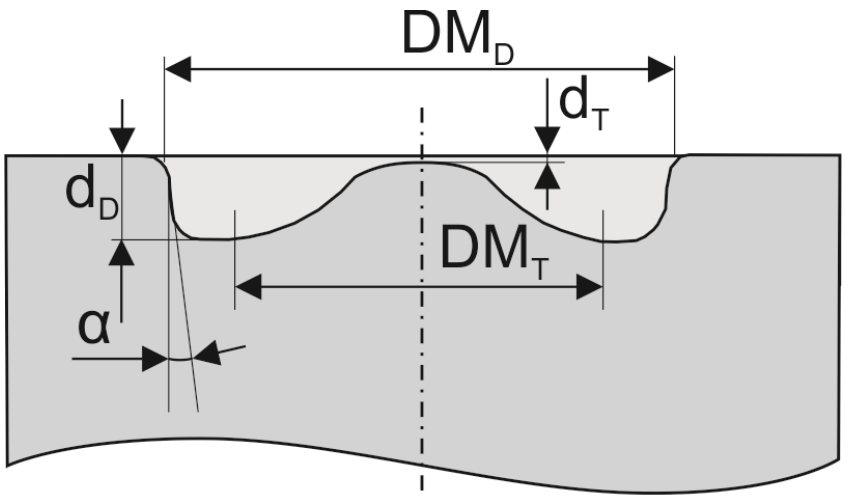
© Fraunhofer IWU

Fraunhofer IWU

3. Sensitivity analyzes

Variation of die geometry

- Input parameters



DM_D	Diameter of die
DM_T	Diameter of thorn
d_D	Depth of die
d_T	Depth of thorn
α	Angle of die

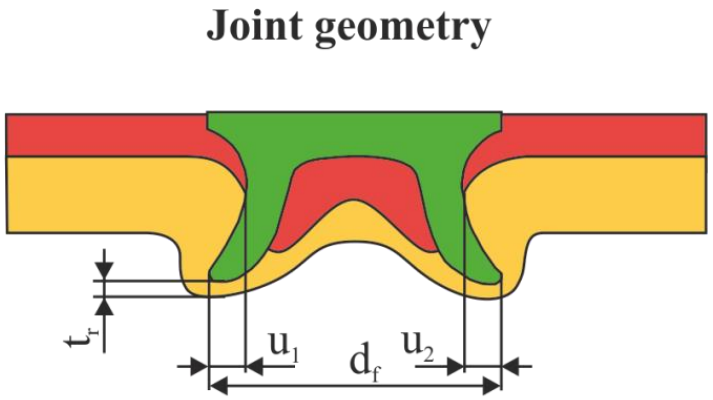
Parameter	Min.	Max.
Diameter of die in mm	9.0	11.0
Diameter of thorn in mm	7.5	8.5
Depth of die in mm	1.2	2.0
Depth of thorn in mm	0.2	0.6
Angle of die in °	5.0	15.0

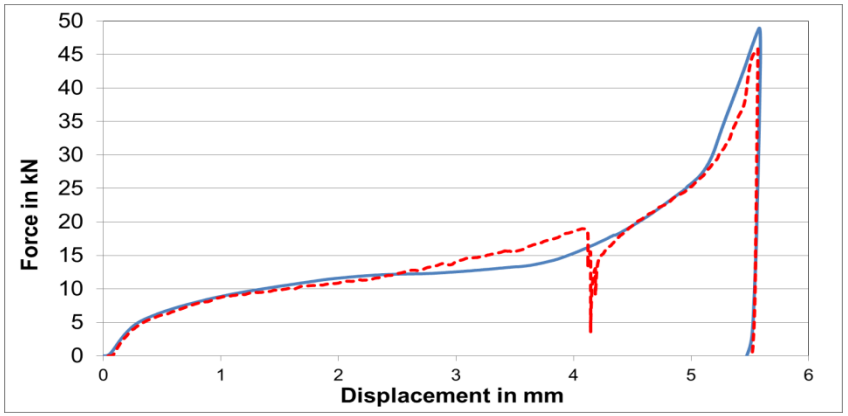
© Fraunhofer IWU

3. Sensitivity analyzes

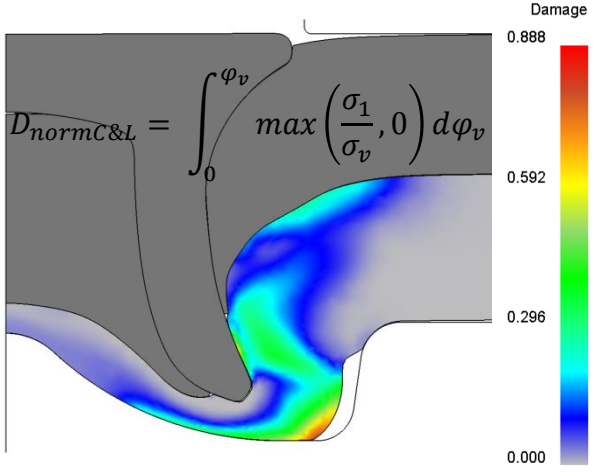
Variation of die geometry

- Output parameters





Parameter	symbol	unit
Interlock	$u_{1,2}$	mm
Thickness around the rivet foot	t_r	mm
Footdiameter	d_f	mm
Max. joining force	F	kN
Max. damage value die-sided blank	$D_{normC\&L}$	-



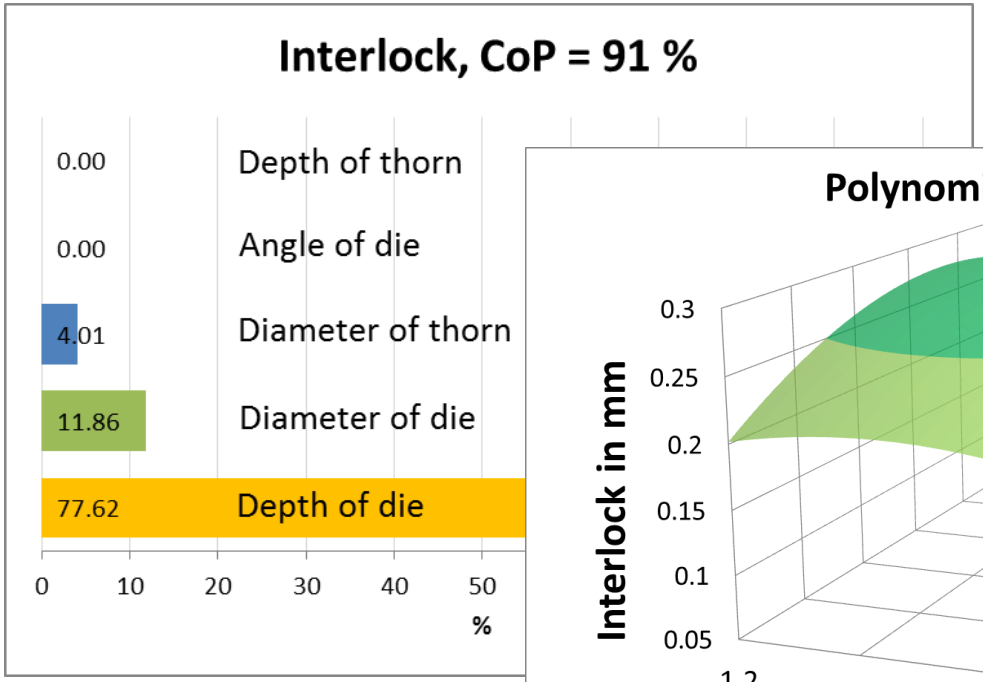
© Fraunhofer IWU

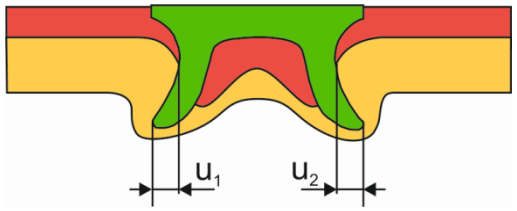
Fraunhofer IWU

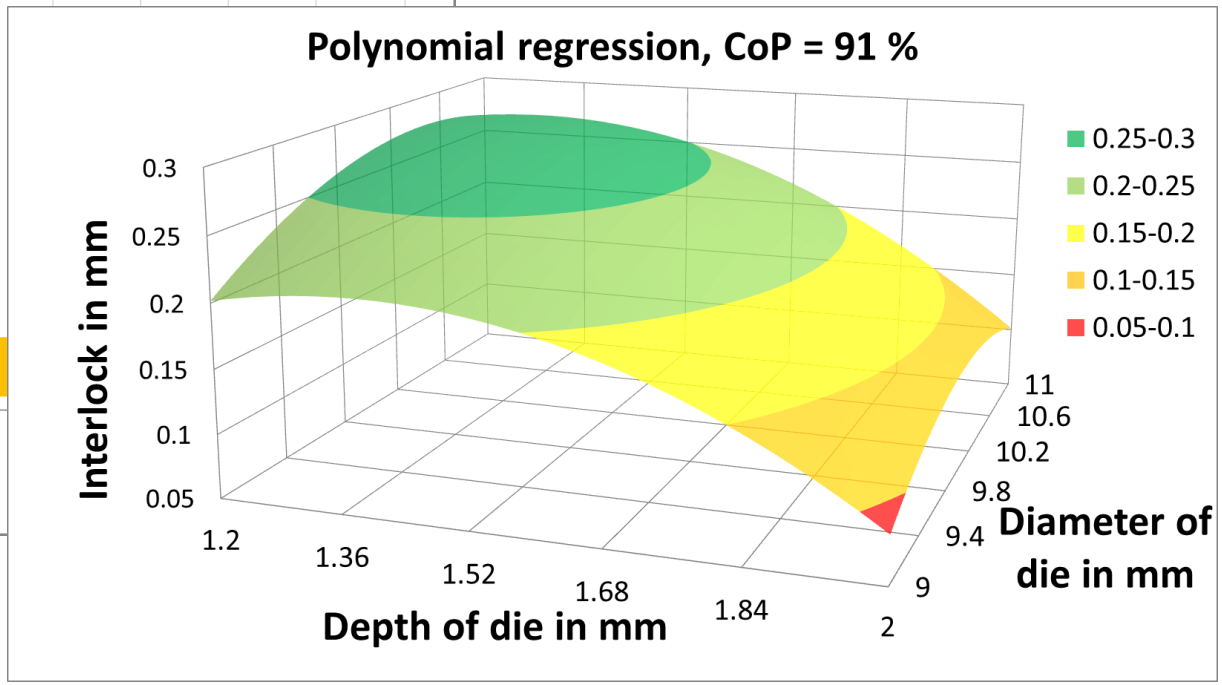
3. Sensitivity analyzes

Variation of die geometry

- Results of the analyzis







→ Depth of die has the main influence on all output parameters

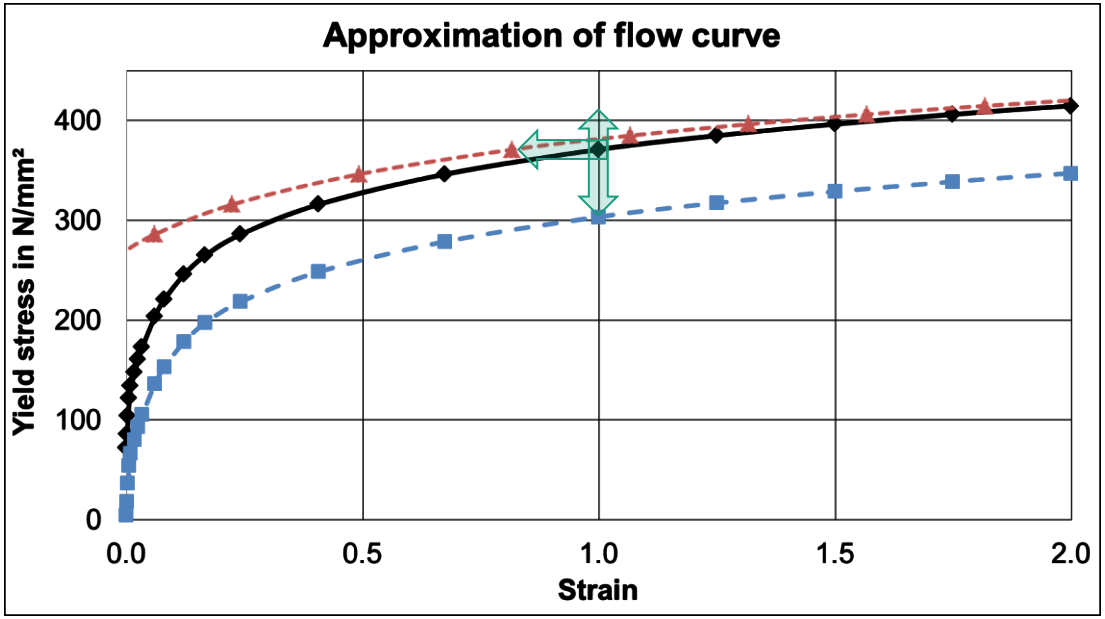
© Fraunhofer IWU

Fraunhofer IWU

3. Sensitivity analyzes

Variation of blank characterisitcs

- Input parameters



Parameter	Min.	Max.
Blankwidth in mm	1.84	2.16
Ult. tensile strength in N/mm²	170	250
Pre deformation in %	0	20

Approximated flow curve experiment

Approximated flow curve (min. ult. tensile strength = 170 N/mm²)

Approximated flow curve (pre deformation 20 %)

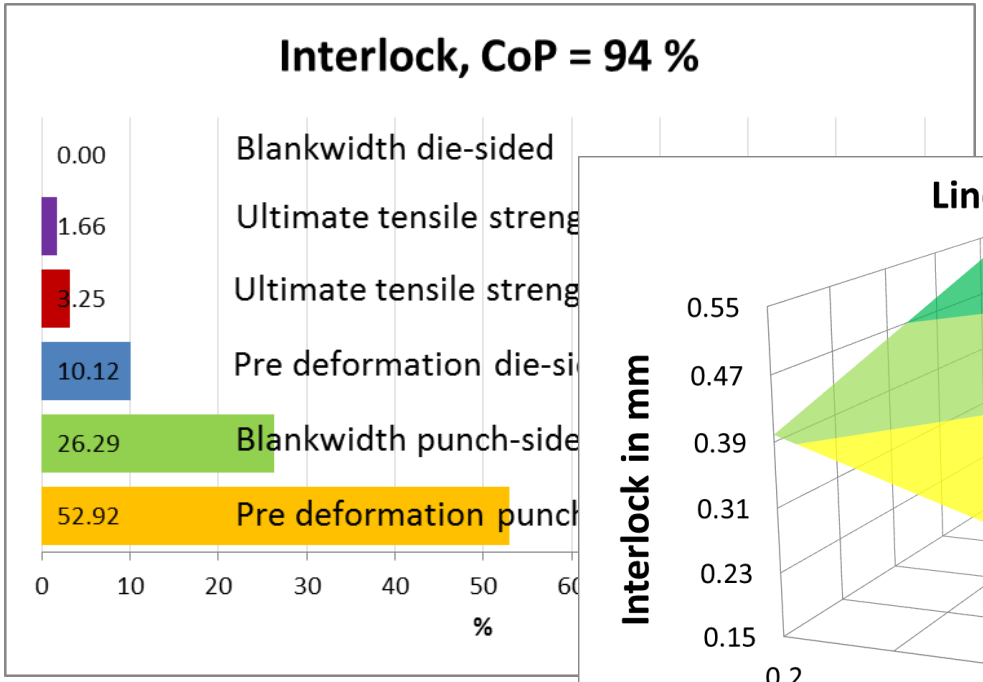
© Fraunhofer IWU

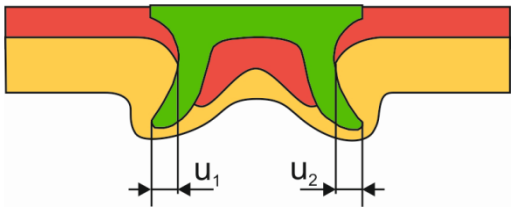
Fraunhofer IWU

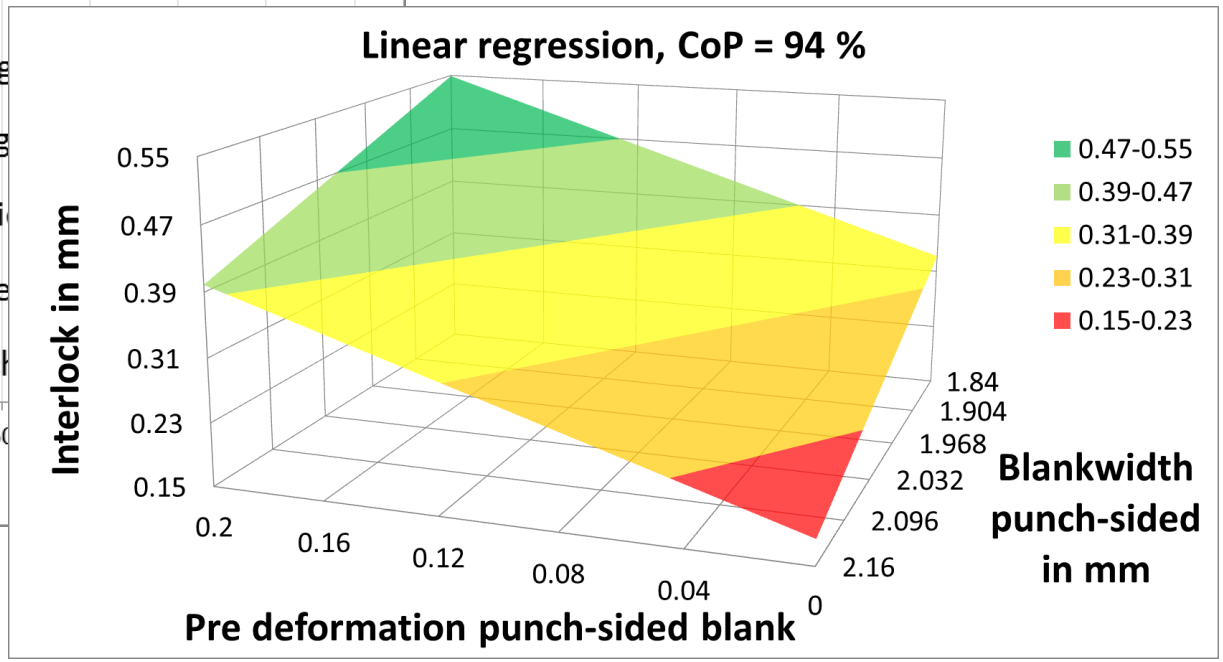
3. Sensitivity analyzes

Variation of blank characterisitcs

- Results of the analyzis







→ Pre deformation of the punch-sided blank has main influence on interlock

© Fraunhofer IWU

Fraunhofer IWU

CONTENTS

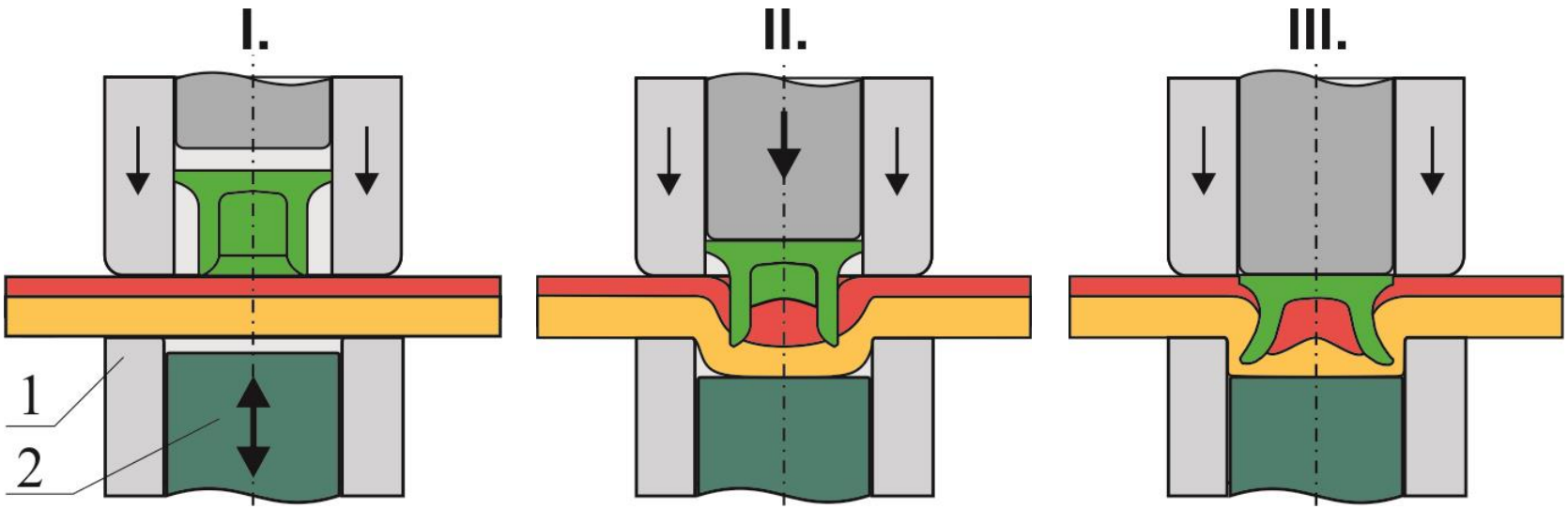
1. Self-pierce riveting with semi-tubular rivet (SPR-ST)
2. Simulation model and verification
3. Sensitivity analyzes
4. Improving flexibility of SPR-ST
5. Cyber physical systems to improve SPR-ST
6. Conclusion

© Fraunhofer IWU

Fraunhofer IWU

4. Improving flexibility of SPR-ST

- Alternative concept with a separated die → moveable die bottom



1. Die ring 2. Moveable die bottom

→ Possibility to change die bottom before setting

→ Compensation of changing boundary conditions, e.g. variation of blanks

→ Constant joint quality

© Fraunhofer IWU

Fraunhofer IWU

CONTENTS

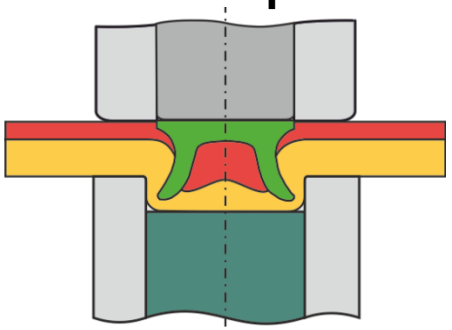
1. Self-pierce riveting with semi-tubular rivet (SPR-ST)
2. Simulation model and verification
3. Sensitivity analyzes
4. Improving flexibility of SPR-ST
5. Cyber physical systems to improve SPR-ST
6. Conclusion

© Fraunhofer IWU

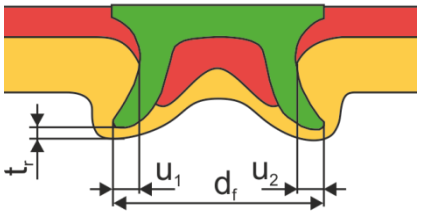
5. Cyber physical systems to improve SPR

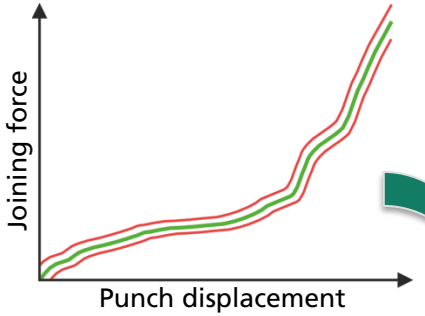
Self-adjusting mechanical joining process

1. Moveable die concept

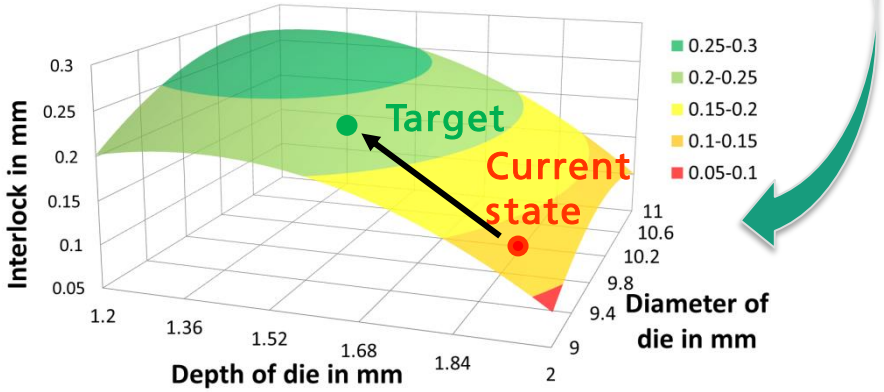


2. In process recording of joining characterstics

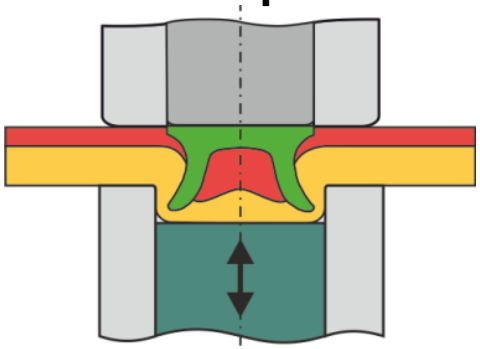




3. Feedback metamodel



4. Adjustment of die depth



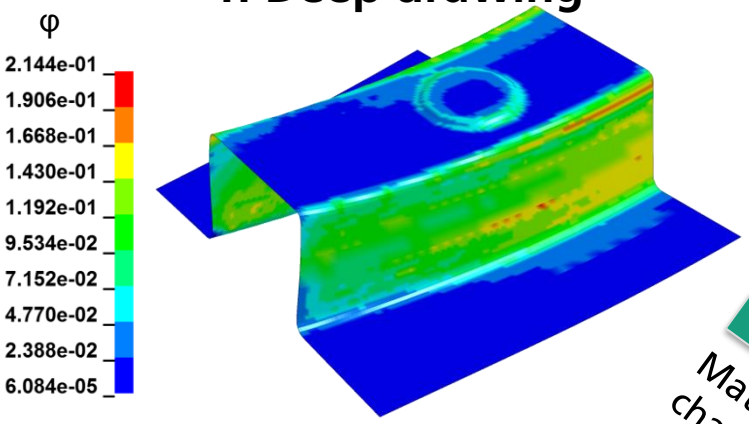
© Fraunhofer IWU

Fraunhofer IWU

5. Cyber physical systems to improve SPR

Link to previous processes

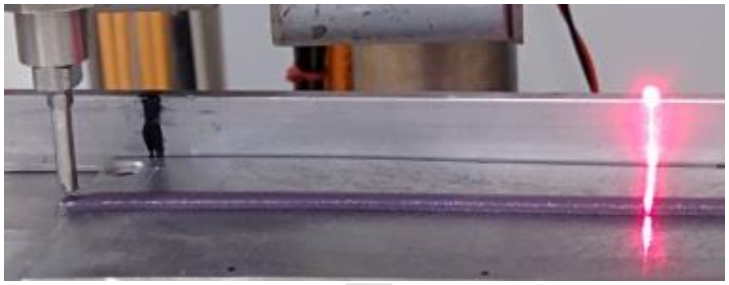
1. Deep drawing



Surface characteristic

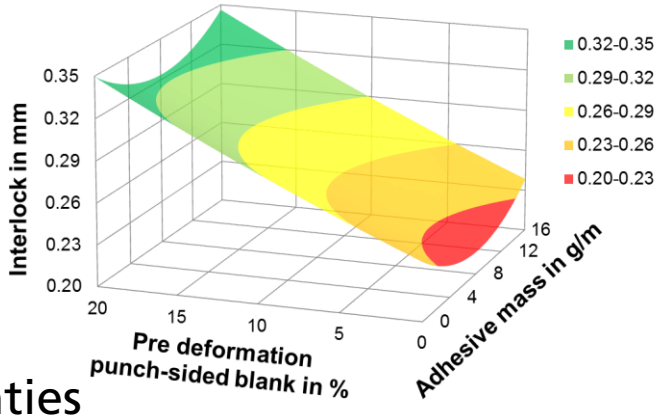
Material characteristic

2. Adhesive application

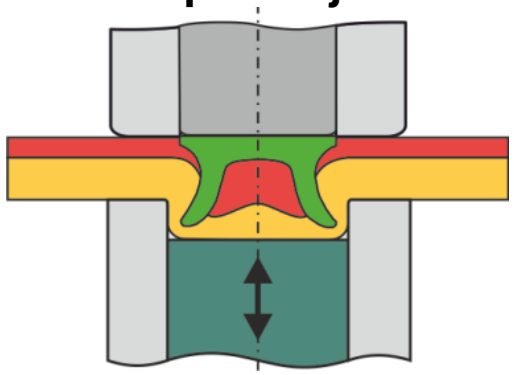


Adhesive volume

3. Feedback metamodel



4. Die depth adjustment



→ Joining process reacts on process uncertainties

© Fraunhofer IWU

Fraunhofer IWU

CONTENTS

1. Self-pierce riveting with semi-tubular rivet (SPR-ST)
2. Simulation model and verification
3. Sensitivity analyzes
4. Improving flexibility of SPR-ST
5. Cyber physical systems to improve SPR-ST
6. Conclusion

© Fraunhofer IWU

Fraunhofer IWU

6. Conclusion

- Validated simulation model of SPR-ST
- Sensitivity analyzes show influence of
  - die geometry parameters
  - and variation of boundary conditions

  on the joining result of SPR-ST
- The analyzis of the die geometry displays the great potential of the alternative die concept with moveable die bottom
- With the adjustable die depth it is possible to
  - → link the joining process to previous processes (e.g. deep drawing)
  - → react on variation of boundary conditions
  - → improve flexibility and quality

© Fraunhofer IWU

Thanks

reinhard.mauermann@iwu.fraunhofer.de

© Fraunhofer IWU

Fraunhofer IWU