CLECIM
FRANCE

Finding the optimal parameters for laser welding of steel plates

Discovery Summit – 2022-EU-45MP-1013

Stéphane GEORGES

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Introduction CLECIM

Identity, Activities

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Laser Welding, DoE, Covariates

Identity Card

CLECIM

- Engineering and production company of equipment for the steel industry
- Montbrison (~Lyon, France)
- 100 years old in 2017
- 120,000 m^2
- 230 employees
- Executives and technicians
- Males 80%
  Females 20%

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Laser Welding, DoE, Covariates

CLECIM's Activities

Main Activities

- Studies and consulting activities for our flat steel producer customers
- Supply of individual machines
- Supply of complete production lines (pickling, annealing, galvanizing, painting, etc.)
- Services (spare parts, maintenance, etc.)

Examples of machines

- Rolling equipment (rolling mill, plate leveller, etc.)
- Automated strip surface inspection system
- Laser welder

Example of a galvanizing line

Automotive market
Length ~500m
Height ~35m

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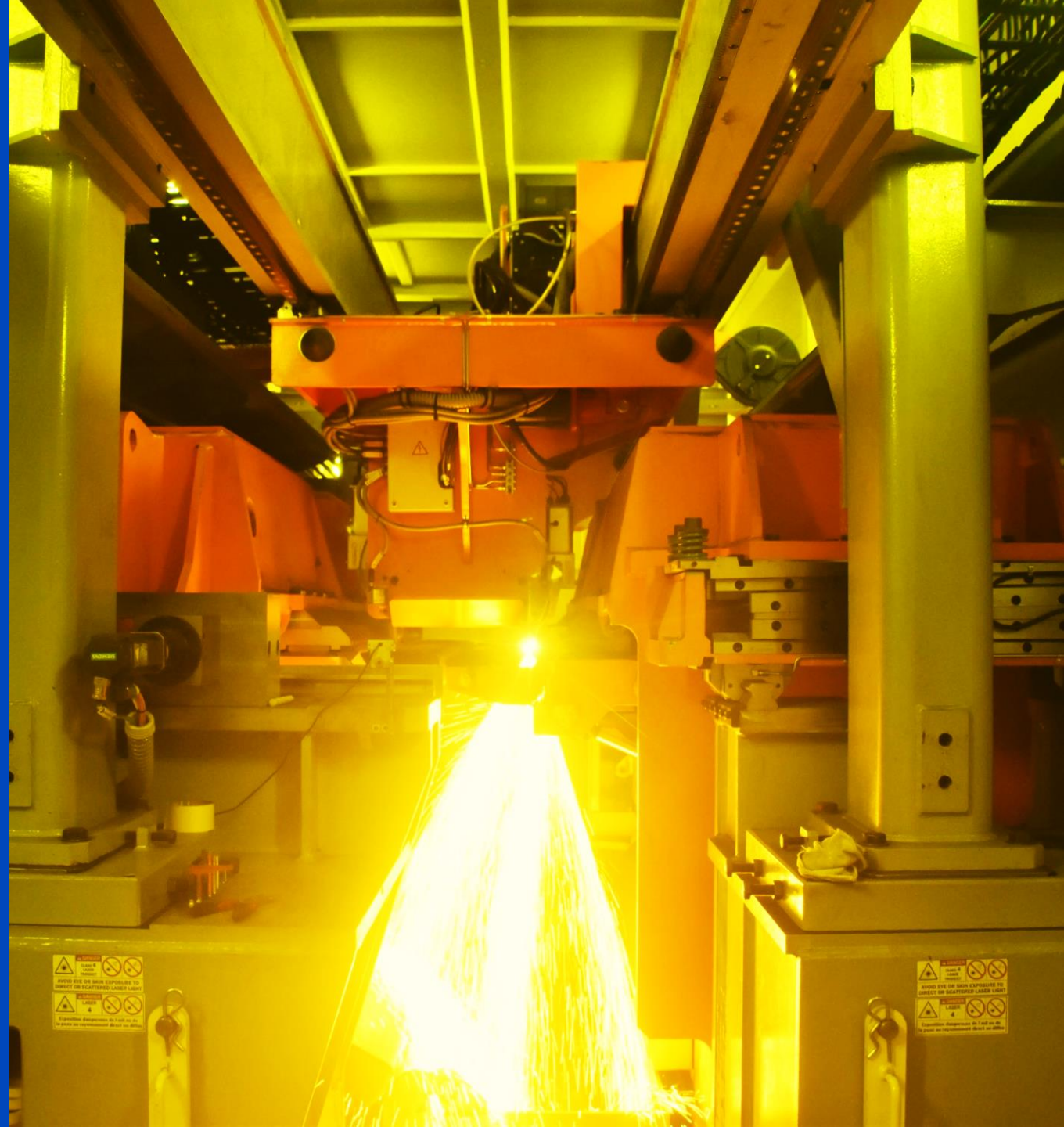
Autogenous Laser Welding

Process, Factors



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Laser Welding, DoE, Covariates

Subject of our Study – Laser Welder

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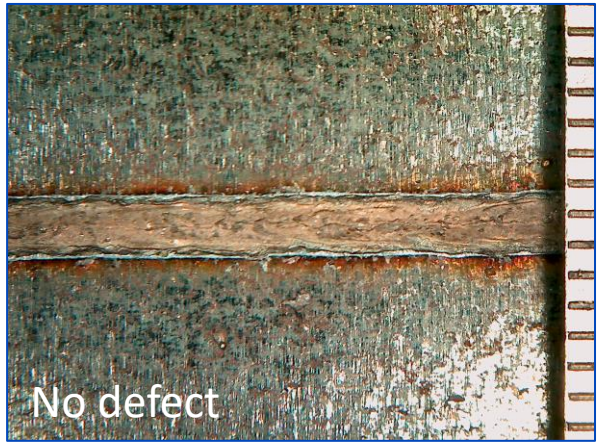
Laser Welding, DoE, Covariates

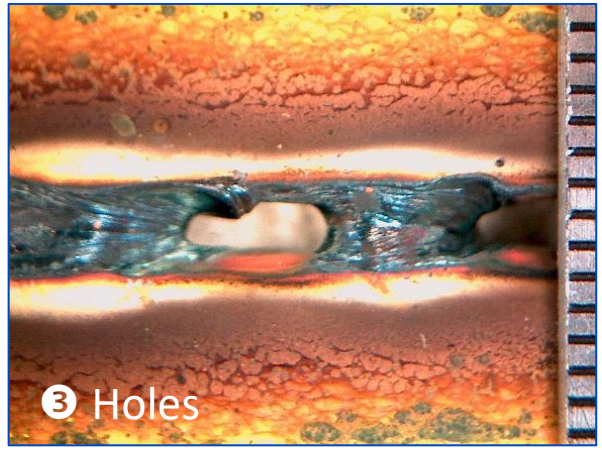
Objectives and Constraints

! A good weld = 2 objectives

The weld bead must:

- **Be free of defects**
  - Without spatters ❶
  - Without chain of pearls ❷
  - Without humpings
  - Without underdfilling
  - Without holes ❸
  - Etc.
- **Have a good resistance**
  - Evaluated via an Erichsen type cupping test
  - Be as close as possible to the strength of the material itself





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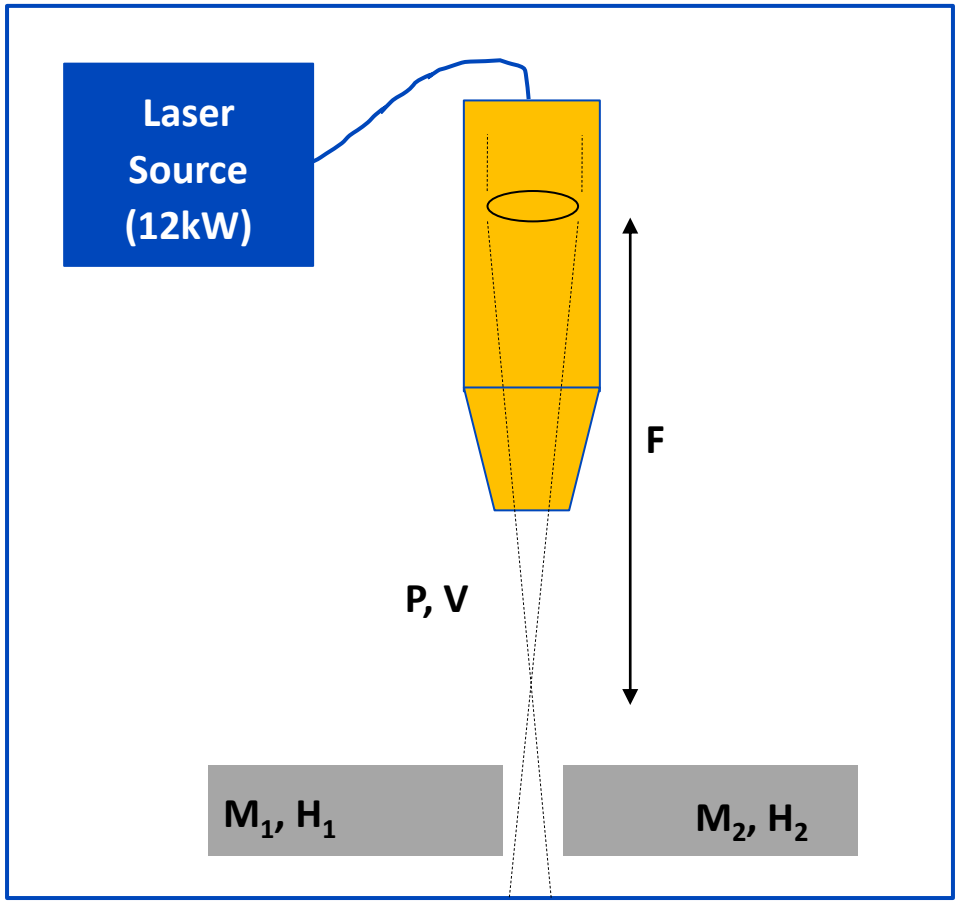
Laser Welding Parameters



Material Parameters

M Material type
H Material thickness

Process Parameters

P Used laser power
V Travel speed of the welding carriage
F Focusing distance
G Gap between the plates
TT Thermal treatment
Etc…

In the rest of the presentation:

- Only P and V will be considered
- Materials will be identical and of the same thickness

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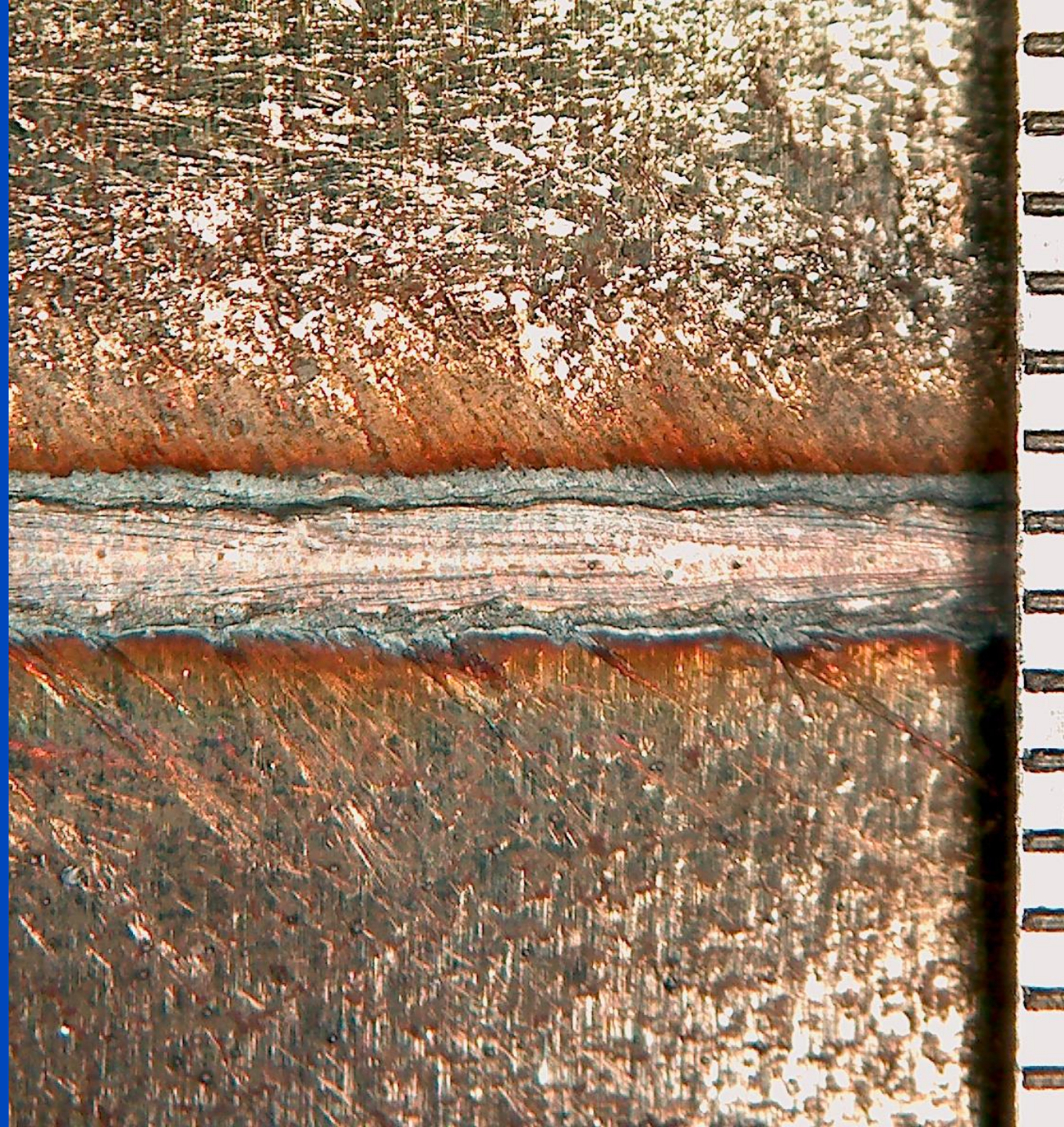
Towards a Good Weld

JMP Analysis



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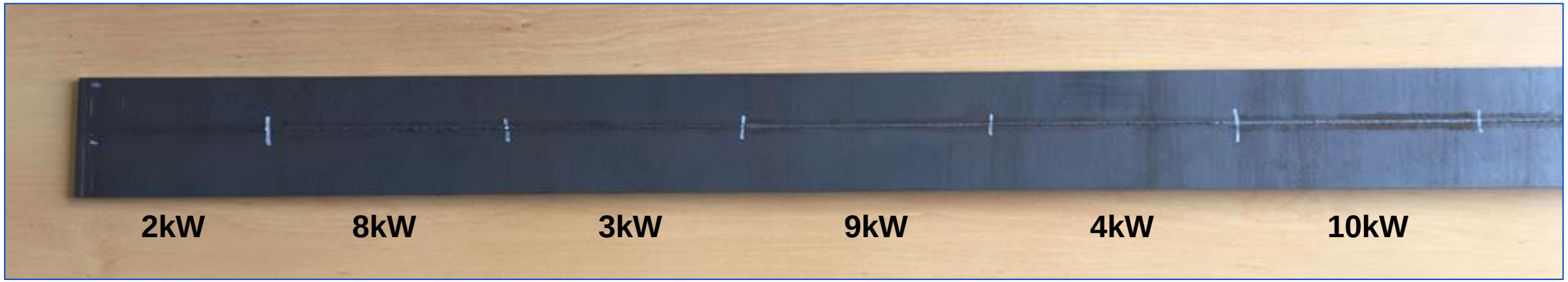
Weldability Lobe

Data acquisition using the so-called « Power Jumps » procedure

- Fixed welding speed
- On the same sample, 11 successive power jumps (from 2 to 12kW)
- Visual examination of the weld beads

Mapping of defect areas can be viewed with the **Graph Builder** platform



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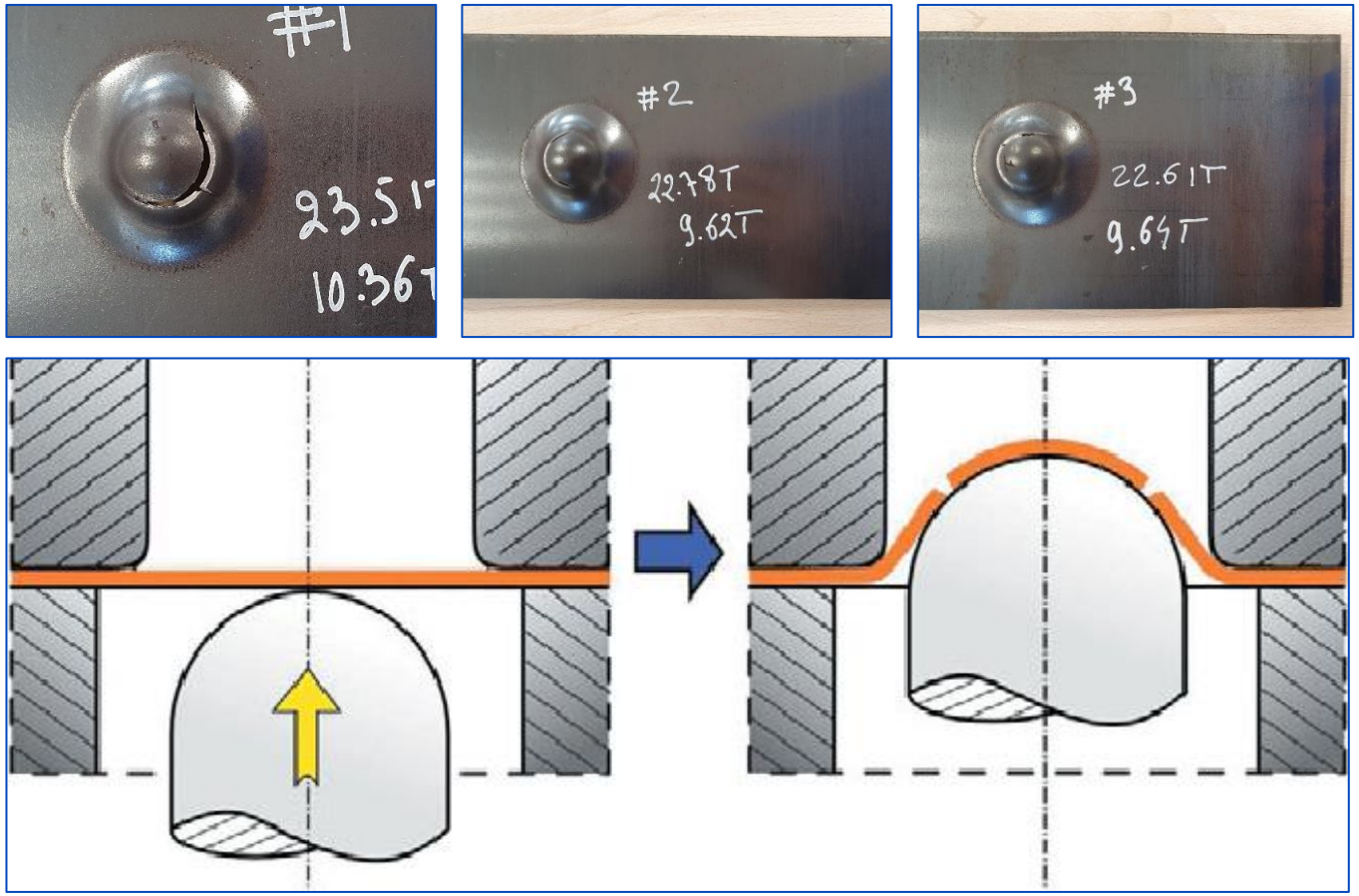
Basic Material Strength

Evaluation of the basic strength of the material via an Erichsen-type cupping test

3 objectives

- Establish a reference for the material, as a point of comparison
- Check that the 2 test plates supplied by the customer are comparable
- Check that the plates are homogeneous and do not present any resistance profile in their width

The **Fit XbyY** and **Distribution** platforms are used for these studies.



Crédit photo: Application of laser speckles to localized necking and cracking detection in Erichsen cupping test, CEZARY JASIŁSKI, ROK WYD. LXXIII, ZESZYT, 9/2014

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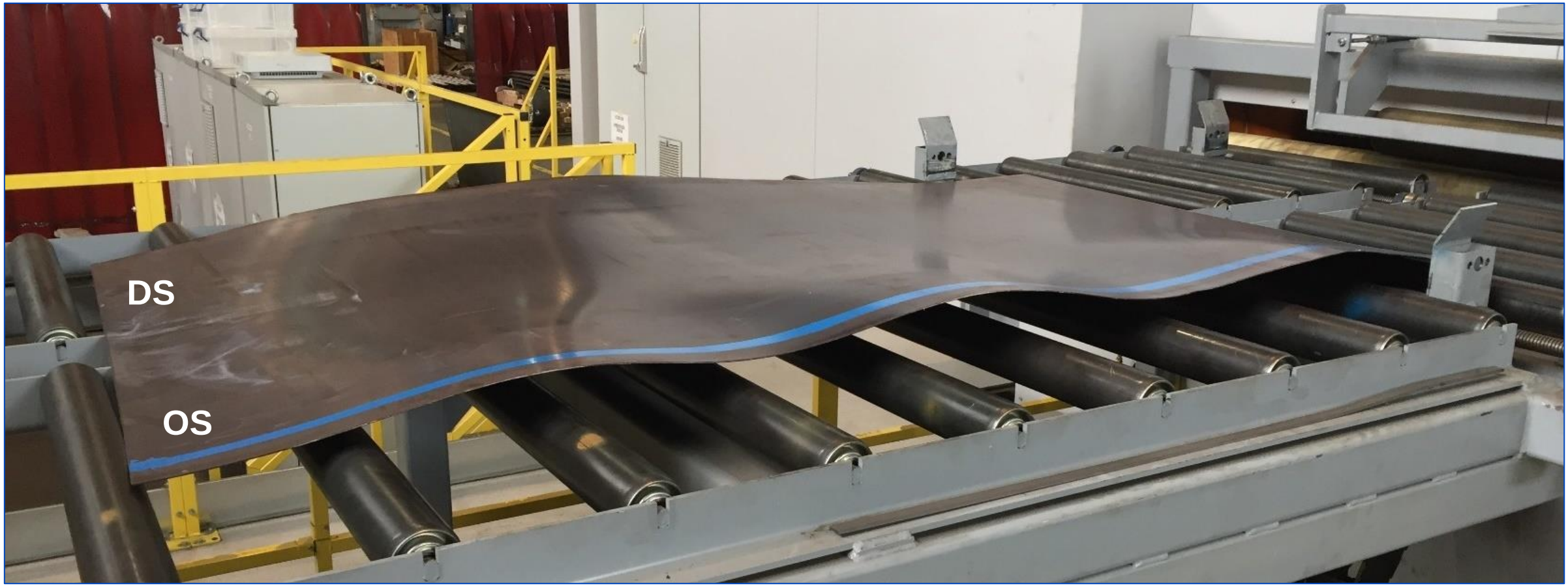
Appearance of the Sheet Metal



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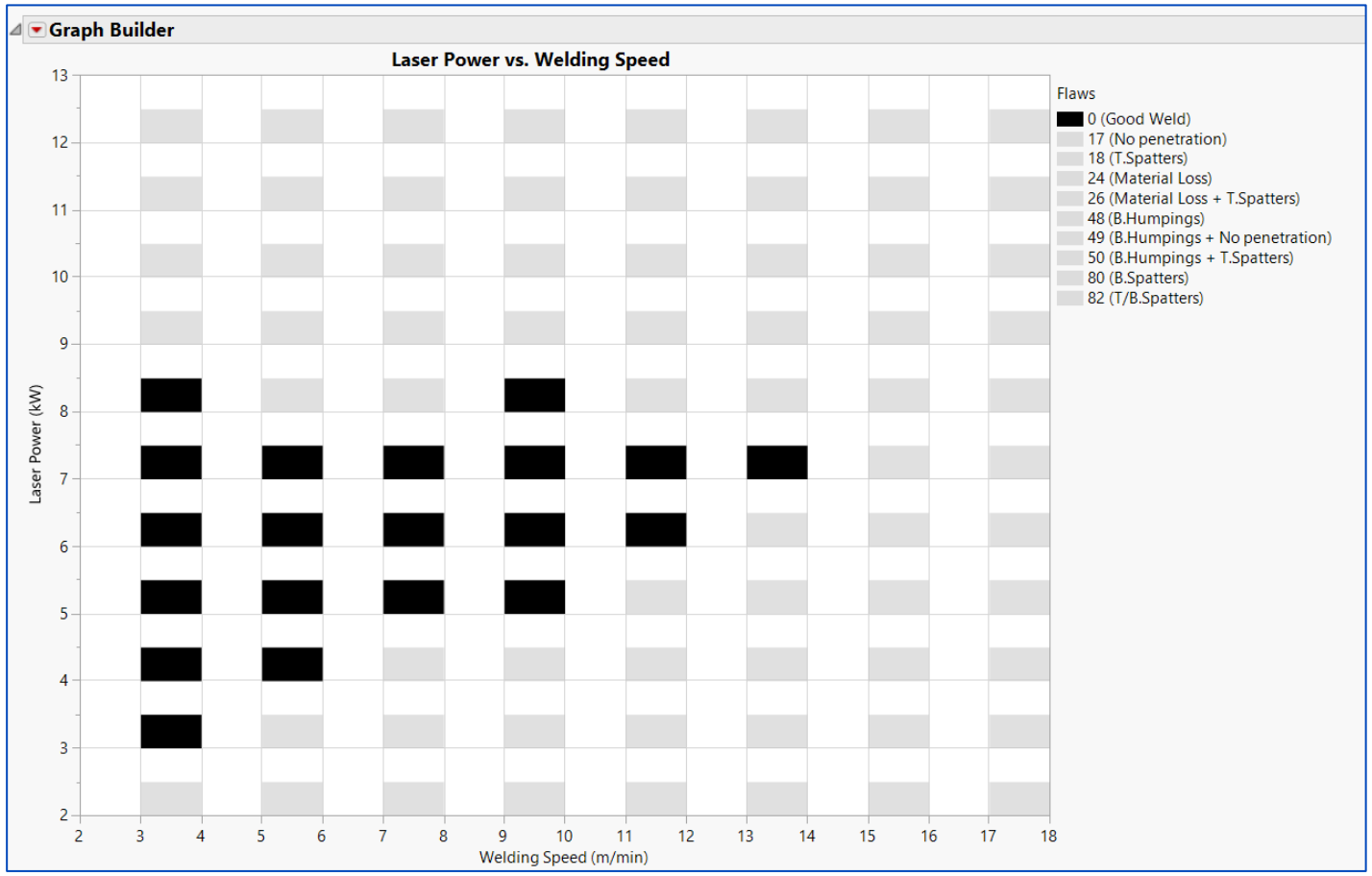
Weld Strength and Constraints



Very irregular study area

The traditional way would be to fill in linear constraints.

Instead, use the **Candidates Points** technique (**Covariates**)

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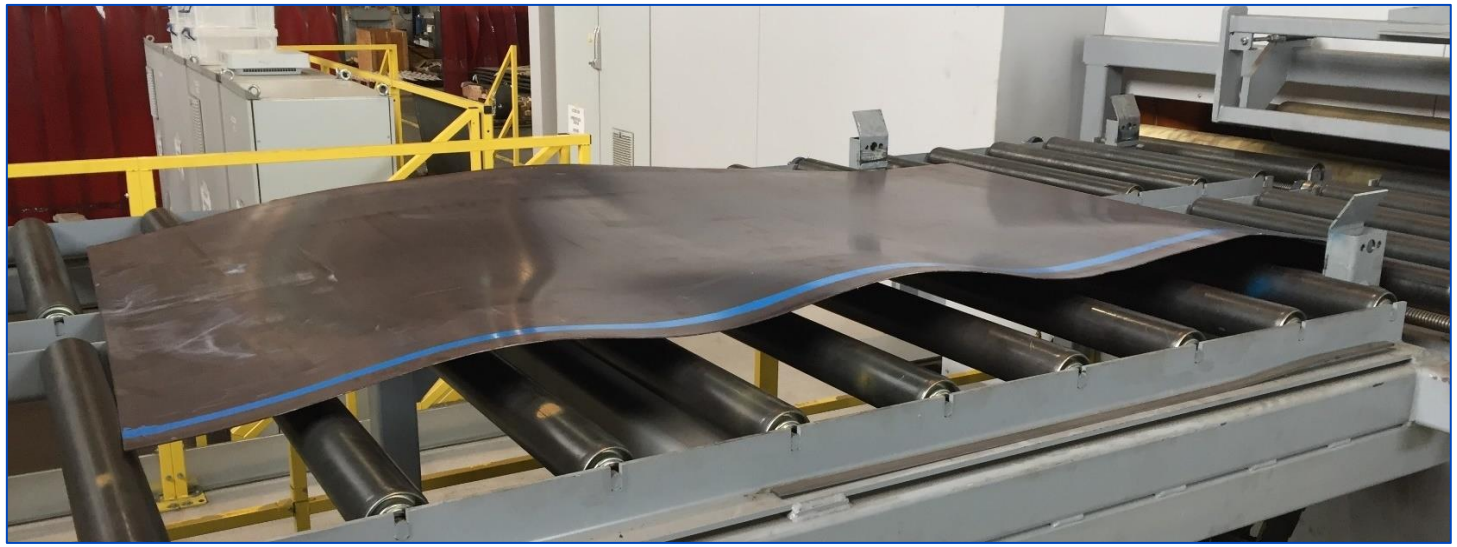
Weld Strength and Constraints



Inhomogeneous plate

Strength variations in width

jmp | **3 Levels-Categorial** parameters (DS, C, OS)

Incurred strength variations in length

jmp | Weld position as an **uncontrolled** parameter

Non-independent strength values DS, C and OS (belong to the same treatment)

jmp | **Hard/easy-to-change** parameters (split-plot design)

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Confirmation of the Optimum (1/2)

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Confirmation of the Optimum (2/2)

DS-Strength - **89.9%**

C-Strength - **94.1%**

OS-Strength - **96.6%**

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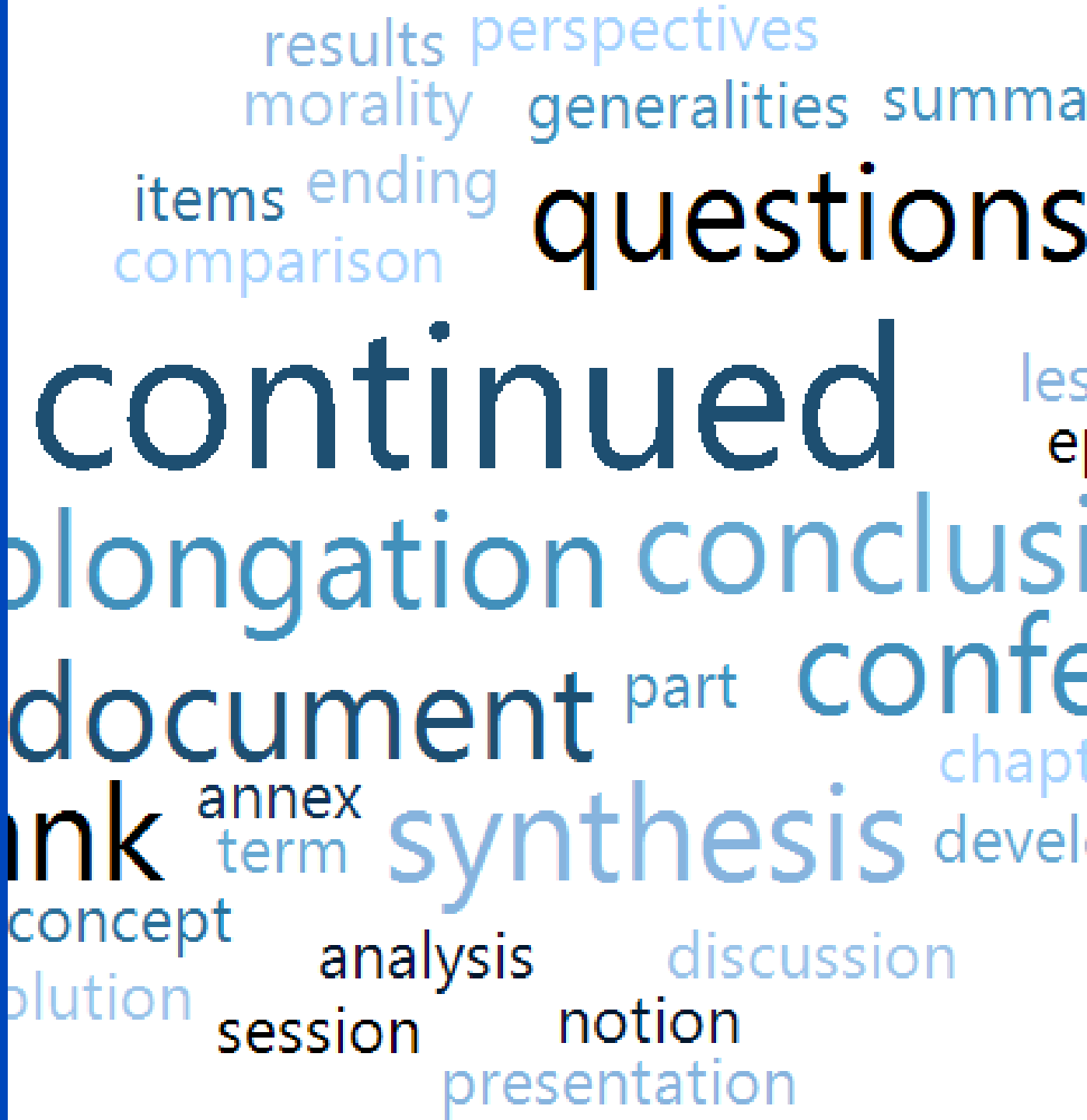
Conclusion
Resources
Questions



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Conclusion

[Learn more about Covariables]

JMP User Community

Ryan_Lekivetz STAFF

What is a covariate in design of experiments?

Webinar

Developer Tutorial - Handling Covariates Effectively when Designing Experiments

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> “Facts are stubborn things, but statistics are pliable.”
>
> Mark Twain
> American humorist, journalist, lecturer and novelist

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