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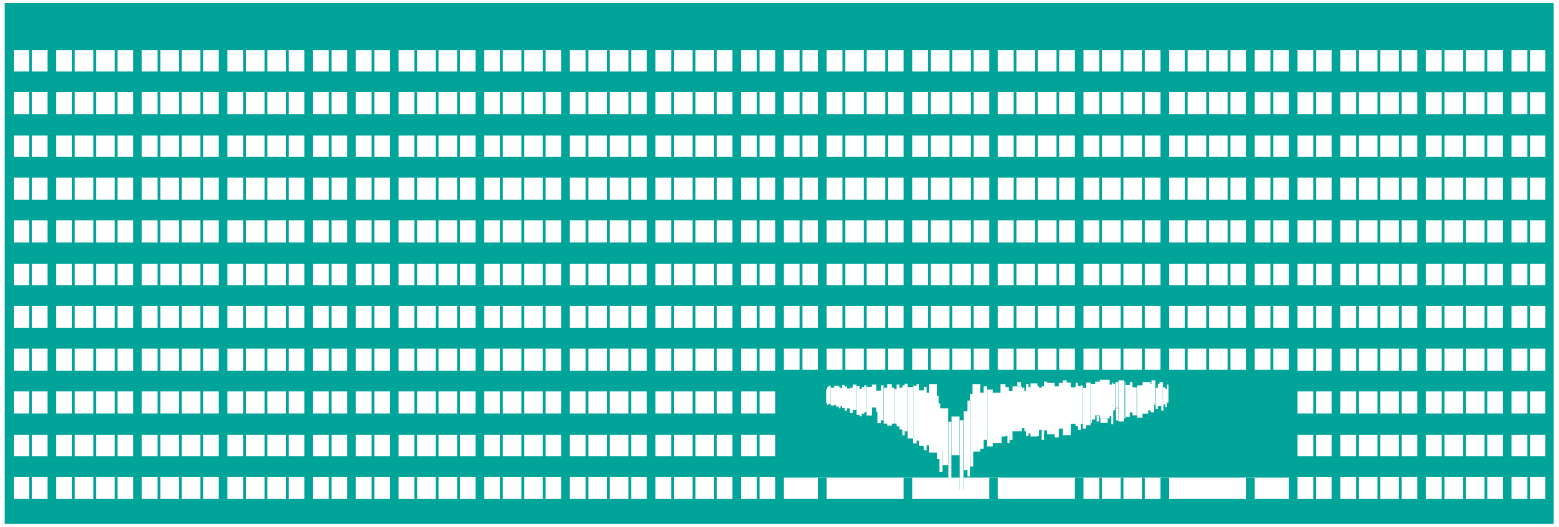

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VSB TECHNICAL UNIVERSITY OF OSTRAVA | FACULTY OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE | DEPARTMENT OF CYBERNETICS AND BIOMEDICAL ENGINEERING

Using sensors and advanced signal processing for the needs of Industry 4.0 and SMART technologies

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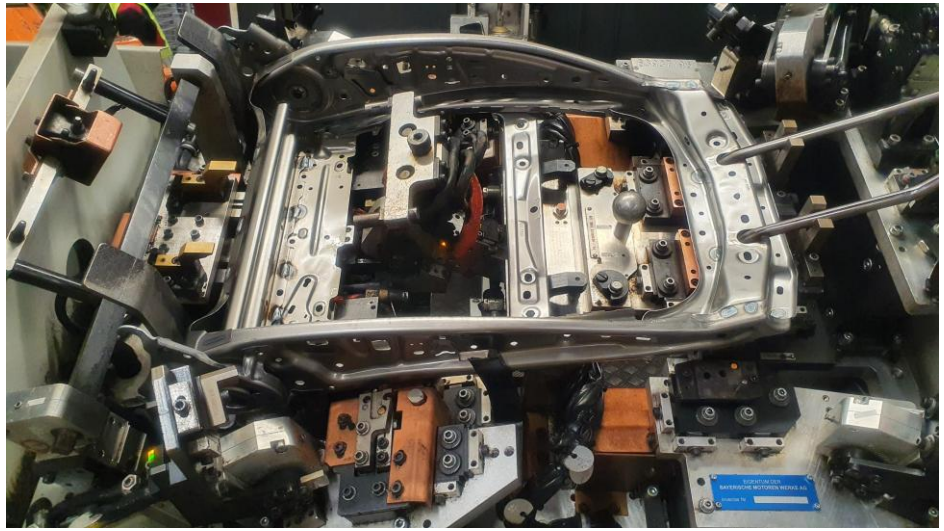
Process Investigated: Robotic Welding

Arc welding with a consumable electrode in active shielding gas – Metal Active Gas MAG.

Weld defect detection system was designed and tested within the robotic workplace.

Acoustic emission monitoring and analysis in the field of welding.



Monitoring System

PC-based system with a data acquisition board

- Sampling rate: 51,2 kS/s
- Resolution: 16-bit ADC

Measured Signals:

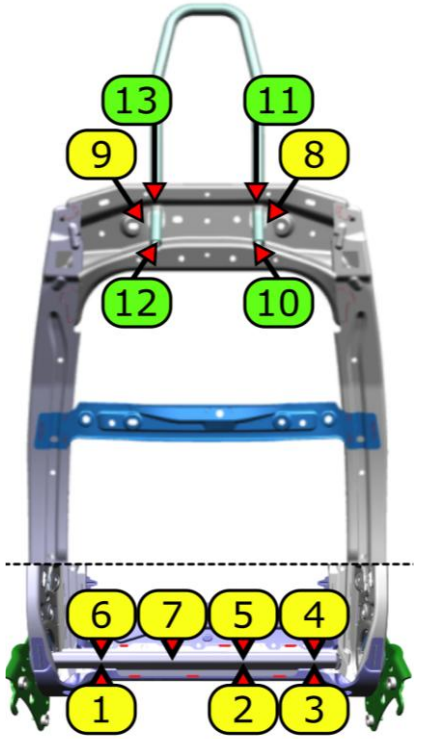
- Acoustic emissions
- Arc voltage and current

Test Conditions:

- Short weld joints
- Various product geometries
- Performed inside partially or fully enclosed welding cells

Welding Cell and Weld Locations

Each product (car seat) contains 13 welded joints at predefined locations.



Welding Machine Parameters Configuration:

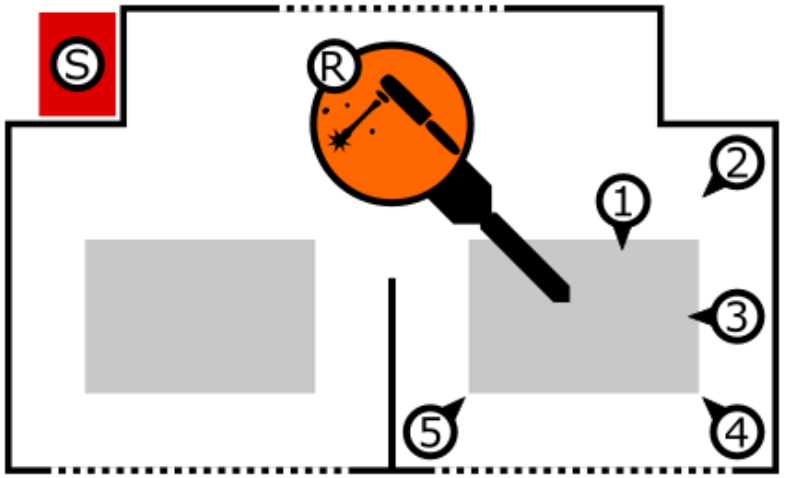
- Joints 1–6: Parameters varied to produce both OK and NOK welds.
- Joints 7–13: Parameters set for correct welds only.

Acquired Signal Dataset:

- 8× OK products
- 6× NOK products

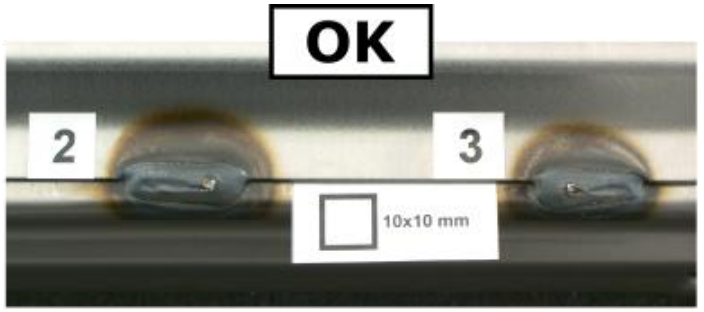
Microphone Placement:

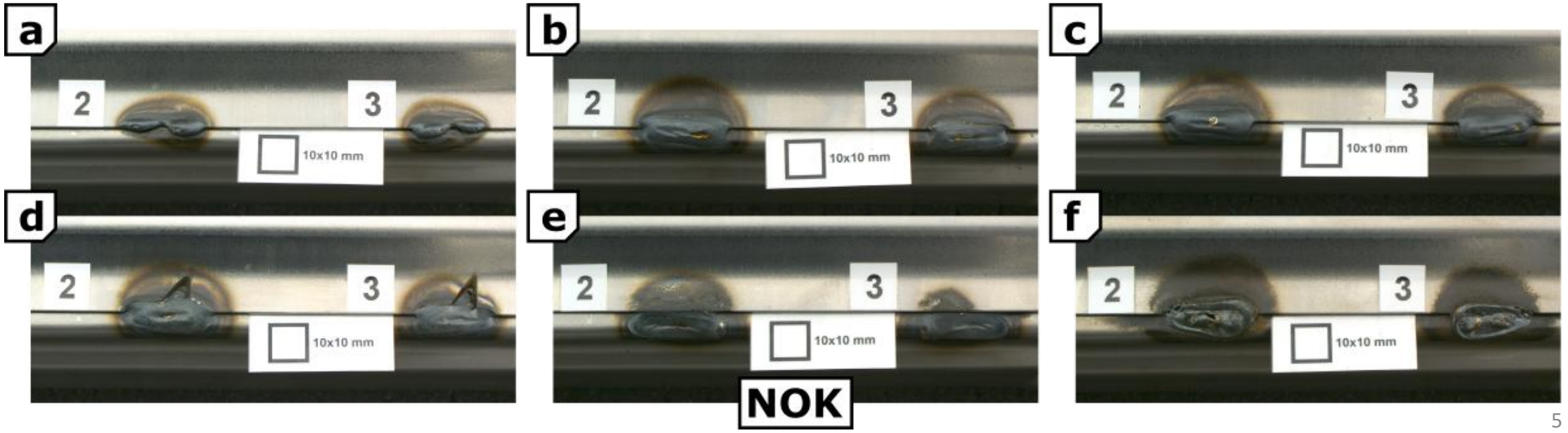
- 5 microphones mounted along the inner wall of the welding cell.
- Signal characteristics vary based on the microphone's position relative to the weld joint.



Welding Parameters for NOK Welding Joints

a) Welding wire feed speed
b) Arc length correction
c) Dynamics correction
d) Surface damage
e) Weld position
c) Shielding gas atmosphere





Spectrograms of Defective Weld Joints Sound

Columns:

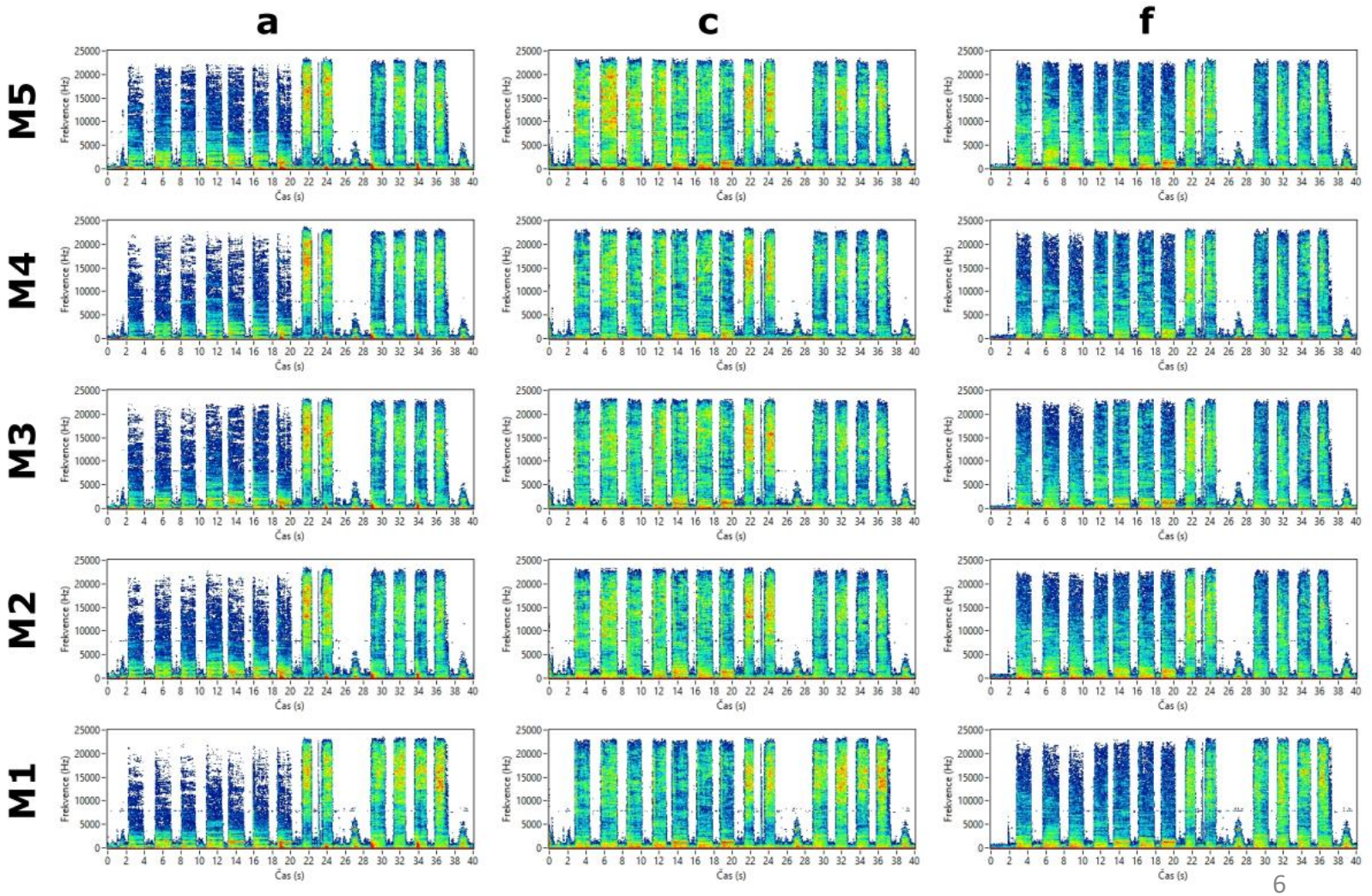
a) Welding wire feed speed

b) Dynamics correction

c) Shielding gas atmosphere

Rows:

M1 – M5 microphones



Detection of Significant Features in Signals

Type of Modification	Time Domain	Frequency Domain	Time-Frequency Domain
Welding wire feed	**Yes**	**Yes**	**Yes**
Arc length correction	No	No	No
Dynamics correction	No	Inconclusive	Inconclusive
Surface damage	Inconclusive	No	Inconclusive
Weld position	No	No	No
Shielding atmosphere	**Yes**	**Yes**	**Yes**

Heuristic method used. Some recordings could be distinguished by changes in the intensity of the measured signal and changes in the ratios between the frequency bands.

YES = subjectively, a person can distinguish this 2 types of NOK cases from data analysis.
NO = no chance to distinguish

Classifier Design and Optimization

Dataset preparation: extracted the weld joints Nr. 1-6 (potentially defective)

Each product has 6 weld joints, each measured by 5 microphones → 30 recorded signals per product

In total signals from 14 identical products recorded, (but different welding machine parameters setup)

- 8 OK (reference) products measured, 8x6= 48 welds, 48x5 mic = 240 signals recorded
- 6 NOK products with introduced different known defect type measured, 6x6= 36 welds, 36x5 mic = 180 s.r.

Dataset	Type	Size	Description
Input vector	Frequency domain	20	Frequency bands
	Microphone ID	1	Defines its position in the welding cell
Output vector	Binary classifier	1	OK / NOK
	Multiclass classifier	7	OK / 6 types of NOK

Classification by Frequency Bands

8 OK products, 8x6= 48 welds
6 NOK products, 6x6= 36 welds
Total 84 welds

60% learning dataset
20% validating dataset
20% testing dataset

Sensitivity - how many positive records correctly predicted.

Specificity - how many negative records correctly predicted.

Precision - how many correct predictions out of all predictions for a specific class.

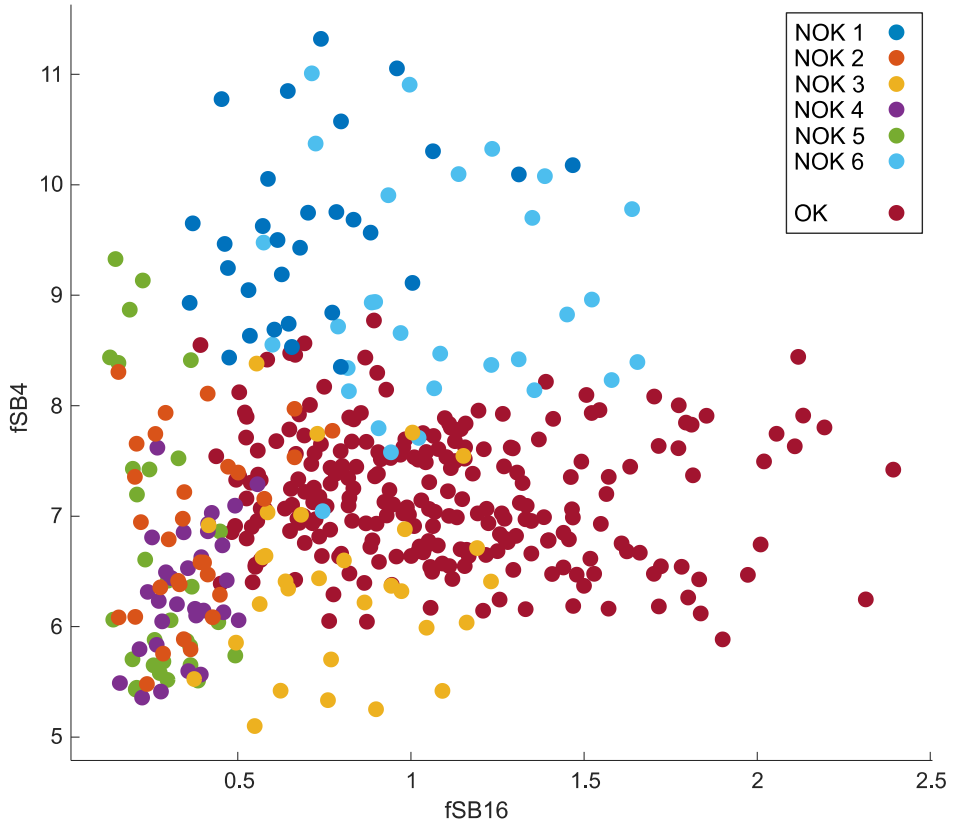
SVM – Support Vector Machines

	Prediction		
Type	OK	NOK	
OK	**48**	**0**	100,00 % **Sensitivity**
NOK	**3**	**33**	91,67 % **Specificity**
	Precision		**Accuracy**
	94,12 %		96,43 %

ANN – Hidden Layer (100)

	Prediction		
Type	OK	NOK	
OK	**47**	**1**	97,22 % **Sensitivity**
NOK	**1**	**35**	97,92 % **Specificity**
	Precision		**Accuracy**
	97,22 %		97,62 %

TN	FP	FN	TP



Monitoring of Normal Operation

Objective:

- Capture weld defects while maintaining optimal welding process parameters.

Measurement Setup:

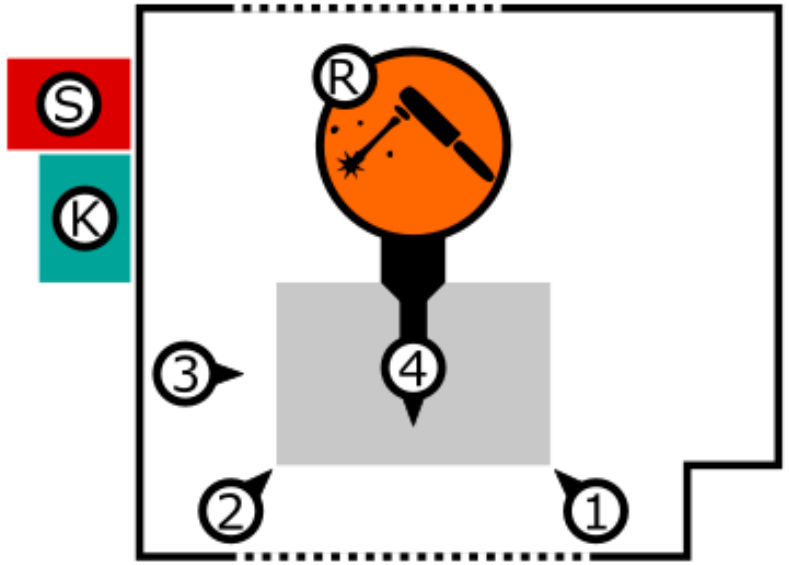
- Microphones mounted along the inner wall of the welding cell and on the welding torch.
- Multiple welding cells were used for testing.

Dataset Overview:

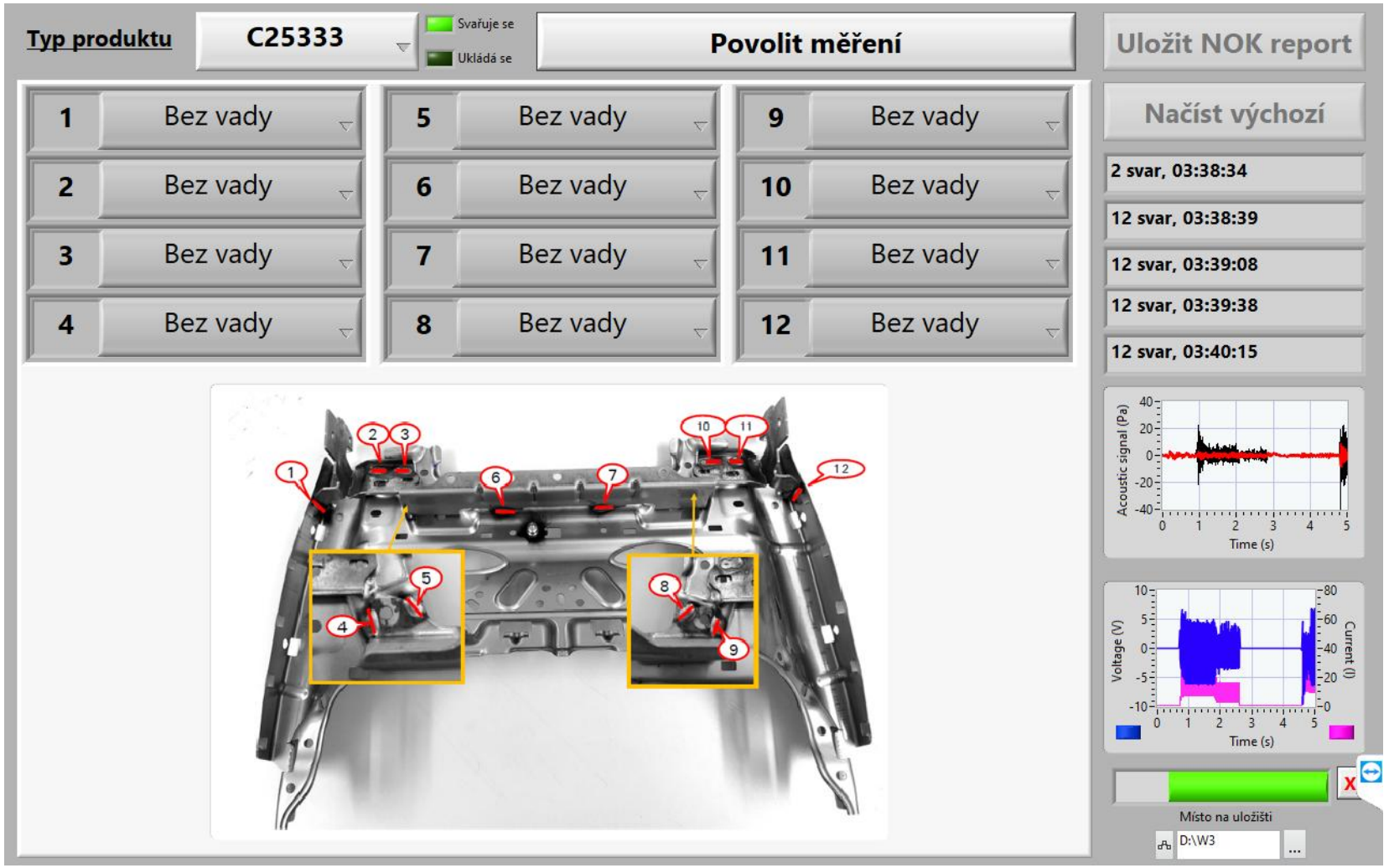
- Signals recorded from 27 000 products,
- 1 067 samples were annotated by an operator,
- among them, 19 samples contained an actual weld defect (NOK).

Usage:

- Dataset served to verify the proposed defect identification procedure.
- Detected historical trends in metrics, e.g., wear of copper cooling blocks.



Operator User Interface for Records Annotation



Summary

Time and Frequency Domain Analysis:

- Defined 17 time-domain and 21 frequency-domain metrics to describe the welding process.
- Initial results showed suboptimal classification performance (87.4%).

Feature Set:

- Introduced 20 metrics based on frequency band analysis.
- Trained Support Vector Machine SVM and Artificial Neural Network (ANN) models.
- Achieved classification accuracy of up to 97.6%.

Acoustic Emission analysis is effective for:

- Detecting abnormal welding conditions.
- Identifying artificially introduced weld defects.
- Integration into robotic welding cells is feasible and promising.

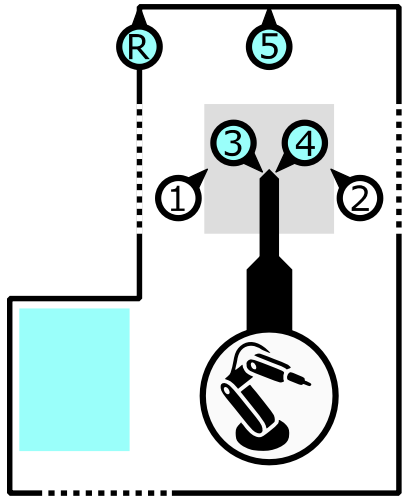
Process Investigated: Car Seats Noise

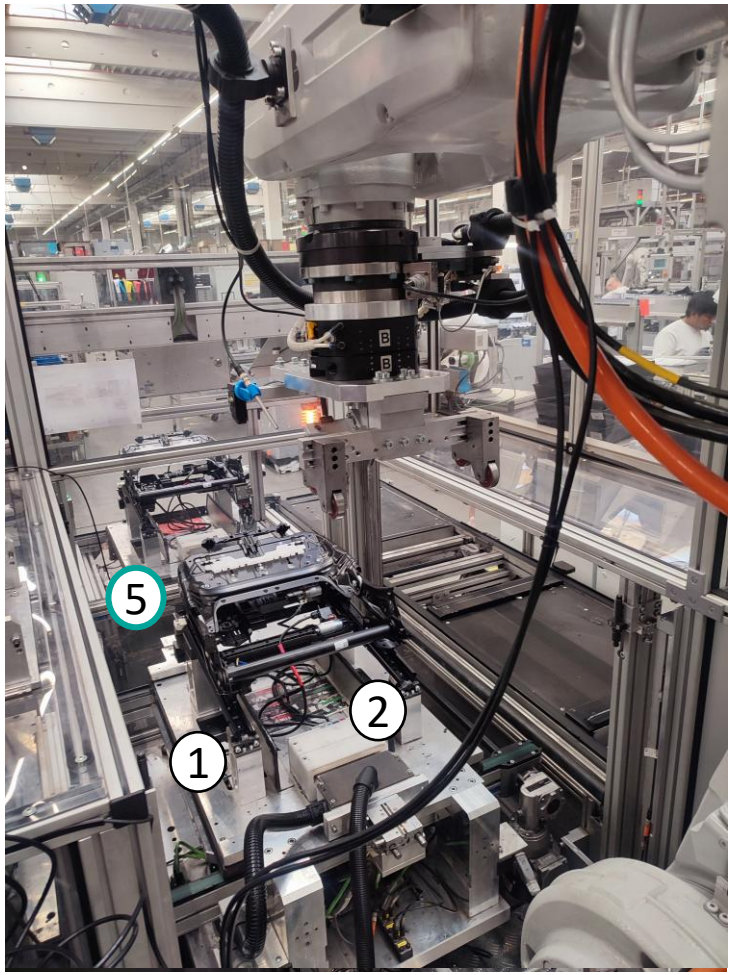
Defined Scope:

- Test scenarios focused on seat adjustment mechanisms,
- vibration data collected using two accelerometers,
- initial evaluation based on standard vibration metrics.

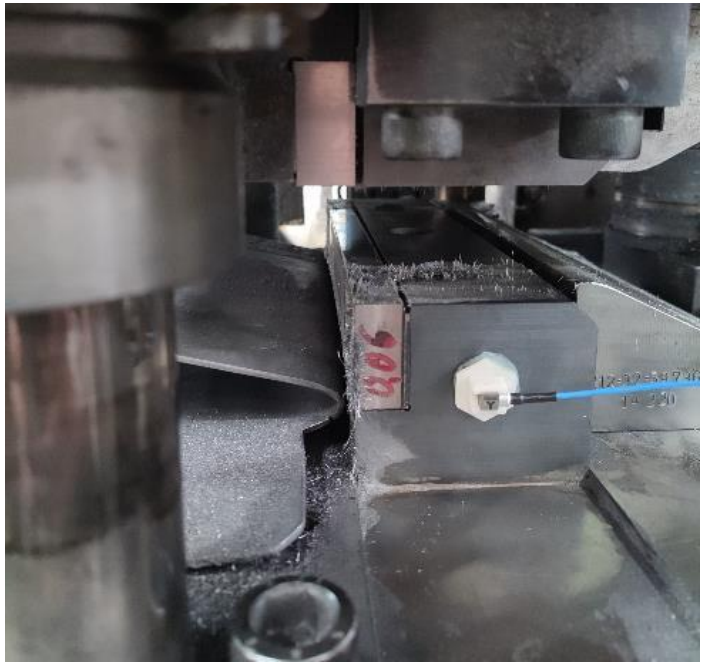
Extended Experiment:

- Ongoing collaborative effort to improve defect detection,
- acoustic emissions captured using three microphones,
- one reference microphone used for comparison, calibration, background noise reduction
- development of custom metrics for enhanced quality assessment.





Wear of Machine Shears Blades

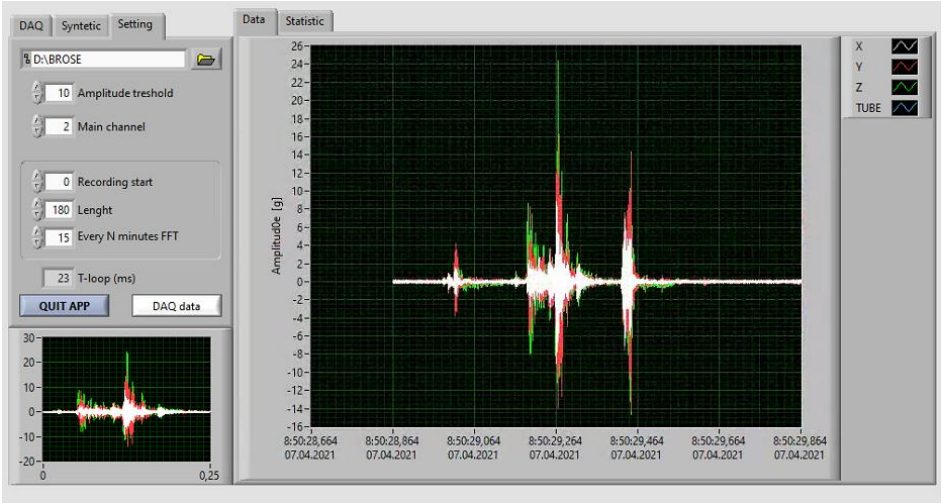


Condition Monitoring and Predictive Maintenance in Sheet Metal Cutting.

Standard 3-axial accelerometers used for vibrations acquisition.

Additional optical fiber Bragg grating sensor used.

Advanced signal processing methods used to evaluate shears blades wear.



Thank you for your attention

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