

T5.5 Case study for Problem-Based Learning (PBL)

Title of Case Study / Problem-based learning case:

Cracking of COVAR - Tantalum joint in Aerospace Application

Author: ir. W Verlinde, IWE, IWI-C
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Background:

- The Tantalum tube is welded by **laser welding** to a Kovar (54Fe - 29Ni - 17Co) adaptor
- TA
 - Diameter = 4.77 mm
 - thickness = 0,5 mm
- COVAR
 - Chemical composition KOVAR: 53% iron, 29% nickel, and 17% cobalt
 - Diameter = 6,35mm
 - Thickness = 1 mm
- A crack was discovered after vibration tests.

Technical challenge

- What tests can you perform to determine the nature and cause of cracking (Root Cause Analysis = RCA)?
- Use AI (Perplexity) to find a scientific article to check the weldability (problems) of COVAR-Ta. This might help to decide on how to solve the problem.
- Determine after the RCA what test you could perform to pass the vibration test successfully?
 - How can you test this on small samples?
 - Additional constraint: there is no time for extended fatigue tests



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Illustration of the case study

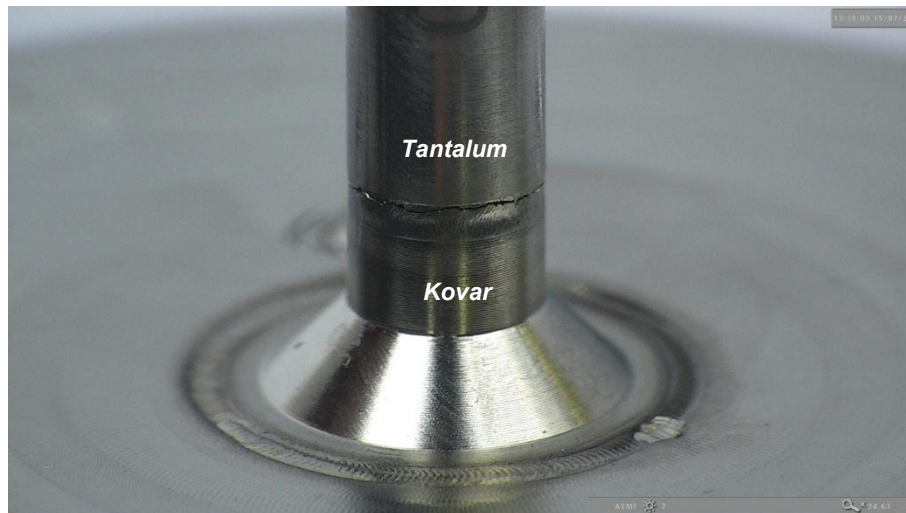


Figure 1: Stereoscopic view of the crack

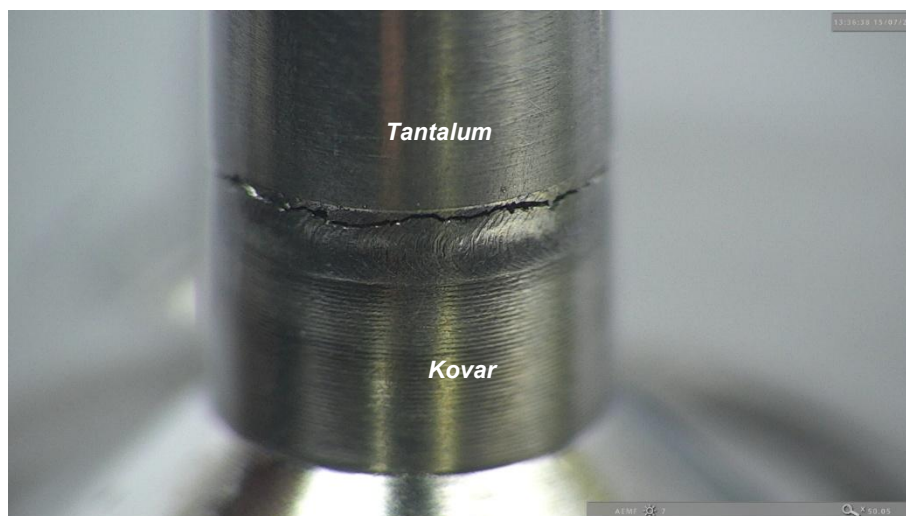


Figure 2: Stereoscopic view of the crack



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Detailed solution/ process

- Root cause analysis
 - Electron microscopy: SEM-investigation reveals a brittle fracture (large grains) and the chemical composition in the cracked area is a mixture of tantalum and Kovar (rich in tantalum)
 - Scientific articles
 - Use AI, e.g. [Perplexity](#) (or other)
 - Goal: find a publication
 - Context Keywords: academic - scientific
 - Format Keywords: brittle fracture – tantalum – kovar – laserweld - microstructure
 - No articles were found in the scientific literature on joining Kovar with tantalum by laser welding.
 - An article was found on “Microstructure and Mechanical Properties of Laser-Welded Joint of Tantalum and Stainless Steel¹”, which discusses a brittle TaFe₂ phase. Since the article is about stainless steel (containing $\pm 65\%$ Fe) and not Kovar ($\pm 54\%$ Fe), there is obviously no one to one relation. However the SEM analysis of the fracture surface (see Figure 6) shows also an Fe-Ta peak, which could indicate this brittle TaFe₂ phase is also present. Link to article: <https://www.mdpi.com/2075-4701/12/10/1638> (free download)
- A comparative test (between different welding solutions) which could consist out of:
 - Non-destructive testing:
 - RX for internal imperfections
 - Penetrant for surface imperfections
 - Destructive testing
 - Macro to evaluate joining quality
 - Hardness measurements are not possible due to limited thickness
 - Tensile test
 - To check whether the joint fails in base metal/weld metal/ heat affected zone. If the sample fails far away from the joint, which means that the joint is not the limiting factor for static strength.
 - As fatigue test cannot be performed:
 - Factor strength/elongation (ductility requirement) which could be an indication of fatigue strength
 - Measure the elongation (ductility requirement) which could be an indication of fatigue strength
 - SEM-investigation to check fracture surface to evaluate brittleness

¹ <https://www.mdpi.com/2075-4701/12/10/1638>



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Additional pictures/information

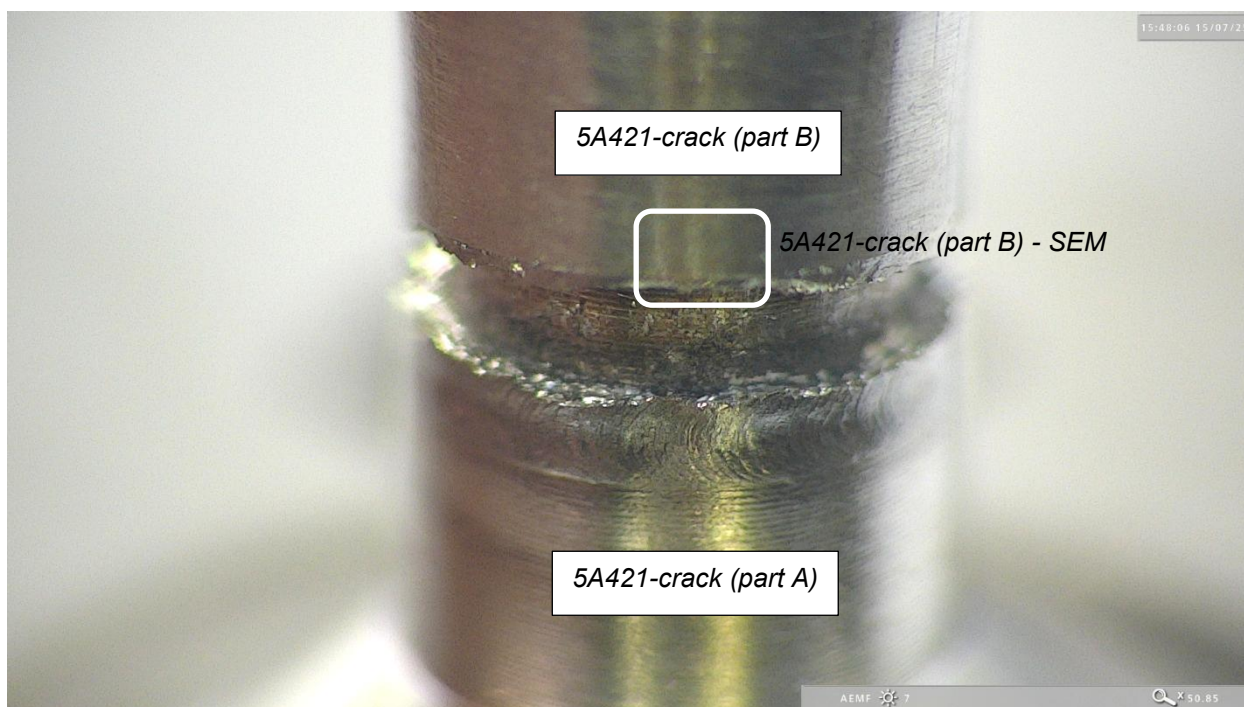


Figure 3: Stereoscopic view of the crack, after dismantling

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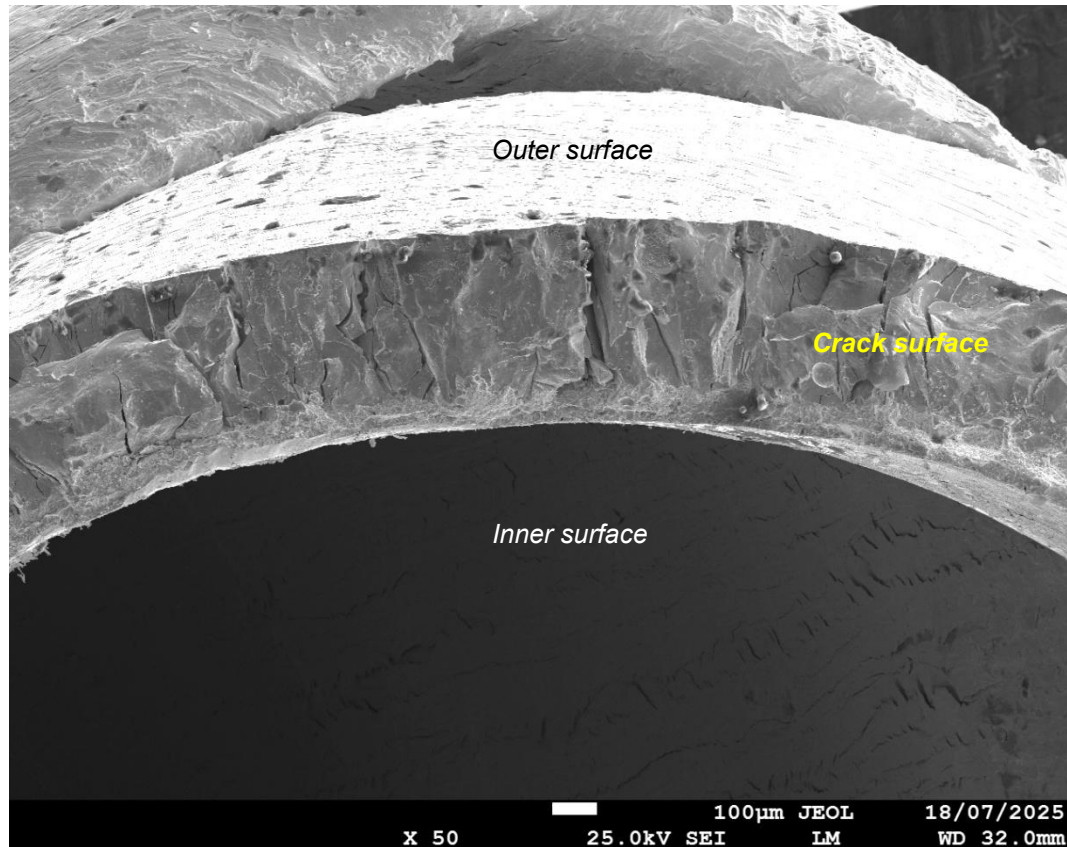


Figure 4: SEM-view of the crack surface part B



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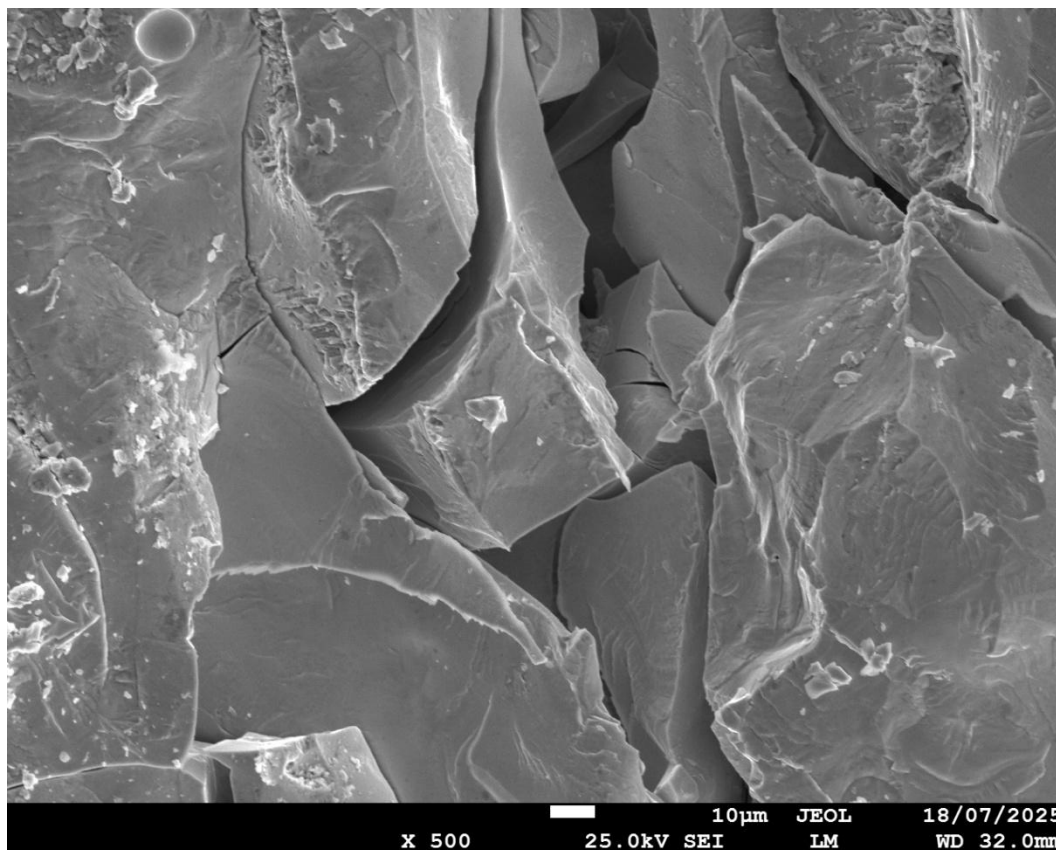


Figure 5: Detail of brittle SEM microstructure



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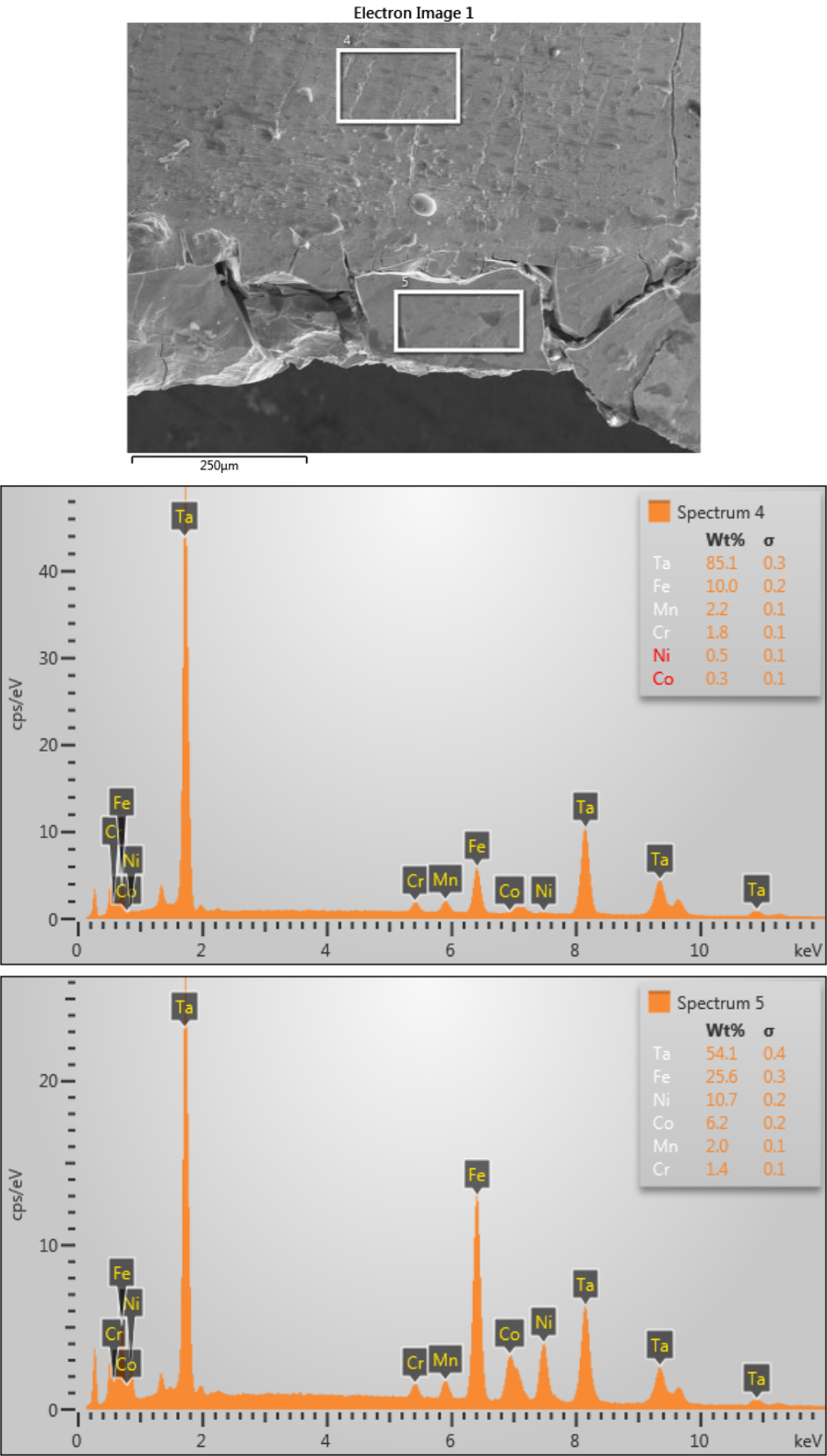


Figure 6: SEM-view of 5A421-crack (part B), with corresponding analyses



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The Purpose of the elaborated Case Studies

Case studies are structured examinations of real-world situations or challenges designed to bridge theory and practice. They are developed both as a research method and as a learning tool to strengthen analytical and problem-solving skills. By engaging with authentic industrial scenarios, students gain practical insight into complex professional environments.

The purpose of this case studies is to encourage active, learner-centred engagement. They support approaches such as problem-based learning by enabling students to work independently or collaboratively, with or without instructor guidance. Through analysing theoretical concepts within realistic contexts, students learn to interpret data and test results, evaluate alternative courses of action, and develop well-reasoned, creative solutions.

This approach is particularly valuable in sectors such as aerospace, defence, and advanced manufacturing, where challenges are multifaceted and solutions are rarely singular. Because multiple valid solutions often exist, guided facilitation is frequently beneficial to help students structure their reasoning, assess trade-offs, and justify their decisions effectively.



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Competence unit coverage:

AILEEN competence units		Covered CU
AW_01	Welding: Advanced Metallic Materials in Aerospace and Defence Sectors	x
AW_02	Welding: Advanced Welding Processes and Equipment in Aerospace and Defence Sectors	X
AW_03	Welding: Advanced Welding Applications in Aerospace and Defence Sectors	X
AW_04	Welding: Introduction to brazing technology Knowledge for quality brazed joints	
AW_05	Welding: Fundamentals of Industrial Brazing: Main Processes, Quality Standards & Applications	
AI_01	Inspection: Non-Destructive Testing (NDT) in Additive Manufacturing for metals and polymers	
AI_02	Inspection: Metrology in Additive Manufacturing for metals and polymers	
AI_03	Inspection: Inspection of AM parts. Material Quality	
AAM_01	AM: Qualification, Certification and Standards for AM in A&D	
AAM_02	AM: Quality Assurance & Quality Control for AM in Aerospace & Defence	
AAM_02/3	AM: Design of AM parts for A&D (2 courses - for DED & PBF)	
AD_01	Digital: Introduction to Digital Technologies in Advanced Manufacturing	
AD_02	Digital: Data Acquisition and Analysis	
AD_03	Digital: Industrial Internet of Things (IIoT) and Advantages in Advanced	
AD_04	Digital: Artificial Intelligence and Advantages in Advanced	
AD_05	Digital: Automation and Advantages in Advanced Manufacturing	
AD_06	Digital: Potentials of Advanced Simulation and Modelling in Advanced	
AD_07	Digital: Potentials of Digital Twins and Smart Factory Automation in Advanced Manufacturing	
AD_08	Digital: Unlocking the Potential of 3D Models Beyond Technical Drawings in the Aerospace and Defence Sector	
AG_02	Green: Sustainable Design and Environmental Compliance in Aerospace and Defence	

