NEW CHALLENGES IN THE DEVELOPMENT OF THE LIGHTWEIGHT AND HIGH PERFORMANCE TITANIUM EXHAUST SYSTEMS

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Titanium in automotive industry

• Demands for improving fuel efficiency, reducing exhaust emissions and improve vehicle performance.

  ➤ Weight reduction contributes to the reduction of fuel consumption.

• Designers are constantly trying to reduce weight in their design, and material plays a large part in the design equation.
Titanium exhaust system

- Since titanium was introduced as an alternative material for exhaust systems its use is rapidly expanding because its advantages in weight reduction, processability, freshness and trendiness.

BMW M3 (E90)

- OEM: 45.1 kg
- Akrapovic: 21.2 kg
  - 23.9 kg (-53%)
Titanium exhaust system

- A closer look to the durability tests results and FEM simulations show that we have some additional space for weight saving.

- Parallel with our standard design process, several new approaches are introduced to additional reduce the exhaust weight.

Reducing wall thickness
Benefits of reduced wall thickness

- Reduced wall thickness means less material.
  - Significant product cost reduction
Sample preparation

• A sample with 28% lower wall thickness was prepared.

➢ Weld analysis
➢ Visual control
➢ Durability test
Weld analyze

- Penetration of weld is sufficient.

- Difference in hardness between weld area and rest of material is 41 Vickers. OK regarding our standard (max $HV = 50$)
Visual control of outer surface

- Muffler is a visual part and it should have no visual faults (scratches, surface bends, etc).
- Due to relatively low wall thickness, the input of the energy is so big that causes the bending of the outer sleeve (not acceptable for the customer).

- To improve/prevent bending of the outer sleeve, additional tests were performed.
Preparation of welded specimens

• Sample specimens.
  ➢ Bracket was welded on preloaded base plate.

• Analyze of results.
  ➢ Preloaded specimens show better resistance to bending.

Additional static load tests
Static load test

• Set up of test rig.
   Specimen was clamped in test rig and loaded.

• Test results.
   Specimens were loaded up to 10kN
   No break points on welds

 Preparation of samples for durability tests
**Durability test results**

- Sample mufflers were prepared and sent to our customer for durability test activities. 10,000 Km roller-bench test and 25,000 Km road test were performed.
  
  - Muffler is perfect condition, no damages or other faults.
New possibilities in the use of thinner sheet thickness

• Thinner thickness mean less stiffness of outer sleeve. To increase the stiffness additional reinforcing ribs should be added. This could be taken as an advantage because we can introduce some additional design elements.

➢ Mufflers look more dynamic and trendy.
Design of flexible joints made out of titanium

- A closer look to a car exhaust system shows that between downpipes connected to the engine end, rest of the system a flexible joint is installed.

- Usually flexible joints are made out of stainless steel.

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Design a flexible joint made out of titanium.
Design of flexible joints made out of titanium

- A standard design of flexible joint was selected.

- Material of flexible joint: Ti-Gr37 (ASTM B265)
- Thickness of main body: 0.54mm

> Flexible joint specimen

> Analize of wall thickness after deformation
Installation of flexible joint

- Flexible joint was installed on a race car.

- Different tests were performed. Results were not satisfactory. Flexible joint has not enough flexibility.
- Redesign of flexible joint is needed
Current challenges in joining two different materials

• Sometimes is not possible to avoid usage of different materials in the set up of the exhaust system. Usually a conventional method with a clamp is used to join two parts of exhaust system.

  ➢ To additionally reduce the exhaust system weight an alternative solution with brazed joint was studied (connection of titanium and stainless steel)

• Based on the recommendations from literature, two different types of braze joints were studied.
Braze joint type 1

- Braze joint with foil filler material (Incusil ABA):
  - Silver-Indium-Titanium based brazing filler.
  - Used to join stainless steel and titanium.
  - Temperature of brazing below titanium phase transformation (beta transus)
Braze joint type II

- Braze joint with wire filler material (AWS BAg-8)
  - Silver-Copper based brazing material
  - Used to join stainless steel and titanium.
  - Temperature of brazing below titanium phase transformation (beta transus)
Analyze of braze joints

- Lower mechanical properties to comparable used joints.
  - looking into appropriate geometry solutions that will raise mechanical properties.

- Expensive (high temperature vacuum process), high price of some brazing materials.
  - looking to be more cost effective

- Some joints could be subject to corrosion problems in case of chloride environment (salted roads).
  - testing of corrosion properties
Summary

- It has been proven that thinner sheet thickness could be used for muffler outer sleeves which give us at least two big improvements:
  - Reducing the production costs
  - Reduce the weight of the exhaust system

- Actual version of the titanium flexible joints need to be redesigned due to its not sufficient flexibility.

- Two different brazed joints were studied, currently we are evaluating pros and cons of this alternative approach of connecting titanium and stainless steel tubes.
Thank you!