APPENDIX M

Background of the WABTEC/SAB-WABCO Brake Disc

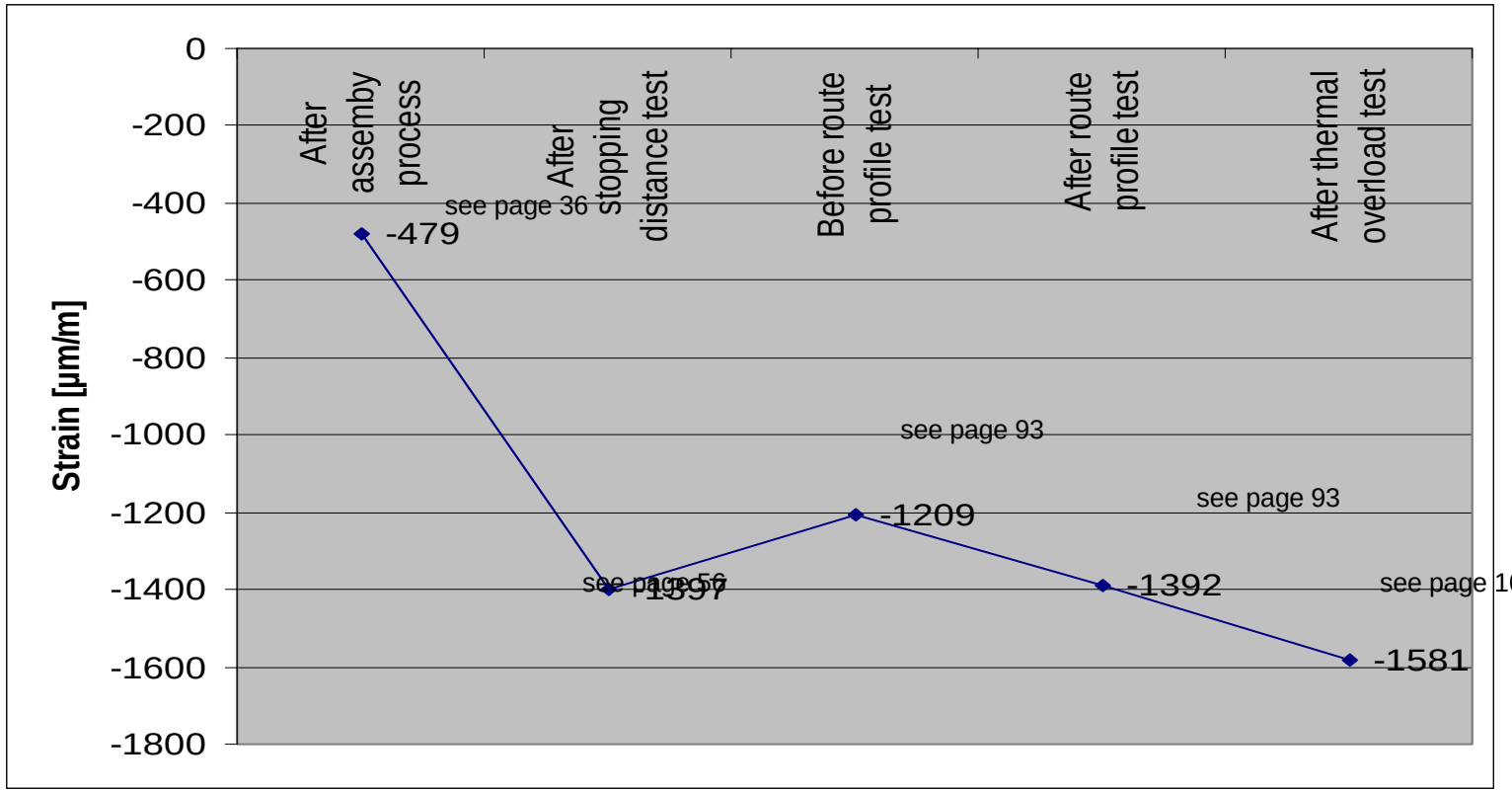
(Prepared by Faiveley Transport)

Residual Compressive Stresses in Spokes

- Compressive stresses level in used disc defined by assembly process of disc on axle and due to shrinking effects of friction ring caused by yielding in friction surface
- The compressive stress caused by the assembly process depends on the interference fit between axle and hub
- The compressive stress caused by the shrinking of the friction ring depends on the overall temperature level as well as on the differences in the friction surface e.g. caused by hot spots
- The overall compressive stress level stabilizes during service before yielding point

Residual Compressive Stresses in Spokes

- Example for the development of compressive strains based on the measurement at the spoke during dynamometer test at Faiveley Transport (see dynamometer test report V/V98-101-Rev00)



Note: Increase after stopping distance test and start of route possibly caused by external influences (temperature @ measurement,slight shifting in strain gauge, etc.)

Design Principle

- The principle design consideration for the brake disc was the high thermal load resistance of the monoblock disc as required by the specification. The design of the Acela monoblock brake disc and especially the spoke design had to be adapted to this requirement.
- The basis for this design option is the fact that the thermal expansion of the friction ring is related to a certain dimension.
- The basis for this design option is the fact that the thermal expansion of the friction ring and the loads on the spokes are related to certain dimension, i.e. the elongation of the spoke is defined by the geometrical value of the expansion of the friction ring.
- The elongation of the spoke is defined by the geometrical value of the expansion. Therefore the stress level in the spoke from thermal expansion depends directly on the length of the spoke.
- To resist the high thermal requirement the spokes length has been increased to reduced the stress level caused by the thermal expansion of the friction ring.
- By increasing the spoke length, the stress level in the spoke could be reduced significantly against a more rigid fixing of the spoke e.g. at the inner diameter of the friction ring.
- To support the minor influence of the specified lateral shocks, a web has been applied to the spoke in lateral direction to increase the stiffness against the specified lateral shock.
- To increase the strength and resistance a tempered cast steel material has been chosen as the brake disc material.

Design Principle

- Theoretical background for stress level by thermal expansions

$$\varepsilon = \Delta l / l_0$$

where:

ε = strain at the spoke

l_0 = "normal" spoke length

Δl =elongation of the spoke by thermal expansion of the friction ring

$$\sigma = \varepsilon * E$$

where:

σ = nominal stress level in spoke

ε = strain at the spoke

E =modulus of elasticity

- The length , size and the connection of the spoke to the friction has a significant influence on the overall tensile stress level caused by thermal expansion because the elongation of the spoke is geometrical defined by expansion of the friction ring.
- For example a spoke with approx. 25% shorter length would lead to at least 40% more strains caused by thermal loads

Design verification process

- The brake disc design has been validated by a theoretical and practical approach utilizing common tools, such as the FEA calculation, dynamometer tests, vehicle test, etc.
- A first preliminary internal FEA calculation was completed in 1996 for the initial design discussion for the Acela axle mounted disc. After the internal reviews of this design, comments led to a revision of the design and an updated FEA calculation in 1997. The revised and updated FEA calculation was summarized in a final report (see document V/A97-092 Rev00) and formed the basis for the final proposal for the disc design. Based on this proposal the design was been jointly accepted.
- The evaluation of the FEA has been realized acc. to Smith, Watson and Topper by applying an S/N-curve and the corresponding damaging factor P_{SWT}. The evaluation of the FEA shows no indication for concern even under the assumed unrealistic scenarios.
- The dynamometer test simulated various load conditions such as the route profile under service load condition and continuously overload conditions. Also the dynamometer test shows no indication for concern even under the applied overload conditions.
- A vehicle testing has been performed confirming the results from the previous verification process and also here no indication for concern could be detected.
- Based on the verification process the disc has been jointly accepted for the use in the Acela vehicles.