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Structural durability design recommendations for forged automotive aluminium chassis components submitted to spectrum and environmental loadings by the example of a tension strut

N. Hägele [a], C.M. Sonsino [b,*]

[a] BMW Group, Knorrstr. 147, 80788 Munich, Germany
[b] Fraunhofer Institute for Structural Durability and System Reliability LBF, Bartningstr. 47, 64287 Darmstadt, Germany

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ABSTRACT

The structural durability design of a tension strut of forged aluminium (EN AW 6082 T6), which is a safety component of the automotive chassis, is described. The first step of the structural durability design is the knowledge of the mechanical and environmental loadings. The mechanical loadings are the spectrum loading for the designated normal driving conditions and unintended special event loadings by e.g. braking over road bumps, which are introduced into the component through the wheels. The local stresses imposed on the component are also influenced by kinematics, stiffness, axle mass, dampers, bearings, bump geometry, etc. The environmental loading is the corrosion caused, in winter-time, by salty water on the roads. For design according to the local stress concept, the knowledge of Woehler-curves without and with salt corrosion effects is necessary. On this basis, cumulative fatigue under spectrum loading, which also comprises the special events mentioned, is assessed for a standard configuration and for an optimised one. The numerical results are verified by experimental proofs on the component in the laboratory and on the proving ground as well as by field tests with vehicles.

1. Introduction

As chassis components belong to the category of safety components, which must never fail, their structural durability design has to be carried out through a consideration of all possible types of service loadings, Fig. 1.

These are service spectrum loading including special events and corrosion resulting from salty roads in winter. The methodology for the consideration of these effects for aluminium components has already been studied and proposed on behalf of the German automotive industry [1] and will be summarised in the next section. The proposed paper will demonstrate using the example of a forged aluminium (AlMgSi1 T6 (EN AW 6082 T6)) tension strut, Fig. 2, a safety component of the BMW 3-series, how the design must be carried out and verified. Details on the loading of this component are given in [2–4].

In the following, a short overview will firstly be given of the state of the art in considering salt corrosion and spectrum loading in the structural durability design of automotive aluminium safety components, the loading conditions and the parameters influencing the stresses of the forged aluminium tension strut will then be compiled, and finally the structural durability will be assessed, using the specific material data and derived spectra.

2. Short state of the art in considering salt corrosion and spectrum loading effects on aluminium chassis components

Independently of the manufacturing mode, i.e. cast, forged or welded, fatigue strength due to salt corrosion under constant amplitude loading decreases in the high-cycle regime ($N > 10^6$ cycles) with increasing lifetime, as displayed in Fig. 3. However, under spectrum loading, the decrease of fatigue strength due to corrosion is significantly lower [1,5].

This knowledge was obtained for a corrosion cycle 20–25 min dry and 5 min spraying with 5%-NaCl solution during continuous mechanical cyclic loading [1,5]. Under these conditions, within typical chassis frequencies (1–100 s^{-1}), an additional frequency effect on fatigue life is not observed. This corrosion cycle, recommended for testing purposes of automotive components, is considered to be sufficiently severe and consequently conservative, because the corrosion conditions are intensified [1].

The following design recommendations for aluminium alloys of the 5000 and 6000 groups of the international alloy register were derived from this knowledge [1]:

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* Corresponding author. Tel./fax: +49 6151 705 244.
E-mail address: c.m.sonsino@lbf.fraunhofer.de (C.M. Sonsino).

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Nomenclature

D	damage sum
F	load
L	spectrum size, length
k	slope
σ	stress
v	velocity
t	time

Indexes

a	amplitude
f	failure
o	occurrence
s	survival
x,*y*,*z*	coordinates

- The SN-line for corrosion is determined by reducing the fatigue strength in air at 5×10^6 cycles by 50%. Through this corrosion fatigue strength, the SN-line for corrosion is drawn with a slope of $k_{corr} = k_{air} - 1$. This SN-line has no knee point because of the influence of corrosion. If experimental data are not available, the SN-line in air can be drawn up to a knee point at 1×10^6–2×10^6 cycles with a slope of $k_{air} = 5.0$ and continued beyond the knee point with $k^*_{air} = 22.0$, and the SN-line for salt corrosion can be drawn with a slope of $k_{corr} = 4.0$.
- If a Gassner-line is experimentally obtained in air for a given spectrum, the Gassner-line for salt corrosion can be estimated by reducing the fatigue strength in air by 20–25%.

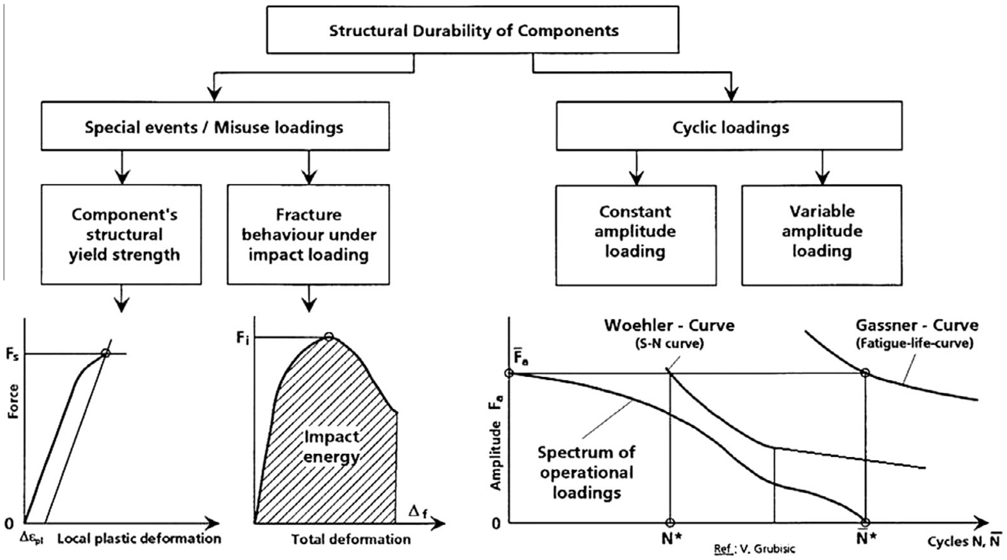

Fig. 1. Loads determining structural durability of chassis safety components.

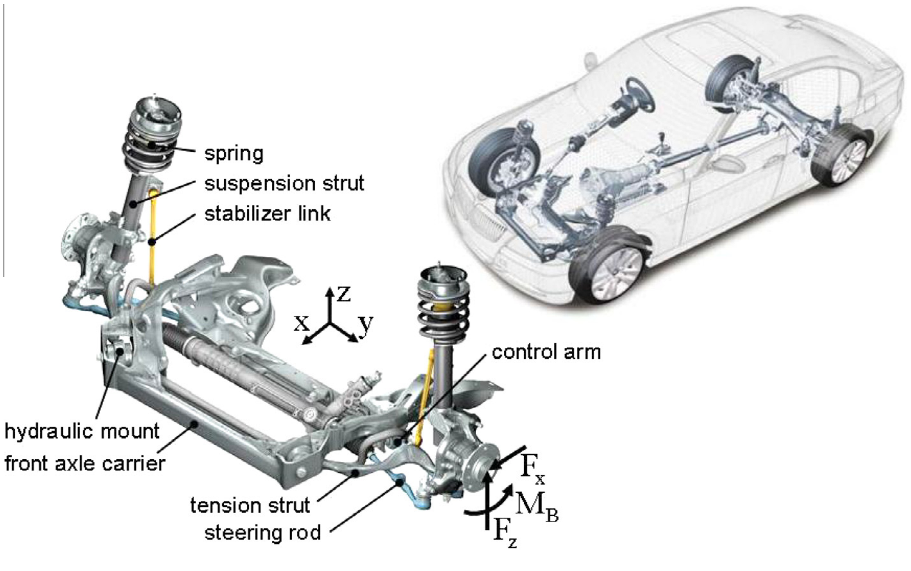

Fig. 2. Chassis system of a BMW (3-series).