

Structural durability of cast aluminium gearbox housings of underground railway vehicles under variable amplitude loading

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Received 21 July 2004; received in revised form 8 October 2004; accepted 6 January 2005

Abstract

Cast aluminium gearbox housings for railway vehicles are complex shaped components undergoing stochastic stresses during service. Early failures of housings led to broad investigations in order to clarify the causes. By a methodology determining the highly stressed areas, the load spectrum for different operational conditions by service strain measurements, the component related material behaviour, fatigue-life calculations and laboratory proof tests, criteria for optimum design, material selection and quality control were worked out. The methodology enabled the design of new housings that would meet the required failureless operational service.

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Keywords: Cast aluminium; Gearbox housing; Variable amplitude loading; Spectrum; Cumulative damage calculation; Fracture mechanics; Fatigue-life assessment; Proof test; Porosity

1. Introduction

Housings of railway vehicle gearboxes, Fig. 1, are examples of components which are subject to complex stochastic stresses during operation and must withstand a service life of at least 30 years without damage.

Stresses are mainly generated by mass forces transmitted from the motor via the flanged connection to the housing neck and also by loading resulting from the lateral drive and starting and braking operations. Moreover, the loads acting on the gear wheels generate bearing forces which must be taken up by the gearbox housing.

To reduce weight, such housings are increasingly made of cast aluminium and about 1200 sand cast housings were installed in the bogies of underground vehicles, Fig. 2, of an European capital about 20 years ago. When some failures, Figs. 3 and 4, occurred, extensive investigations were performed to identify the causes and to improve the principles of design and material selection [1].

The measurement of stresses during the service of the vehicles, the interpretation and evaluation of the measured stresses, material investigations of specimens taken from the housings, simulation tests in the laboratory, an updated fatigue-life assessment, on the basis of SN-curves and crack-propagation data, and finally design improvements are described in the following.

2. Systematics of proof of structural durability

A proof of structural durability is generally based on the following information and steps [1,2]:

- Loading, loading conditions,
- Geometry dependent local stresses (spectra),
- Component related material behaviour (endurable and allowable stresses, SN-curves, threshold and crack-propagation data),
- Comparison of locally occurring and allowable stresses,
- Fatigue-life assessment (damage accumulation, crack propagation),
- Proof tests (laboratory or service),
- Consequences (design improvements).

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Nomenclature

A_5	elongation	Z	area of reduction
C	probability of confidence	$\sigma, \bar{\sigma}$	stress, constant and variable amplitude loading
D	damage sum	σ_{ak}	knee point of the S–N curve
K	stress intensity	ρ	density
L	fatigue life	a	amplitude
L_s, L_m	spectrum size	f	frequency, failure
$N, \bar{N}$	number of cycles, constant and variable amplitude loading	$j_{R,C}$	risk factor
N_k	fatigue life at knee point	j_N	safety factor
P	porosity	k, k'	slope of the SN-curve, slope of the prolongation
P_s, P_f, P_o	probability of survival, failure, occurrence	m	mean
$R_m, R_{p0.2}$	strength, ultimate, yield	n	number of tests, number of cycles
$R_x, \bar{R}_x$	load, stress or strain ratio, $R_x = X_{min}/X_{max}$, for constant and variable amplitude loading	s_N	standard deviation ($s_N = 0.39 \lg(1/T_N)$)
$T_N, \bar{T}_N$	fatigue life scatter between $P_s = 10$ and 90%, for constant and variable amplitude loading	t	time
		th	threshold

The following updated study covers the proof of structural durability performed on sand cast aluminium gearbox housings for railway vehicles to clarify the cause of early failures and to improve the design.

3. Damage of gearbox housings of an underground railway

Damage incurred on housings, Figs. 3 and 4, after service lives of about 1.6 years, or 160,000 km, and 2.9 years, or 290,000 km, respectively, in the subway system of an European capital led to the investigation described below. For preventing further failures and possible accidents, if

the gearbox dropped onto the rail, which could lead to a derailment, all other housings were secured in the neck area by steel belts attached to the bogies.

3.1. Loading, measuring points and stress spectra

A railway vehicle gearbox housing is part of a subassembly consisting of an electric motor, two gearboxes and two flexible couplings between the gearbox and the axle shafts, Fig. 1.

It is not possible to calculate all the stochastic stresses transmitted to the complex geometry of a housing by mass forces from the outside and by the gear wheels from the inside. Because damage is exclusively caused by stresses

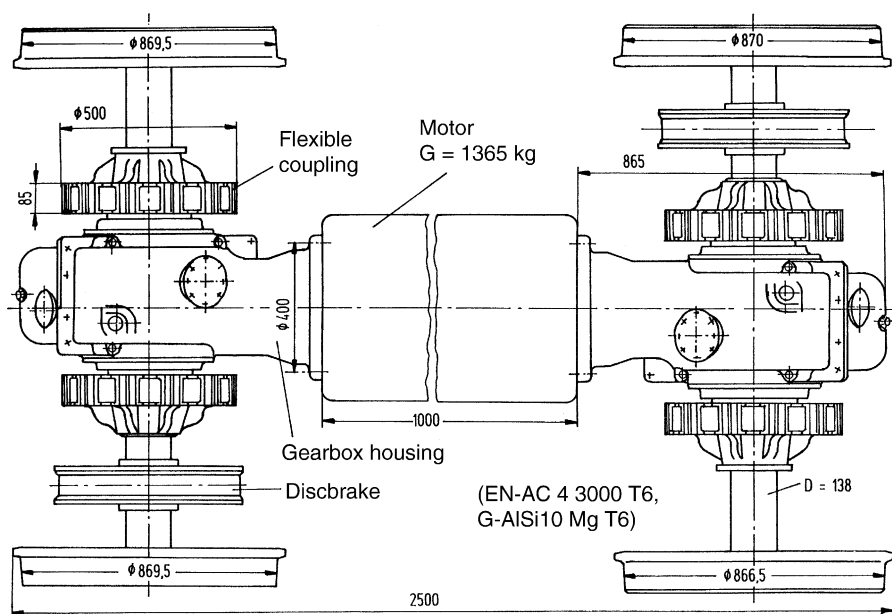


Fig. 1. Drive unit of a subway vehicle with gearbox housings not connected to the bogie frame.

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