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Large-scale friction and wear tests on a hybrid UHMWPE-pad/primer coating combination used as bearing element in an extremely high-loaded ball-joint

P. Samyn[a,*], L. Van Schepdael[b], J.S. Leendertz[c], A. Gerber[d], W. Van Paepegem[a], P. De Baets[a], J. Degrieck[a]

[a]*Department Mechanical Construction and Production, Laboratory Soete, Ghent University, St Pietersnieuwstraat 41, B-9000 Gent, Belgium*
[b]*SOLICO B.V., Solutions in Composites, Everdenberg 97, NL-4902 TT Oosterhout, The Netherlands*
[c]*Ministry of Transport, Public Works and Water Management, Directorate-General, Herman Gorterhove 4, NL-2700 AB Zoetermeer, The Netherlands*
[d]*University of Stuttgart, Staatliche Materialprüfungsanstalt, G-70550 Stuttgart (Vaihingen), Germany*

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Abstract

The surfaces of a heavily loaded ball-joint were initially covered with a sliding spray and suffer wear. A solution is found by incorporating UHMWPE pads (Ultra high molecular weight polyethylene) with a carbon fibre/epoxy reinforced ring as sliding material into the chairs of the structure, while the steel ball-side is covered with a Zn-phosphate primer coating, protecting against corrosion. The local static and dynamic behaviour of the hybrid UHMWPE pads in contact with steel or Zn-coated counterfaces has been large-scale tested on loading capacity, low friction and wear resistance. For protection of the sliding counterface against wear, a polymer lip covering the carbon ring has been experimentally designed to flow over the carbon ring under high contact pressures, assuming the retained polymer disc under hydrostatic conditions. As such, the soft coating resists extremely high contact pressures (150 MPa) with good adhesion to the steel ball. However the application method should be carefully selected, sprayed coatings are the most favourable for low initial static friction. Calculated bulk and flashtemperatures revealed that the UHMWPE melting temperature is not exceeded, although softening of the coating under high contact pressures may be favourable for a 'self-repairing' ability. Pre-sliding creep and intermediate wear paths as manifesting in the ball-joint were simulated, indicating that the maximum design coefficient of friction is not exceeded. Test results are compared to FEM-calculations to verify the practical applicability of the modified sliding system.

Keywords: Large-scale testing; Hybrid UHMWPE pad; Soft coating; Tribology

1. Introduction

Protecting the lands below sea level from being flooded by water requires the construction of dikes and surge barriers. A flexible protection is needed near harbours, providing access to container ships without any height restriction. One solution is found in the construction of a movable retaining wall, consisting of two floating hemispherical gates which can be swung from the banks into the river and sunk on the river bed, as e.g. in the Nieuwe Waterweg near Rotterdam. The retaining walls consist of orthotropic plate structures and are connected to pivots by means of two triangular space trusses made of tubular sections. The rotation and closure of the wall in case of a storm implies horizontal and vertical movements, guaranteed by a pivot or ball-joint with a diameter of 10 m and a weight of 680 tons in the abutments of the structure. The convex and concave ball-joint surfaces were originally (1991) covered with one 10 μm thick layer that is a mixture of MoS_2 and PTFE resin, in order to obtain low friction. For running-in purposes an additional layer of PTFE-spray has been applied to overcome static friction. After several sliding steps the coating was however removed from the contact zone and severe wear marks as cold welding spots were observed due to adhesive steel/steel contact. The modified design finished in 2004 (Fig. 1) contains a primer coating on the convex steel ball surfaces protecting against corrosion and 468 polymer discs or 'pads' incorporated in holes machined into the concave surfaces. The pads have

* Corresponding author. Tel.: +32 9264 3308; fax: +32 9264 3295.
E-mail address: pieter.samyn@ugent.be (P. Samyn).

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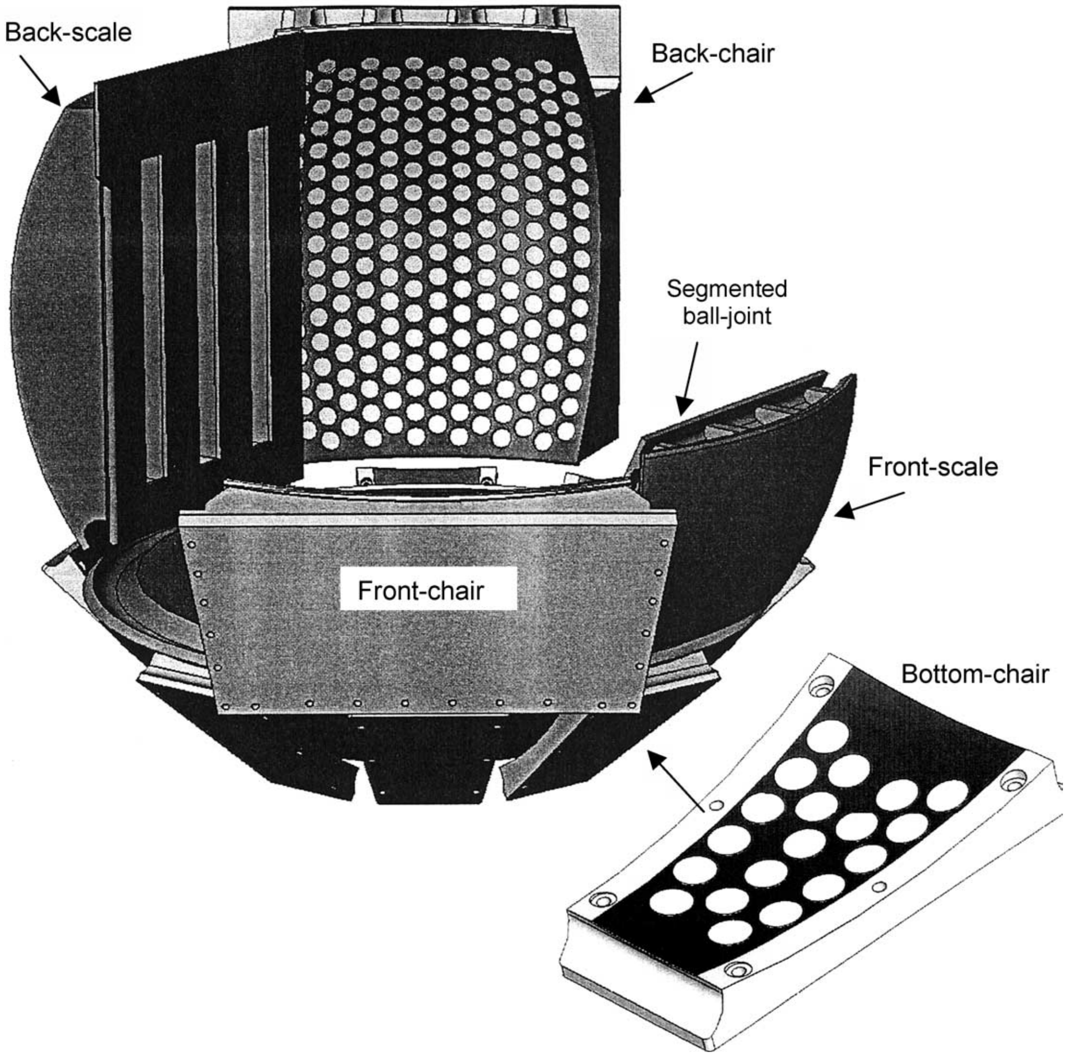

Fig. 1. Modified ball-joint with machined holes (Ø 250 mm × 32 mm) on the back, front and bottom chairs for incorporation of polymer discs.

a nominal diameter of 249 mm and a thickness of 40 mm, positioned into holes of 250 mm diameter and 32 mm depth. As such, the pads have a free surface of 8 mm above the steel surface and the difference in curvature radii of concave and convex surface is reduced from 20 to 10 mm. Those modifications were analysed in combination with the elasticity, compressibility and thickness of the pads, as they determine the stiffness of the interface.

1.1. Functionality of the ball joint

The shape of the facetted ball-joint is achieved by a rectangular kernel on which two convex cast steel elements are bolted, respectively, the back and front scales, in contact with fixed front and back chairs. The bottom of the kernel contains a bearing element with the shape of a convex ring that rests into eight concave bottom scales fixed to a foundation. During a closure operation as defined in Ref. [1] the bottom bearing carries a dead vertical load resultant of 42×10^6 N rotating with a velocity of 0.033 rad/min. By floating the walls, the bearing is increasingly subjected to oscillations implied by wind and a pounding water stream, with a maximum resultant horizontal force of 350×10^6 N under full hydraulic head. Rotation of the walls and deformation of the structure makes the ball sliding over the bottom and back chairs, transmitting respectively vertical and horizontal loads to the anchor block, which introduces them into the foundation. The ball however not only slides through rotation but it is eccentrically loaded by friction, causing additional friction moments and rolling. Therefore, the resulting force displaces and the location where loads are introduced on the chair structure is variable. Just after the storm surge a situation may occur with a so-called ‘negative hydraulic head’ (low water level on the sea side) and then a resultant force of 50×10^6 N moves onto the front bearing.