ABSTRACT

According to the actual European regulations, in structural applications, bolted connections made of austenitic and austenitic-ferritic (duplex) stainless steel according to EN 1993-1-4 are predominantly designed according to the rules originally generated for carbon steel bolts and specified in EN 1993-1-8. However, the load bearing behaviour of stainless steel bolts is significantly affected by their specific material properties, such as nonlinearity and pronounced strain hardening, which must be considered in the design of these connections. Therefore, experimental and numerical investigations and reliability analyses were systematically carried out for austenitic and duplex stainless steel and carbon steel bolts on the tension, single-/double-shear and interaction resistance. Finally, more economical and harmonised design rules for stainless and carbon steel bolts could be developed, fulfilling the European safety concept of the Eurocodes. The new design regulations for stainless steel bolts have already been implemented in the revision of EN 1993-1-4, prEN 1993-1-4, and the German technical approval abZ/abG Z-30.3-6:2022.

KEY WORDS: Stainless steel, austenitic, duplex, carbon steel, bolts, bolted connection, tension resistance, shear resistance, shear coefficient \( \alpha \), interaction resistance, reliability analysis, new design rules

INTRODUCTION AND PROBLEM DEFINITION

Carbon steel bolts are commonly used in various applications in the construction industry. However, whenever bolted connections with high corrosion resistance, sustainability and low maintenance costs are required, like in the offshore industry, oil rigs, pipelines, chemical industry and other structural applications, stainless steel is the appropriate choice. Besides the superior corrosion resistance, stainless steel has unique and promising material properties like pronounced strain hardening and outstanding ductility.

According to the actual European regulations, in structural applications, bolted connections made of austenitic and austenitic-ferritic (duplex) stainless steel are predominantly designed according to the rules originally generated for carbon steel bolts and specified in EN 1993-1-8 as the specific European design standard for stainless steel, EN 1993-1-4, mainly relies on it. In the past, only very few experimental results were available to verify whether the design rules for carbon steel bolts can also be applied directly to austenitic stainless steel bolts without considering their specific material properties. For duplex stainless steel bolts, no specific investigations existed so far.

Most commonly, stainless steel bolted connections are used as non-preloaded bearing type connections (category A acc. to EN 1993-1-8), tension connections (category D) or as bearing type connections subjected to tension and shear loading (categories A + D), see Fig. 1. However, the demand for preloaded bolted connections made of stainless steel is steadily increasing for the use in slip-resistant connections (categories B and C) and preloaded tension connections (category E) when fatigue becomes relevant. It could be shown in various research activities conducted at the Institute for Metal and Lightweight Structures of the University of Duisburg-Essen, Germany that preloading and secure tightening of stainless steel bolting assemblies are in principle possible. Therefore, a Bolt Tightening Qualification Procedure (BTQP) was developed which structures and bundles all necessary steps for the determination of secure tightening parameters for each configuration and batch of bolting assemblies made of stainless steel, see (Stranghöner et al., 2017; Stranghöner et al. 2019; Jungbluth et al., 2022). Nevertheless, in the frame of this contribution, the focus will be exclusively on non-preloaded bolted connections.