International Journal of Offshore and Polar Engineering
Vol. 3, No. 1, March 1993 (ISSN 1053-5381)

Ultimate Behavior of Multiplanar Double K-Joints of Circular Hollow Section Members

J.C. Paul
University of Tokyo, Tokyo, Japan

T. Ueno
Hazama Corporation, Tokyo, Japan

Y. Makino and Y. Kurobane
Kumamoto University, Kumamoto, Japan

ABSTRACT

The results of a test on multiplanar double K-joints with circular hollow sections under balanced axial brace loading are reported. The objective of the test is to investigate influences of the brace diameter to chord diameter ratio $\beta = d/D$, the transverse gap to chord diameter ratio $\zeta_t = g_t/D$, the longitudinal gap to chord thickness ratio $\zeta_l = g/T$ and the out-of-plane angle ϕ_1 on the static strength of the joints. These variables are varied in the following range: $0.22 \leq \beta \leq 0.47$, $0.04 \leq \zeta_t \leq 0.53$, $2 \leq \zeta_l \leq 14$ and $\phi_1 = 60°$ or $90°$. The influences of ζ_l and ζ_t on the ultimate capacity of double K-joints are independent of each other. The ultimate capacity increases with the decrease of ζ_l, but this increase is smaller than for K-joints. The influence of ζ_t depends on the failure type: for a constant value of β, the ultimate capacity increases with ζ_t for the failure type without local deflections of the chord wall between the compression braces and decreases for the failure type with significant local deflections of the chord wall between the compression braces. The ultimate capacity of double K-joints is compared with previous research on double K and T-joints, as well as with AWS, IIW and Cidect design recommendations. Formulae for the ultimate capacity of double K-joints are proposed based on past and present results.

NOMENCLATURE

$P_{u,KK}$: ultimate capacity KK-joint, with brace load as reference
$P'_{u,KK}$: ultimate capacity KK-joint, with resultant of brace loads as reference
$P_{u,K}$: ultimate capacity prediction K-joint (Kurobane et al., 1984)
$P'_{u,K}$: ultimate capacity prediction K-joint (Kurobane et al., 1984), with $d = d'$

$\beta = d/D$: brace diameter to chord diameter ratio
$\zeta_l = g/T$: longitudinal gap to chord thickness ratio
$\zeta_t = g_t/D$: transverse gap to chord diameter ratio
ϕ_1 : out-of-plane angle between planes in which braces lie
ϕ_2 : out-of-plane angle between braces
θ_1 : angle between chord and planes in which braces lie
θ_2 : in-plane angle between chord and braces

INTRODUCTION

Tubular structures are widely used for offshore oil drilling and production. Mostly these are trussed space frames extending from the sea bottom to just above the sea level. In such space frames multiplanar joints are unavoidable. However, since studies in the ultimate behavior of multiplanar tubular joints have started only recently, the basis for the design of such joints is still insufficient. The American Welding Society Structural Welding Code AWS (1992) is the only code that shows general design criteria applicable to many types of multiplanar joints, while the Cidect Design Guide for Circular Hollow Section Joints (Wardenier et al., 1991) proposes criteria applicable only to multiplanar double T, X and K-joints for which data are available (Makino et al., 1984, 1993; Scola et al., 1989, 1990; Paul et al., 1989, 1991; Van der Vegte et al., 1991). The AWS Code proposes the chord ovalizing parameter to account for multiplanar effects, which, however, proved to be contradictory to actual behavior in certain cases: Two compression braces suppress the chord ovalization giving a beneficial effect to the ultimate capacity according to the AWS prediction, while local deflection of the chord wall between the two compression braces gives an adverse effect to the ultimate capacity according to Makino's double K-joint tests (Makino et al., 1984; Marshall, 1991).

Scola et al. (1989, 1990) performed a test on double T-joints, which can be regarded as double K-joints with an infinite longitudinal gap if chord bending influences are ignored. They showed that the transverse gap size is a primary factor influencing the capacity of double T-joints when compared with that of planar T-joints, which resembles the behavior of double K-joints (Makino et al., 1984). Paul et al. (1991, 1993) performed an additional test on double T-joints and presented a closed ring analysis to identify the influence of the transverse gap. The influence of the transverse gap ratio ζ_t was found to be dependent on the failure type. For a constant value of β the ultimate capacity increases with ζ_t for the failure type without local deflections of the chord wall between the braces and decreases for the failure type with significant local deflections of the chord wall between the braces.

Eighteen double K-joints (called KK-joints hereafter) under axial brace loading were tested to fill the void of existing data,

Received December 12, 1991: revised manuscript received by the editors October 23, 1992. The original version (prior to the final revised manuscript) was presented at the Second International Offshore and Polar Engineering Conference (ISOPE-92), San Francisco, USA, June 14-19, 1992.
KEY WORDS: Tubular joints, multiplanar, ultimate behavior, ultimate capacity.