International Journal of Offshore and Polar Engineering
Vol. 7, No. 4, December 1997 (ISSN 1053-5381)

Static Sling Tensions in Heavy Lifts with Doubled Sling Arrangement

Y. S. Choo*, F. Ju and K. H. Lee
Faculty of Engineering, National University of Singapore, Kent Ridge, Singapore

ABSTRACT

The force split ratio, α, for doubled sling arrangements is highlighted in this paper. Three analytical models — namely, the free-slipping model, the fixed model and the friction model — are presented to analyze the tensions of doubled slings. A corresponding computational model is developed to include the effects of structural stiffness, the slippage of doubled slings at the hook, and the sling misfits on the sling tensions. It is found, through both theoretical study and field measurement, that the force split ratio for doubled slings is significantly dependent on the equivalent coefficient of friction and lift configuration. A larger force split ratio, α, for doubled slings may therefore be appropriate for rigging selection and design of lift components to ensure consistent factors of safety during certain lifting operations.

INTRODUCTION

The availability of semisubmersible crane vessels with lift capacities up to 14,000 tonnes has led to the design and installation of integrated decks and jackets weighing more than 10,000 tonnes in the North Sea. There is also a trend in building modularized ship blocks, which are fully outfitted, lifted and joined to complete fabrication of the entire ship. The design and installation of these types of large and heavy structures require a thorough understanding of the behavior of the lift system to ensure safety and cost-effectiveness in the operation. The mechanical behavior of the lift system has been studied from both the static and dynamic viewpoints, with an emphasis to provide the means of calculating the sling tensions under various conditions accurately. Duerr (1988) found that the effect of sling tolerance on the distribution of sling tension is significant. Crull (1990) presented two direct methods to determine the sling tensions in heavy rigging. The aspects of dynamics during lift installation were studied by Tong and Duncan (1991), Wouts et al. (1992) and Lange et al. (1992). The development of design criteria and general design aspects were presented by Bunce and Wyatt (1982) and Mayfield and Zimmerman (1986). The practical rules and methods for the design and analysis of lifted structures are documented in design recommendations, for example, in API (1989) and DnV (1977). A comprehensive study on the impact of sling misfits on sling force distribution and lift dynamics was carried out by Brown and Root (1990) in a joint industry project; some of the results were reported by Mawer et al. (1993). However, most of these studies and industry codes were focussed on the single sling arrangement, while the doubled sling arrangement which exhibits some different phenomena has received less attention.

The authors have been involved in field measurements, carried out in Singapore for lifted structures weighing up to 3,600 tonnes, which involved the doubled sling arrangement. It has been observed that the force split ratio for the two arms of a doubled sling may be as large as 2.0, which is much higher than the value of 1.22 (ratio of 0.55:0.45) normally adopted by the industry. Selected results from one of the field measurements are presented in this paper.

*ISOPE Member.

Received July 14, 1995: revised manuscript received by the editors September 8, 1997. The original version was presented directly to the Journal.
KEY WORDS: Static tension, doubled sling, heavy lift.

The main objective of this study, as motivated by both the theoretical need and measurement results, is to investigate the load distribution between the two arms of a doubled sling. The emphasis is on the force split ratio, α, for the two arms of a doubled sling, since the individual sling tension can be easily determined if this ratio is available. Three analytical models and the corresponding computational model to calculate the sling tensions for the doubled sling lift arrangement are presented in this study. The force split ratio, α, for a doubled sling is found to be significantly dependent on both the lift geometry and the frictional effect of the contact area between the sling and hook block. The ratio of 0.55:0.45 (α_o = 1.22) normally used by the industry is found to be lower than the measured results, and may thus not be a conservative assumption for certain lifts. The effects of sling misfits and structural stiffness of the lifted module on the sling tensions and the ratio α are also evaluated.

The dynamic effects resulting from environmental factors (such as wind, wave and current) and the coupled crane-barge/module motions during the lifting operation have a significant effect on sling tension. In addition, the structural stiffness of a lifted module can be computed accurately by applying the static condensation technique to a refined finite element model which may be used directly in sling tension computation. Because the focus of this paper is on the force split ratio between the two arms of a doubled sling, a simplified spring model to represent the structural stiffness is adopted in this study. Results from ongoing studies on the dynamic behavior during lift installation and the accurate representation of structural stiffness will be reported in subsequent publications.

ANALYTICAL MODELS FOR DOUBLED SLING

The doubled sling arrangement is used for some single-hook or dual-hook lifts, and an example of the dual-hook, doubled sling lift arrangement is shown in Fig. 1. The two sides of the rigging arrangement — say, side A and side B — are usually arranged symmetrically to the longitudinal direction (x-axis) to minimize possible tilt. Each of the two doubled slings on side A, for example, is indicated in Fig. 1 to be doubled at hook block 1, with the lift points on the structure (points a, b, c, d) co-linear. A two-dimensional model, on the real plane of the slings which is inclined to the horizontal plane (as shown in Fig. 2), may be used to calculate the sling tensions. Slings 1 and 2 are the two arms of doubled sling I on the left, while slings 3 and 4 are the two arms