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PERFORMANCE-BASED OPTIMIZATION OF THE WELDED BOX OF A SINGLE GIRDER OVERHEAD TRAVELLING CRANE ACCORDING TO EC3 AND EC1

Demetrios T. Venetsanos[1], *Efrossini-Aikaterini T. Magoula[2] and Christopher G. Provatidis[3]

[1] National Technical University of Athens, School of Mechanical Engineering, 9, Iroon Polytechniou Ave, 15780, Greece
dvenet@central.ntua.gr

[2] National Technical University of Athens, School of Mechanical Engineering, 9, Iroon Polytechniou Ave, 15780, Greece
efimgl@yahoo.gr

[3] National Technical University of Athens, School of Mechanical Engineering, 9, Iroon Polytechniou Ave, 15780, Greece
cprovat@central.ntua.gr
http://users.ntua.gr/cprovat

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ABSTRACT

Overhead travelling cranes are used in industrial applications for moving loads without causing disruption to activities on the ground. They can be described as machines for lifting and moving loads, consisting of a crane bridge which travels on wheels along overhead crane runway beams, a trolley which travels across the bridge and a hoist for lifting the loads [1]. One of the most popular crane types is that of a single girder having a welded box cross-section. Since the main demand is the safe operation of the crane, the dimensioning of the cross-section must be based on standards, such as the Eurocodes (EC's), which describe the minimum requirements concerning the performance of a steel structure, the aforementioned cranes being included.

According to EuroCode 1, the loads that a crane is desirable to carry must be appropriately amplified so that not only dynamic effects but also various scenarios ranging from typical use of the crane up to accidental actions are covered. In this way, it is ensured that the dimensions of the girder cross-section will provide adequate safety against failure not only for the nominal operation but also for certain extreme cases.

According to EuroCode 3, the performance of a crane must comply with constraints concerning its ultimate limit state, its serviceability limit state as well as its resistance against fatigue. The estimation of the resistance against yielding and buckling is complicated and cumbersome because the application of the actual loads causes local effects that can be neither ignored nor easily calculated [2]. Furthermore, there is an uncertainty with respect to the applied loads, while studies have been reported in reliability analysis involving statistical models for crane loads [3]. Another issue of major importance is the fatigue, since it is the most common type of failure in practice. In a typical case, as the loaded trolley of an overhead crane travels along the girder, it

imposes a cyclic loading that cause the appearance of local stresses which may be sufficiently high to initiate fatigue cracks.

The problem of finding the optimum design of a welded box girder beam is a constrained optimization problem, the constraints being all the verifications concerning the previously described performance of the crane. The commercially available steel plates, which, when appropriately cut and welded together, form the crane girder, have standard thicknesses. For the width and height of these plates, the standard design procedure is to round off their values to the nearest higher integer. Consequently, the actual optimization problem at hand is of a discrete combinatorial nature. However, solving the same problem as a continuous variable problem results in a continuous solution which when compared to the optimal discrete one provides the designer with information that may prove to be of crucial importance. Such cases occur when a negligible violation of the active constraints results in having zero scrap material which is the best possible scenario for a manufacturer. Within this frame, the present paper presents the investigation of 75 cases, resulting from the appropriate combination of three design parameters, namely the crane bridge span, the total hoisting mass and the trolley wheel-base. Each one of these cases was optimized first with a powerful optimizer (fmincon routine) embedded in MatLab and then with an in-house optimizer.

The MatLab optimizer provides an optimal design vector derived from a continuous optimization procedure. The in-house optimizer performs an exhaustive discrete search, which is both user-controllable and iterative, around the current design vector and provides a discrete optimal design vector. The basic characteristic of this optimizer is that every time a cycle of exhaustive search is completed the user has the ability either to stop the optimization procedure and use the derived feasible design vector or to initiate another cycle of exhaustive search around the derived vector, with or without changing one or more of the controlling parameters. In this way, the user has the ability to communicate interactively with the optimizer, introduce his/hers experience and guide the optimization procedure towards a certain design trend. It is clarified that for this optimizer, convergence is considered to have been achieved when the user establishes no improvement in the structural weight after three or more search cycles.

For each one of the examined cases and for each optimizer, the minimum weight and the corresponding design vector were recorded. With this data at hand, it was possible to reveal the sensitivities of representative quantities, such as the minimum structural weight and the normalized values of cross-sectional properties, with respect to independent design variables, such as the geometrical dimensions of the cross-section. Based on these results, appropriately defined normalized indices were introduced, illustrated and evaluated. Information of this kind is most useful in determining reliable and most cost effective trends concerning the design of crane girders, thus making the present work significant both for research and for practicing engineering purposes.

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