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PERFORMANCE-BASED OPTIMIZATION OF A WELDED OPEN CROSS SECTION RUNWAY BEAM ACCORDING TO EC3 AND EC1

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ABSTRACT

Overhead travelling cranes are machines for lifting and moving loads that typically rest on a crane support structure consisting of a crane runway beam and a set of columns [1]. The crane runway beam is either rolled or welded, almost always being of an open cross-section. In any case, the designer must select a beam profile that carries with safety the applied loads during the operational life time of the crane [2]. In turn, this means that constraints with respect to the behaviour of the runway beam must be taken into consideration. However, the designer has much more freedom to form a welded beam profile since it is possible both to select among plates that are commercially available in various thicknesses and to cut the plates in any desirable width or height. In this case, the costs, for purchasing the plates and for carrying out the necessary processes of cutting and welding, vary significantly between different designs. Obviously, it is highly desirable to minimize the corresponding total cost as much as possible. Therefore, the design of the runway beam belongs to the category of performance-based optimization problems, where structural optimization methods replace the traditional “trial-and-error” process [3].

The present paper deals with the weight minimization of a welded open cross-section runway beam, the behavioural constraints being in accordance to the Eurocodes 1 and 3 (EC1 and EC3). The EC1 standard refers to the actions induced by hoists and cranes on runway beams and describes the way the crane loads must be amplified so that dynamic effects as well as various scenarios, ranging from typical use of the crane up to accidental actions, are covered during the design optimization procedure. The EC3 standard complies with the principles and requirements for the safety and serviceability of structures, fatigue being included. 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 [4]. Taking the aforementioned standards into consideration, it is ensured that the optimized runway beam profile will exhibit adequate safety against failure not only for the nominal

operation but also for certain extreme cases.

A welded open cross-section runway beam is assembled from commercially available steel plates, which are appropriately cut and welded together. These plates have standard thicknesses, while, for practical reasons, their height and width are rounded to integer values. Therefore, the optimum design of the runway beam is actually a discrete optimization problem, for the solution of which an in-house optimizer, performing a sequential exhaustive-type search about each current design vector, was developed. The basic characteristic of this optimizer is that the user has the ability to change some or all of the controlling parameters, such as the domain of each design variable and the step size, at the beginning of every new search cycle. In this way, the designer does not remain a passive spectator any more but participates in the optimization procedure introducing his/hers personal experience and judgement thus leading the optimization procedure towards a certain design trend. At this point, it is clarified that convergence is considered to have been achieved when the user establishes no improvement in the structural weight after three or more sequential search cycles.

For the evaluation of the proposed performance-based optimization procedure, a total of 108 cases were studied, resulting from the appropriate combination of four design parameters, namely the crane runway beam span, the crane bridge span, the total hoisting mass and the end-carriage wheel-base. Each one of these cases was optimized first with the aforementioned in-house optimizer and then with a typical branch-and-bound optimization technique. For each one of the examined cases and for each optimizer, the minimum weight and the corresponding optimum design vector were recorded and compared.

On top of that, with the aforementioned 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 runway beam cross-section. Based on these results, appropriately defined normalized indices were introduced, illustrated and evaluated, while these illustrations can be used for a quick first approximation of the performance-based optimum design of a runway beam. Information of this kind is most useful in determining reliable and most cost effective trends concerning the design of runway beam, thus making the present work significant both for research and for practicing engineering purposes.

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