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OPTIMISATION OF AN OVER-SIZED BEAM, PART OF A CRANE BRIDGE, BY APPLYING THE ECONOMICAL CRITERIA

Abstract:
Most of the time, the strength structures who have not been statically determined, cut to the right sized, and checked out by the classic methods of the material strength cause the over sizing, because specialists use approximate measurements in order to decrease the number of mathematical calculation. This paper work describes the optimization of the main beam of a strength structure of a traveling crane used in metallurgy – by using economical criteria. In order to accomplish the best suited size, we have to perform both an analytic and experimental study about the performance of the traveling crane. Both the analytic and experimental studies have pointed out that we are able to come up with the best sizes in order to reduce the material consumption we used during the production process of the main beam within the strength structure of the traveling crane we have analyzed.

Keywords:
optimization, economical, criteria, beam, crane-bridge

INTRODUCTION

In general, the optimisation is defined, [4], as being the search of a problem, finalised with a result that, compared with other possible results, it is the best one. Based on this result, technical or economical decisions can be made.

A solution for an optimisation problem can be obtained only if we equally take into account all the factors that determine it. In this respect, the resistance structures can't be approached apart from the construction they are part of, because it is an evident interdependence between them and the rest of the construction. This interdependence shall be expressed in the optimisation process. In the same time, it was found that, at least in the current stage, it is not possible to realise an overall optimisation that leads to a general solution capable to satisfy all the imposed aspects and requirements. That's why the current researches aim only the optimisation of certain technical, technological and economical aspects.

The present-day simplification of the optimisation problem consists of the schematisation of the real solutions, by introducing simplifying hypotheses with covering character.

Having in view this aspect, a part of the solutions found so far has been applied in practice, because they were finalised as algorithms and computational programmes, [4].

OPTIMISATION CRITERIA OF THE RESISTANCE STRUCTURES

The resolution of an optimisation problem presumes the definition, for the analysed case, of the following elements: designing variables, designing restrictions and objective function. The correlation between the variables, *restrictions and the objective function can be realised through an optimisation criterion that offers the possibility to choose the most adequate solution for the analysed problem. Currently, the main optimisation criteria applied to the resistance structures, are: technical and economical.*

Regarding the technical criteria used to optimise the resistance structures, they are considered a problem of "extreme" (maximum or minimum), being applied to different parameters to determine the best solutions for realising the resistance structure. This criterion refers to an optimisation scheme, namely: determination of the structure form and sizes, which corresponds to a certain type of loading able to lead to optimum parameters as regards to the resistance and rigidity criterion.

Regarding the technical criteria used to optimise the resistance structures, we can say they are multiple, each of them being able to lead to a different optimum as to the same parameter. The researches performed until now, in order to apply the economical criteria to the sizing of the resistance structure, start, in principal, from two ideas: mitigation of the specific weight of the structure and reduction, as much as possible, of the fabrication costs, [4]. If this criterion underlies of the optimisation process, then the objective function is the cost price of the structure.

The optimisation based on the technical criteria leads to the determination of constructive solutions for the resistance structure, solutions that ensure its resistance and stability in operation, and the optimisation based on the economical criteria leads to the structure specific weight mitigation or to lowest fabrication expenses, which represents a measure of the economical efficiency.

Currently, it is considered that a rational solution for a resistance structure can be obtained only if there are equally taken into account all the factors that determine it, this think imposing the harmoniously combination of the technical and economical criteria. The interdependence between these ones is explained by the fact that the cost price of a resistance structure is made, on the one hand, of the costs of the materials used to make its elements and the costs of fabrication, transportation and montage and, on the other hand, from the maintenance costs during the entire existence period of the construction whose part the structure is. In their entirety, the material costs are practically proportional to the material weights, e.g. any material price reduction determines the metallic structure weight mitigation.

According to the literature, for the activity of designing and re-designing of the resistance structures that belong to metallurgical equipments, the optimisation criteria refer especially to the reduction of: consumption of steel they are made of, cost price of the materials used to make to structure, manpower and execution time.

At the resistance structures made of one solus material (the case of the metallurgical equipments), the mitigation of their weight implicitly ensure the cost reduction in the optimisation process.

If the material quantity represents the determining element in establishing the structure cost, then the criterion gets the form of the minimum weight condition. This situation is frequently met in case of the resistance structures of the metallurgical equipment made of standardised elements, whereat their processing and building-up costs are usually evaluated based on weight.

In this paper, it is presented the optimisation of a central beam, part of the resistance structure of a bridge-crane that operates in the Continuous Casting hall of an integrated steel plant.

THE OBJECTIF OF OPTIMIZATION

The travelling crane we are analysing is able to lift up to 100 KN, and the items are lift up to 17,3 m. Therefore, the strength structure is made of two longitudinal beams, as well as two end beams: left and right. The cross section of the resistance elements – caissons – is symmetrical and made of universal iron – they are weld together. Fig.1 presents the constructive scheme of one of the longitudinal beam of a crane bridge. We have found the best sizing of this beam with the help of the OPTSTAR module, and it belongs to the finite-elements COSMOS calculation software.

In order to make the calculation, we have come up with the design of the longitudinal beam we have complied with the geometrical design and the operation process, [1], [2], [3]. The calculation pattern is described in fig.2.

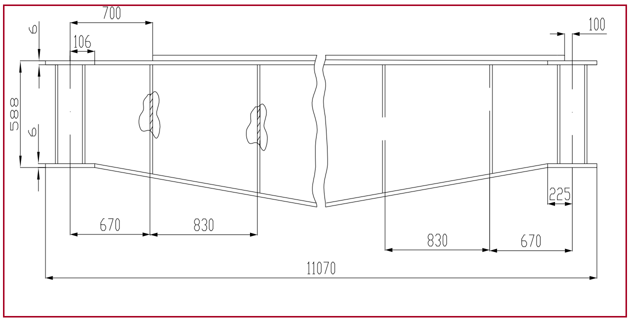

FIGURE 1. Design scheme of the longitudinal beam from the resistance structure of the crane bridge

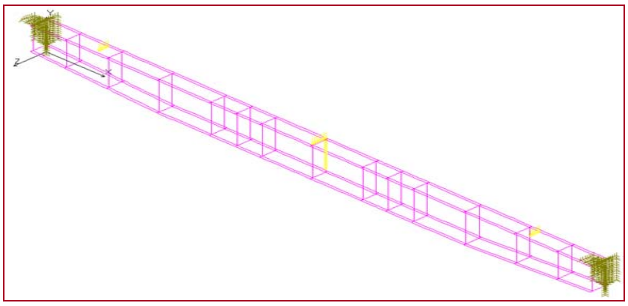

FIGURE 2. The pattern of the calculation pattern used for the best sizing of the longitudinal beam

MATHEMATICAL MODEL

The definite mathematical pattern for the problem of finding the best sizing for the longitudinal beam we have considered the following elements, [3]:

- designing variable features: the width of the plate of the stringer: $\delta_{min} < \delta < \delta_{max}$;
- designing restrictions – we consider the equivalent tension specific for the shaping up: $\sigma_{von\ Misses} < \sigma_{adm.}$;
- the objective function – the weight of the resistance structure's stringer: $G = G_{min.}$.

We have produced several different variants for the calculation software – the side cores. All the variants are the following:

variant 2: $\delta_{t\ sup} = \delta_{t\ inf} = 7{,}5$ mm and $\delta_{i\ lat} = 6$ mm; variant 3: $\delta_{t\ sup} = \delta_{t\ inf} = 7{,}5$ mm and $\delta_{i\ lat} = 5$ mm; variant 4: $\delta_{t\ sup} = \delta_{t\ inf} = 6$ mm and $\delta_{i\ lat} = 6$ mm; variant 5: $\delta_{t\ sup} = \delta_{t\ inf} = 6$ mm and $\delta_{i\ lat} = 5$ mm; variant 6: $\delta_{t\ sup} = \delta_{t\ inf} = 5{,}5$ mm and $\delta_{i\ lat} = 6$ mm; variant 7: $\delta_{t\ sup} = \delta_{t\ inf} = 5{,}5$ mm and $\delta_{i\ lat} = 5$ mm

The loadings have been considered in the elastic field, and therefore the elastic constants have been introduced, corresponding to the material OL 37.

Variant 1 is considered the original variant, where: $\delta_{t\ sup} = \delta_{t\ inf} = 8$ mm and $\delta_{i\ lat} = 6$ mm. Fig. 3 describes a cross section of the main beam, subject to our fitting. We have: $\delta_{t\ sup,\ inf}$ - the width of the upper bed plate, and the lower bed plate of the bin; $\delta_{i\ lat}$ – the width of the side cores of the beam.

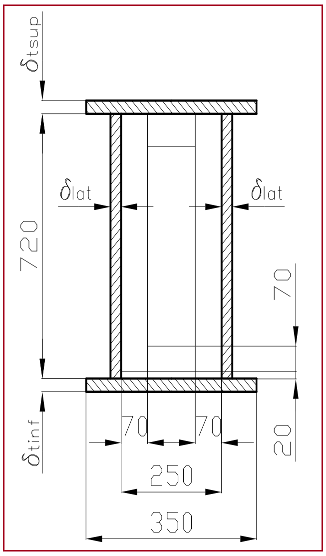

FIGURE 3. The cross section of the resistance elements

RESULTS

As a result of the calculation software based on finite elements for the variants we have already mentioned, we should enumerate the significant results of the fitting process.

After we have studied and interpreted the results we had obtained, we have observed that the smallest size to reduce the width of the bed plates is 5.5 mm, and 5 mm (variant 7) for this fitting variant, the equivalent tensions which is specific to any reshaping for the longitudinal beam I goes between 20.135 N/mm^2 and 161.08 N/mm^2 fig. 4, 5 and 6, [3].

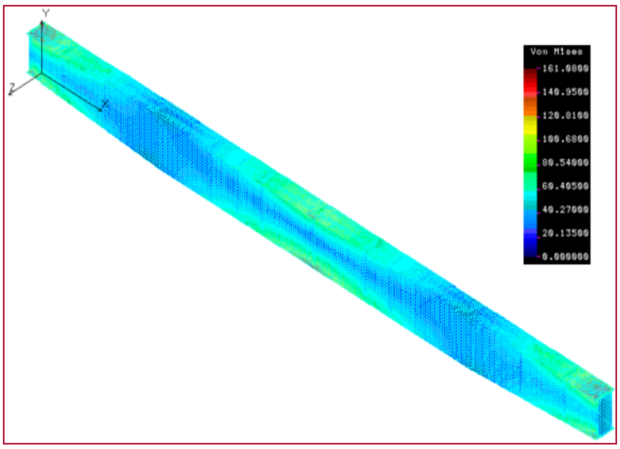

FIGURE 4. The distribution of the tension $\sigma_{Von\ Misses}$ for the fitted longitudinal beam

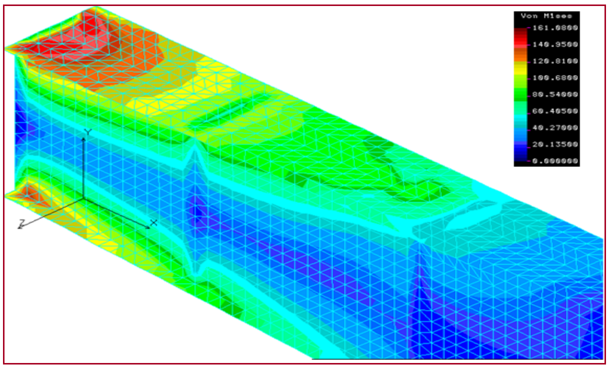

FIGURE 5. Details about the distribution of the $\sigma_{Von\ Misses}$ tension for the fitted longitudinal beam

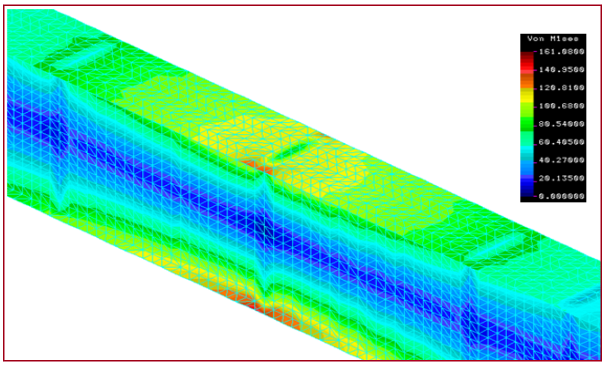

FIGURE 6. The distribution of the $\sigma_{Von\ Misses}$ tension for the fitted longitudinal beam I at the middle of the opening

As far as we see, von Misses equivalent tension reaches the highest values at the ends of the longitudinal beam, at the connection points with the end beams, at the upper bed plate and the lower bed plate – 161.08 N/mm². As far as the middle of their opening, we see that we have reached highest values at the level of the beam wings 143.78 N/mm² (sides of the lower bed plate), and at the connection point between the lower bed plate and the side core, we have 151.74 N/mm².

After we have analyzed the distribution of the results for the $\sigma_{von\ Misses}$ equivalent tension we have obtained after finding the best fitting with the results we have obtained by experimenting (we have described them in detail in [3] and [4]), we see that the difference amongst them reaches 10%. As far as the experiments are concerned, we have been able to perform them with the help of the resisting electrical tensiometry; for that reason *the crane bridge has been loaded with steel lingots with specific precise weight. In the case of the strength structure we have analyzed, we knew the sizes of the cross-sections, and the fact that all the elements had been subject to static stress (their loads had been increased until they had exceeded the limit loads). The worst loading version was 120 KN - [5]. This confirms that the calculation pattern we have used is the best, fig.7, [5].*

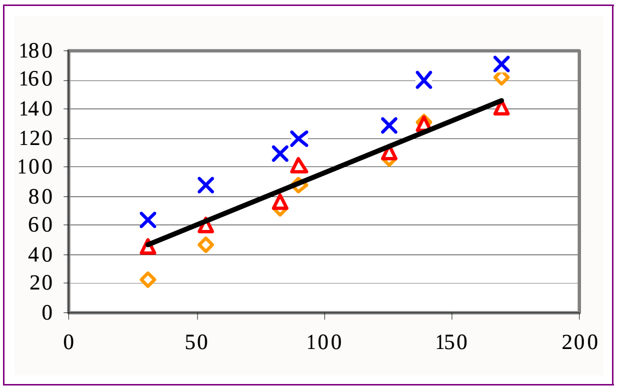

FIGURE 7. The variation diagram of equivalent tension- analytical value, experimental value and optimizing value

For that version, we should calculate how much raw material we would use, and establish the percentage we are able to saved. We have to calculate the weight of the main beam according to the relation (1):

$$G = g \cdot \rho \cdot \sum_{i=1}^{4} A \cdot l_i \qquad (1)$$

This relation (1), contains the following elements: G – total weight of the stringer, [kg]; g – gravitational speed, [m/s²]; A – cross-section area of an element of the stringer, [m²]; l – the length of the stringer, [m]; ρ - the density of the raw material, [kg/m³].

After we have calculated it, we have been able to reduce the weight of the I-type longitudinal beam with almost 8,46 % - for version no. 1 – and with 20,6 % - for version no. 7.

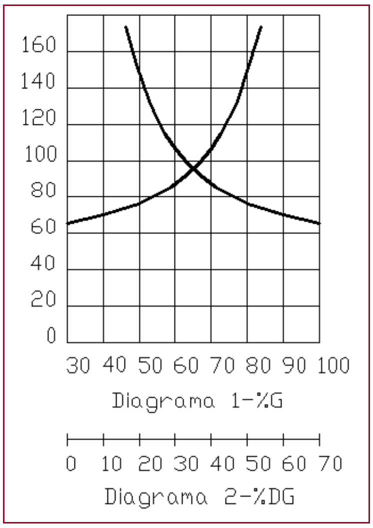

FIGURE 8. The variation diagram of the highest equivalent tension of an element situated in the middle of the opening of an longitudinal beam

In fig.8 we describe the highest equivalent tension variation of an element situated in the middle of the opening of the I-type longitudinal beam, which is situated on the lower plate, close to the connection point with the side core, and according to the weight „G" of the whole strength structure; we must also reduce the weight - ΔG.

CONCLUSION

In this paper work we have analyzed the best sizing of the main beam within the strength structure of a traveling crane that we use for the continuous casting in a metallurgy plant.
Thus, we have considered that the walls of the cross-section (caisson-type) of the longitudinal beam I have changed their features, meanwhile the height of the sections remained the same; we have theoretically reduced its weight with almost 20,6% (considering the production technology of the plates that the caisson is made of), but practically we have reduced it to 8,46%, without exceeding the required resistance of the raw material.
The prevailing economic criterion is to cut off investments, considering the opportunity cost. Beam weight reduction eliminates the costs calculated during the initial estimation, while maintaining the same results. From this point of view it is necessary to consider the revision, the site organization, element replacement, their assembly and testing, involving at least 20% less raw material required to produce the beam.
The optimisation based on the technical and economical criteria leads to the structure specific weight mitigation or to lowest fabrication expenses, which represents a measure of the economical efficiency.

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