Design and Optimization Experiment of Steel Channel Composite Beam Crane Structure

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Abstract. I-shaped beam is mainly adopted as the walking girder profile in single beam cranes which are currently used. The girder of the I-shaped beam has many advantages. However, the girder of I-shaped beam also has the following defects in actual use, namely the weight is heavy, external components are conflicted with monorail easily, monorail derailment occurs, etc. A lifting system with built-in crane girder and built-in driving crane as the main structure is designed and studied in order to make up for the defects of I-shaped beam structure. The I-shaped beam track is designed into a steel channel composite (L]-shaped) track. A built-in flat wheel trolley is used for driving in the track instead of me-shaped beam monorail crane. The steel channel composite beam crane undergoes factory loading test and stress-strain analysis in order to better analyse and collect structure optimization data, and its feasibility and practicability are verified by experimental data. The advantages of the steel channel composite beam crane structure are summarized, and the future built-in crane lifting system is prospected finally.

1. Introduction
I-shaped beam is mostly adopted as the crane girder profile in single beam cranes which are currently used. I-shaped beam girders has the advantages of wide application, simple structure, simple processing technology, mature processing installation and technology, etc. However, I-shaped beam girder also has some shortcomings in actual use: firstly, I-shaped beam girder is relatively heavy, which is inconvenient for transportation and installation; secondly, the girder function is single, it is inconvenient to hang cables and other components on I-shaped beam externally; thirdly, the monorail crane suspended on I-shaped beam has the possibility of derailment. Derailement was available on the monorail crane during no-load operation. The steel channel composite beam crane is designed by referring to the design technology of modularity and built-in module structure in order to make up for the deficiency of I-shaped beam crane [1, 2].

2. Another section of your paper
Steel channel composite beam crane mainly consists of two steel channels, intermediate reinforcement device, suspension point connection structure, built-in crane and limit devices at both ends, etc. The built-in crane is mainly composed of front plate, rear plate, sprocket component, driving wheel, driven wheel, auxiliary wheel, load-bearing shaft, lifting ring, baffle and chain, etc. The chain is pulled to rotate the ratchet wheel, and the driving wheel is driven to move on the flange in the steel channel through...
gear drive. The two inside end surfaces of the steel channel are regarded as running track aiming at the auxiliary wheel. It is mainly used for preventing the trolley from deviation. The built-in hand-held trolley front plate, rear plate and load-bearing shaft, etc. require non-standard processing. Standard parts such as roller, bearing and ratchet, etc. are purchased for assembly in the factory.

The steel channel undergoes force analysis according to simply supported beams due to the role of sling load and own gravity. The formula [3] is shown as follows:

$$
\begin{align*}
M_{\text{max}} &= \frac{P}{4} L \\
\tau &= \frac{P}{A} \\
\varepsilon_{\text{max}} &= \frac{PL^3}{48EI} \leq [\varepsilon] \\
\sigma &= \frac{M_{\text{max}}}{W} \leq [\sigma] \\
\tau &\leq [\tau] \\
[\varepsilon] &= \frac{L}{1500}
\end{align*}
$$

In the formula: L - suspension point spacing, mm; A - Steel channel cross section area, mm²; Mmax - maximum bending moment, Nm; Fmax - maximum vertical static deflection, mm; [f] - allowable vertical static deflection, mm; σ - Bending stress, MPa; [σ] - allowable bending stress, MPa; τ - Shear stress, MPa; [τ] - allowable shear stress, MPa; W - Section modulus in bending, cm³; I - cross section axial moment of inertia, cm⁴; E - Elasticity modulus, Pa.

The lifting weight is considered according to 2t. No. 12 steel channel made of Q235A material is regarded as the beam crane girder. A middle reinforcement structure is designed on the steel channel girder in order to improve the structure strength. The stress and strain measurement experiment of steel...
channel composite beam crane before and after installation of the intermediate reinforcing plate under 2t load are implemented respectively. The stress and strain change before and after installation of intermediate reinforced structure is analysed and compared.

3. Stress-strain measurement experiment and data analysis

3.1. Experimental preparation
Strain gauges are pasted on the middle two flanks and two sides of the steel channel composite beam crane, and the strain measurement data collection system is set up after the experimental device is assembled. The number in front of the symbol "-" indicates the pasted position of the strain gauge in strain gauge label 1-1, 1-2, 2-1, 2-2, 3-1, 3-2, 4-1 and 4-2. 1# and 3# are located symmetrically on the bottom flange of the steel channel. The following numbers represent the pasted direction of the strain gauge. 1 represents the direction parallel to the length direction of the steel channel girder, and 2 represents the direction perpendicular to the length direction of the steel channel girder. After the strain gauge is stuck, the center cross section at the length direction of the steel channel composite beam crane above the steel channel girder is regarded as the starting zero point. The left side and right side are marked at the interval of each 20cm. A total of 7 points are selected as longer stop points of the load, thereby the static strain testing instrument can collect sufficient data (static strain tester is used for collecting 1 point at the interval of every 5s).

![Figure 2. Preparation of stress-strain measurement experiment](image-url)
A 2t hand-pulled hoist is suspended on the build-in crane. 2t counterweight is loaded. Strain detection is carried out. Namely, the monorail crane is driven to move towards the other side from the -60cm stop point on one side of the steel channel girder. The crane is suspended for 1-2 minutes on each stop point, which returns after reaching the 60cm stop point on the other side, and the experiment is stopped when the crane reaches the -60cm stop point again. Strain data are recorded by TST3822E static strain tester.

![Image](1) Lifting weight ![Image](2) Dwell measurement

**Figure 3.** Operation strain stress measurement experiment implementation

### 3.2. Treatment of experimental data

#### 3.2.1. Solid Works simulation calculation. Solid Works software is utilized for simulation calculation on the stress strain condition of the steel channels before and after installation of the intermediate reinforcing place under 2t load. Corresponding stress and displacement simulation values are obtained as shown in the following figure. It can be seen from the figure that the transverse stress value of girder bottom flange paster is 39.5mpa, and the transverse displacement value is 0.00008mm. The vertical stress value on the side wall paster is 136.6mpa, the vertical displacement value is 2.323mm, the transverse stress value is 39.5mpa, and the transverse displacement value is 0.0003mm respectively.

![Image](1) Stress simulation diagram ![Image](2) Displacement simulation diagram

**Figure 4.** Solid Works simulation calculation of steel channel composite beam crane before installation of intermediate reinforcing plate under 2t load

It can be seen from the figure that the transverse stress value of girder bottom flange paster is 33.7Mpa. The transverse displacement value is 0.00003mm. The vertical stress value on the side wall paster is 67.5mpa. The vertical displacement value is 1.07mm, the transverse stress value is 13.4mpa, and the transverse displacement value is 0.00008mm.
Figure 5. Steel channel composite beam crane Solid Works simulation calculation after installation of intermediate reinforcing plate under 2t load

4. Conclusion
The crane is designed in the girder aiming at build-in crane beam crane. It has the following advantages: (1) the lifting scope can be expanded, the track is not limited to straight line, cable-stayed operation is allowed, and more suspension points can be applied. (2) The crane is operated in the pipe track, the track is smooth without debris and dust accumulation as well as good passability. (3) The overall structure is simple, the weight and cost are low, which are convenient for installation and track extension. (4) The crane does not derail when heavy objects are lifted, and it is safe and efficient. (5) Lifting operation can be carried out by manual and electric means.

The result of load test shows that the performance data of steel channel composite beam crane is better. However, the lifting structure is a load-bearing structure, which requires high safety performance. More build-in crane girder model design and corresponding verification experiments are still required in order to extend the structure to practical engineering application. Cost-effective build-in crane beam crane structure form can be selected.

References
[1] Editorial Board of 'Nonstandard Mechanical Design Manual', Nonstandard Mechanical Design Manual, Beijing, National Defense Industry Press. (2008).
[2] Editorial Board of 'Steel Structure Design Calculation and Example', Steel Structure Design Calculation and Example, Beijing, People's Communications Press. (2008).
[3] Editorial Board of 'Crane Design Manual (Second Edition)', Crane Design Manual (Volume I), Beijing, China Railway Publishing House (2013).
[4] Liu Hongwen, Material Mechanics (Third Edition), Hebei, Higher Education Press. (1995)