



Finite Element Static Analysis of the Main Beam of Mobile Moulder Grooving Machine

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Author's contribution

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Short Communication

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ABSTRACT

This paper takes the 1500t mobile moulded frame trench making machine as the research object, firstly introduces the structural composition and operation flow of the trench making machine, and establishes the finite element model of the trench making machine by using the parameterized language of APDL in ANSYS software. Since the main beam has a large self-weight and is the main load-bearing part of the machine, the analysis focuses on the stress and displacement maps of the main beam under the typical working conditions of pouring and over-hole. Through the finite element analysis, the maximum stress value of the main beam is 179.78MPa, which occurs in the middle position of the main beam under the concrete pouring condition of Class 8 wind. The maximum deformation in the Y direction of the main beam was -69.90 mm, which occurred at the two end positions of the main beam. In addition, the results of class 11 wind unloaded and different distance working conditions over the hole were also obtained, and found to meet the use

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requirements. The safety of the main girder design is verified by comparing the theoretical calculations with the finite element calculations, and at the same time, the theoretical basis is provided for the subsequent research on whether there is any optimisation space for the main girder.

Keywords: Grooving machine main beam; moving mould frame; finite element analysis; APDL.

1. INTRODUCTION

Trenching machine is a kind of large-scale equipment with its own formwork, which can be moved forward automatically and is developed with the experience of bridge moving mould frame bridge building machine [1]. With the features of simplicity, high efficiency, automaticity and safety, it has been used in the construction of crossings in large-scale projects such as the Dongshen water supply of Guangdong Dongjiang-Shenzhen and the Caohe River crossing and the Scott River crossing in the middle line of the South-to-North Water Diversion in China [2]. Trough machine construction is a new way of ferry construction, which originates from the highway and railway bridge cast-in-place technology, that is, installing the support frame and the whole hole template on the trough pier, and then carrying out the pouring operation and applying pre-stressing in this template, after completing the operation of a hole, the template is demoulded and moved to the next hole together with the mould support structure, and then adjusting and fixing the mould support structure, and then assembling and adjusting the template to carry out new After assembling and adjusting the formwork, a new casting operation is carried out, and so on, until the casting of all the troughs is completed [3]. As a key control project of the South-to-North Water Diversion Project, the design and construction of the turbulent river crossing has very high technical requirements and challenges. Considering the overall layout and structural form of the ferry, the arrangement of the trough was firstly determined in the design stage. The length and span of the ferry were also determined according to the project requirements and geographical conditions. A two-way pre-stressed girder type ferry was selected as the structural form, which is able to withstand larger loads and spans. Detailed calculations and analyses of the ferry structure were carried out to ensure the safety and stability of the structure. A 1:1 model test was carried out to verify the accuracy of the calculation results. Regarding the selection of the construction scheme by studying the two construction schemes, namely, the trough full-bearing method and the trough builder method, a technical and

economic comparison was carried out. Factors such as construction quality, construction period, cost, safety and construction diversion were considered. Finally, the 40m span, 1500t construction scheme of the trough-making machine was selected. The successful implementation of the project on China's large-scale ferry construction equipment, construction technology, construction technology development has an important role in promoting. The successful construction of the turbulent river ferry not only reflects China's technical strength in the field of large-scale water conservancy projects, but also provides valuable experience and reference for similar projects [4,5]. In this paper, a company develops a 1500t maximum span 42m ferry channel making machine as the research object. The main beam as one of the main load-bearing parts of the trough-making machine, especially under the condition that its own weight is also large, the finite element analysis of it is of great significance to the overall equipment safety and subsequent optimisation of the trough-making machine.

2. FINITE ELEMENT ANALYSIS OF SLOT-MAKING MACHINE

As a kind of large-scale water conservancy equipment, trough making machine is mostly non-standard products. The design of the main beam, as one of the important components, is extremely important to the overall safety and cost of the machine. The whole structure of the machine is complex, and the finite element method can be used to deal with the complex leg structure as well as flexibly adjust the size and shape of the mesh to adapt to the different needs of different structures, and use a finer mesh in the area of stress concentration in the contact area of the main girder and the guide girder. In addition, through ANSYS comes with zero-order, first-order algorithm iterative analysis, can be used for the main beam optimisation, in order to reasonably reduce the weight of the whole machine. In summary, through the finite element analysis, the first is to check whether the strength and stiffness of the main beam design meets the requirements, which is conducive to protecting the safety of construction personnel and

equipment safety. Secondly, it is to analyse whether there is any optimization space in the design, which is conducive to saving the manufacturing cost for the enterprise and enhancing the competitive advantage.

2.1 Brief Description of the Structure of the Groove Making Machine

The research object of this paper is the upstream 1500t slot-making machine, which is mainly composed of main beam, guide beam, pick beam, hanging outer rib, No.1 fixed outrigger, No.2, No.3, No.4 movable outrigger, outer mould system, hydraulic inner mould system, end mould system, electrical system and other parts. Among them, the main girder is a box girder structure with top and bottom two layers, and high strength bolts are used to connect the sections and sub-layers, and the guide girder is a truss structure, which is symmetrical in both longitudinal and transverse. In ANSYS firstly run the command flow in the main girder section file, so that the system saves the section data first, then run the main girder command flow file to get the main girder modelling entity and the right side section as shown in Fig. 1 and Fig. 2.

2.2 Trough-Making Machine Operation Process

- (1) The whole machine is located at the top of the two piers, and the 2 and 3 legs are fixedly supported with the top of the pier in pouring mode;

- (2) After completing the process of concrete raising, 2 and 3 legs drop down to demould, and the outer mould system rotates to open to prepare for over-hole;
- (3) Start 2, 3 legs longitudinal shift cylinder machine forward 16m, at this time the No. 1 leg to the top of the pier in front of the support;
- (4) No. 4 leg began to support, and at the same time release the No. 3 leg to lift off and move forward a span to the top of the pier in front of the drop to re-support;
- (5) Loosen leg No. 2 and move forward one span to the front pier top support, the other No. 1 leg loosening lift-off;
- (6) Start the longitudinal cylinder of No.2, No.3 and No.4 legs to move the whole machine forward by 7.5m, and release the No.4 leg;
- (7) Start 2, 3 legs longitudinal cylinder, the whole machine moves forward 18.5m, No. 4 leg hanging forward 7.5m;
- (8) Adjust the heavy load support mode of No.2 and No.3 legs to the end of one working cycle.

3. FINITE ELEMENT ANALYSIS RESULTS OF MAIN BEAM UNDER DIFFERENT HAZARDOUS WORKING CONDITIONS

The main working process of the groove making machine can be divided into two stages, one is the pouring construction process, and the second process of changing the leg over the hole after pouring one span.

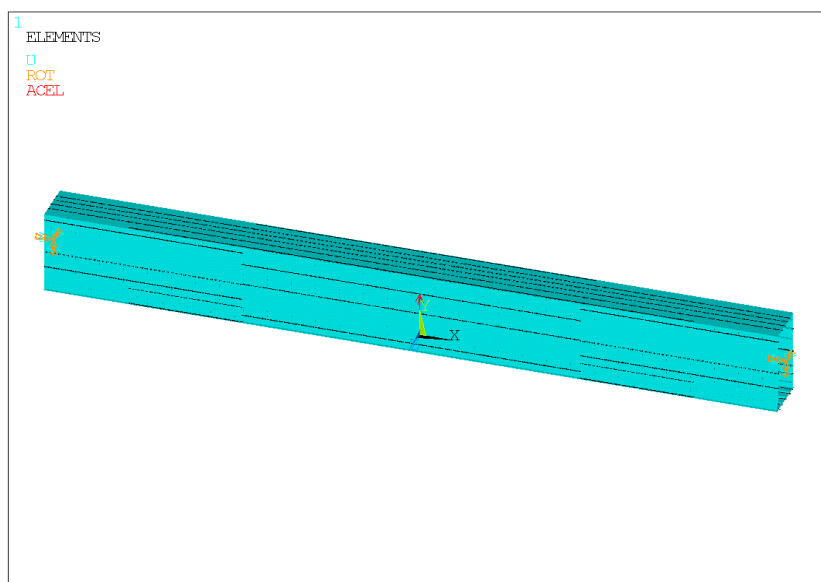


Fig. 1. Solid drawing for modelling of main beam (axonometric view)

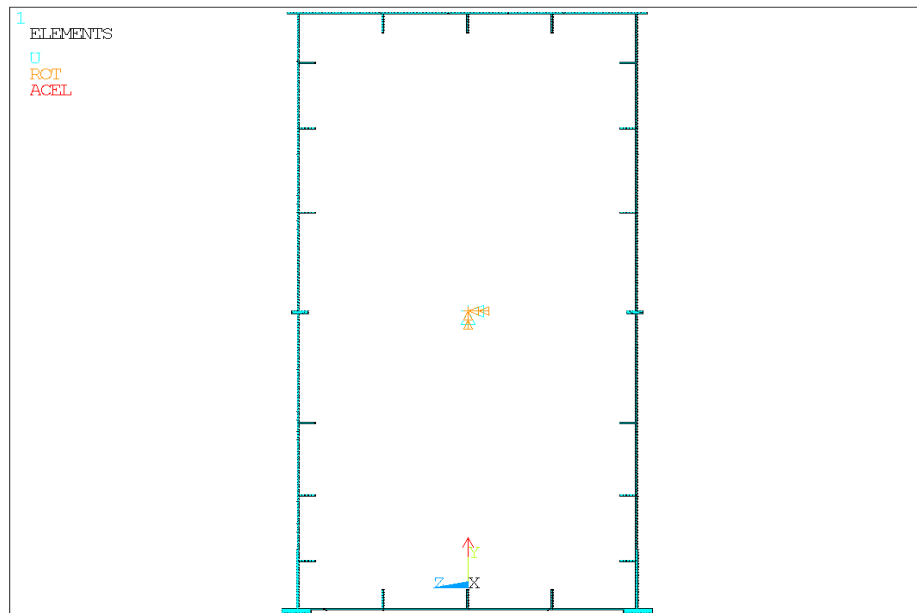


Fig. 2. Cross-section of the right side of the main beam

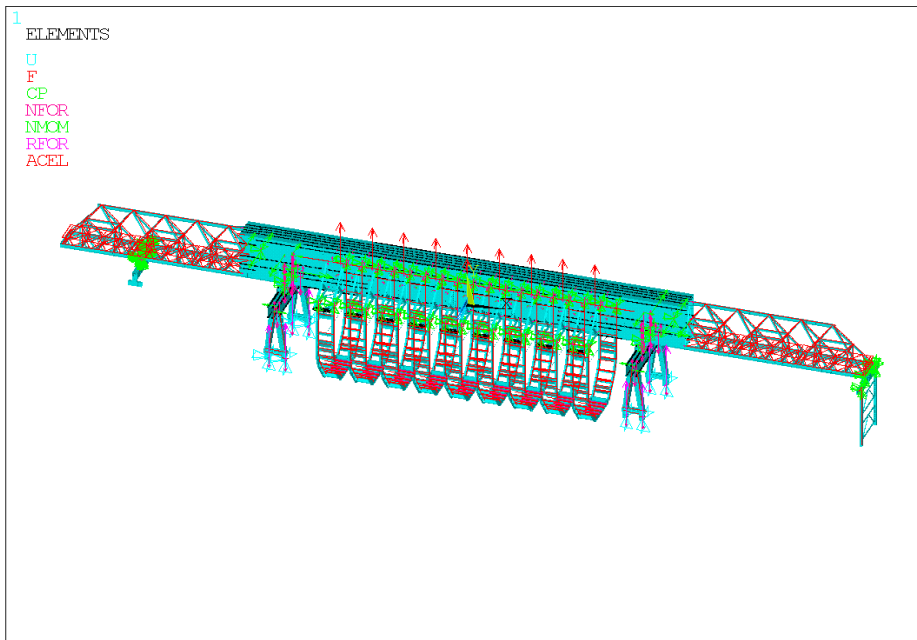


Fig. 3. Finite element model of channel builder under full load condition of class 8 winds

3.1 Analysis of Pouring Operation of Groove Making Machine

The finite element analysis is carried out when the stress and deformation of the main beam is the largest at level 8 wind, at this time, the groove maker carries out the casting operation under the action of the No.2 and No.3 outriggers, and the load received includes the weight of the concrete beam and the

inner mould in addition to the machine's own weight and the wind load, and the overall load applied to the groove maker is as shown in Fig. 3.

The main beam is extracted individually by APDL command to view the stress cloud and displacement cloud of the main beam. The command flow is as follows: esel,s, sec, 33154,33157 ! Main beam.

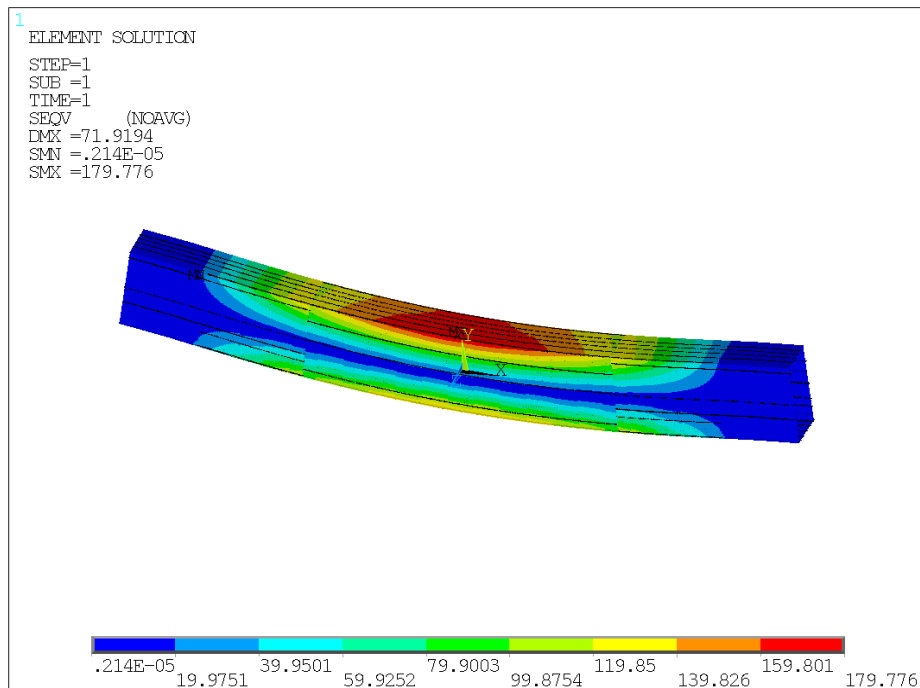


Fig. 4. Equivalent force cloud diagram of the main beam of the groove maker under full load of force 8 winds

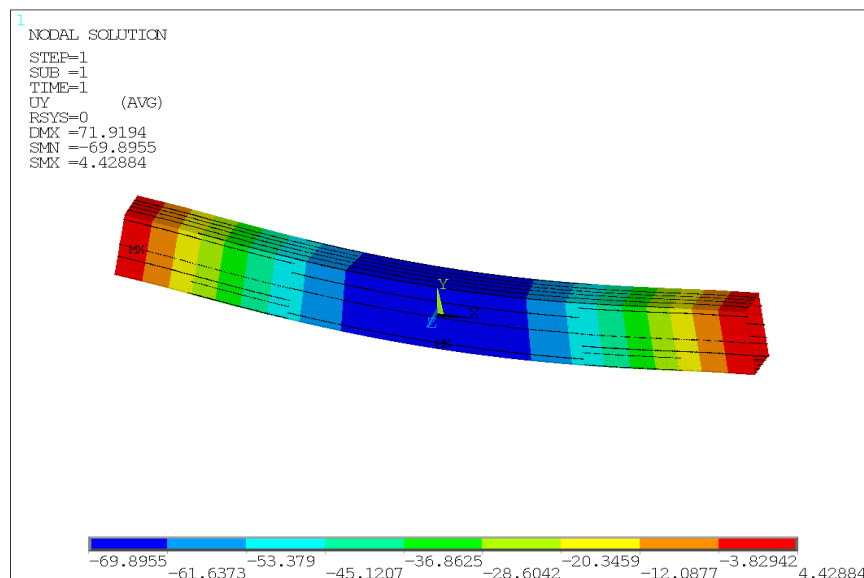


Fig. 5. Displacement of the main beam of the groove maker under full load of force 8 winds

The permissible stress method is used to check the strength of the main beam [6,7].

$$\sigma \leq [\sigma] = \frac{\sigma_s}{n}$$

Where: σ is the yield limit of the material; n is the safety factor of the material; $[\sigma]$ is the permissible stress of the material.

By the main beam equivalent stress map Fig. 5 can be seen at this time the maximum value of stress is 179.78MPa, occurring in the middle position of the main beam. The material of the main beam is Q355B, and the permissible stress is 236.7MPa, so the strength of the main beam meets the use requirements. From the main girder displacement and deformation cloud diagram Fig. 6, it can be seen that the maximum

deformation of the main girder in the Y direction is -69.90mm, which occurs at the two ends of the main girder. Considering the influence of the deformation of the outrigger, the maximum deformation of the main girder in the middle of the span is $69.90\text{mm}-11.58\text{mm}=58.32\text{mm}$, of which 11.58mm is the maximum deformation of the Y direction of the outrigger 3, and taking into account the deformation of the main girder under no-load, the maximum deflection in the middle of the span is: $69.90\text{mm}-11.58\text{mm}=58.32\text{mm}$. Considering the deformation caused by the self-weight of the main girder when it is unloaded, the maximum deflection of the main girder at mid-span is $58.32\text{mm}-20.55\text{mm}=37.76\text{mm}$, of which 20.55 is the maximum deformation of the main girder in the Y direction when it is unloaded by the wind of class 8. The permissible deflection is 45mm, so the stiffness of the main girder meets the use requirements.

Four important working conditions are selected to analyse the stress and deformation of the

main beam when the groove-making machine is working, and the results are shown in Table 1.

In summary, it can be seen from the chart that the stresses at the two ends of the main girder and the displacement at the middle of the main girder are much smaller than the permitted values, leaving a large margin of safety, taking into account the different wind loads of the casting and over-hole conditions.

3.2 Stress Analysis at the Joint between the Main Beam and Box Guide Beam When the Groove-Making Machine Passes through the Hole

Since the connection between the main beam and the box guide beam is weak when the slotter passes through the hole, the local stresses at this position are analysed separately. The stress results are shown in the Fig. 6.

Table 1. Stress and deformation of main beam under different working conditions

working condition		Main beam	
		Maximum stress/Mpa	Maximum deformation in Y direction/mm
pouring operation	At full load in force 8 winds	179.78	-69.90
	Force 11 winds unloaded	81.45	-26.16
perforation	Force 6 winds through the hole 16m	53.82	-17.76
	Force 6 winds over the hole 33m	40.07	-15.9

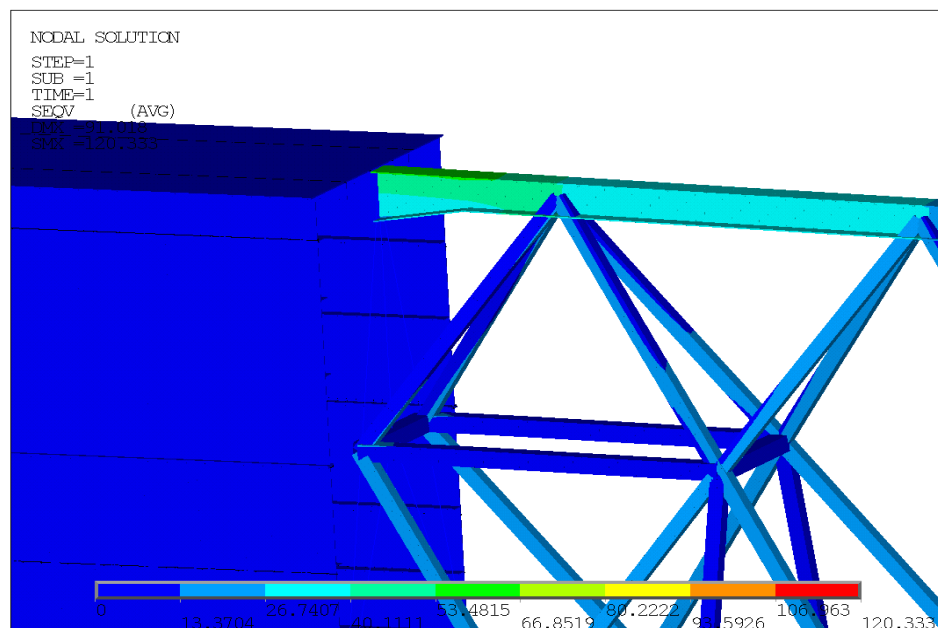


Fig. 6. Local stress cloud of 0m over the hole for class 6 winds

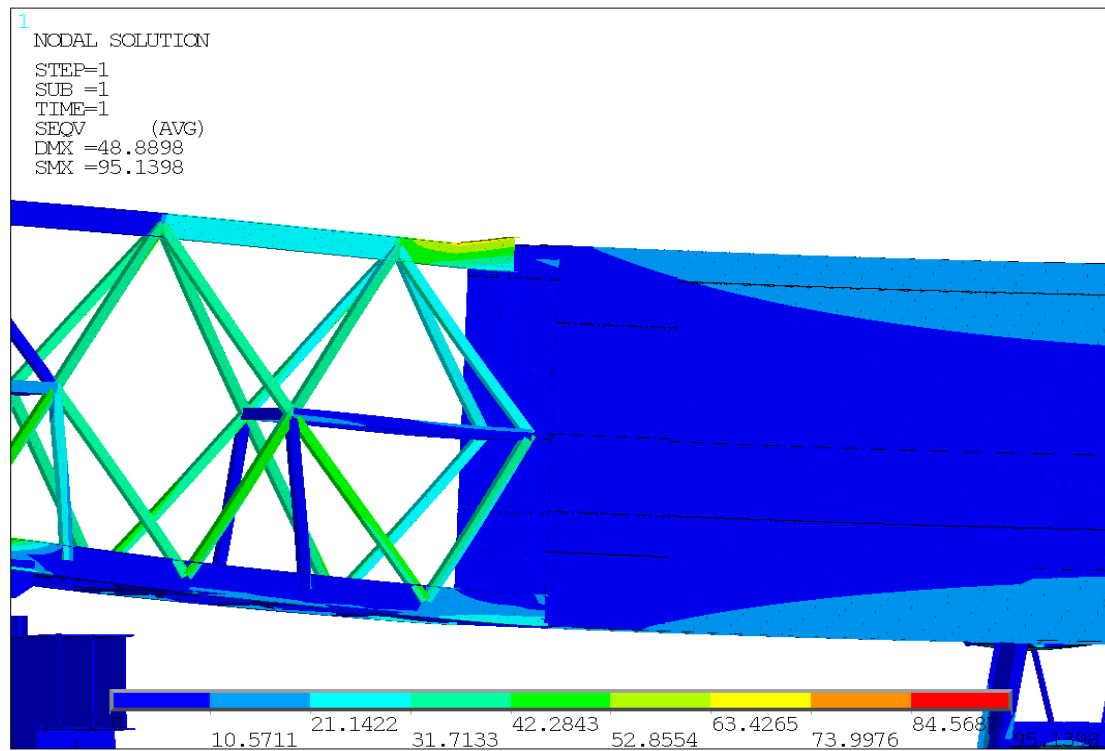


Fig. 7. Local stress cloud at 10m over the hole for class 6 winds

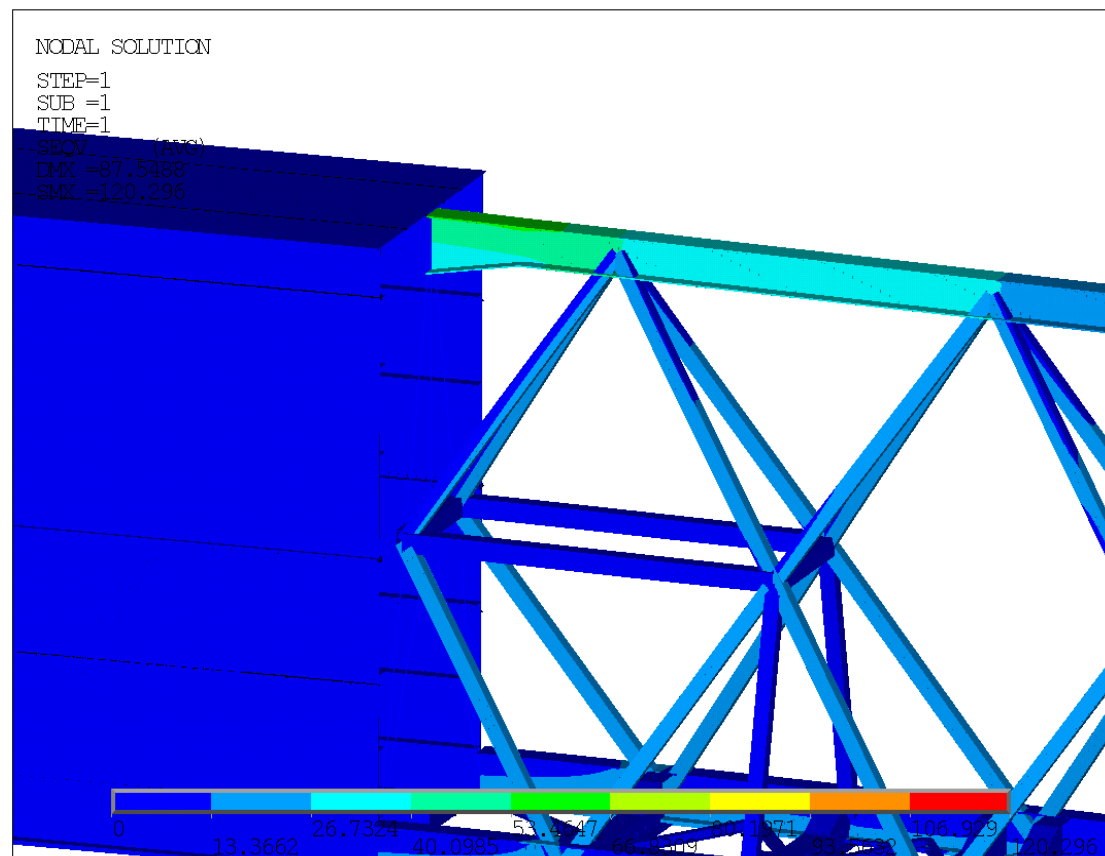


Fig. 8. Local stress cloud at 16m over the hole in force 6 wind (2 and 3 outrigger supports)

4. CONCLUSION

This paper uses ansys finite element software to check the strength and stiffness of the main beam of 1500t trough maker under dangerous working conditions such as pouring and crossing, and the results are within the permissible range, which verifies the safety and reasonableness of the design of the main beam. From the results of stress, displacement and deformation of the main beam in the paper, it is concluded as follows: the stress of the main beam of the groove maker is concentrated in the middle position under the construction condition of pouring in eight winds, and the comparison between the permitted stress method and the results of finite element analysis shows that the strength meets the requirements for use. When the groove maker is shifted through the hole, considering that the main beam and guide beam have large local stress, through the analysis of local stress and displacement cloud diagram, it is found that the local structure meets the requirements of strength and stiffness. Through the analysis of the main beam stress, displacement and deformation results, it is known that there is room for optimisation of the main beam, which provides a reference for further research on the optimisation of the main beam.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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