Stress Analysis of Crane Hook with Different Cross Sections Using ANSYS

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Abstract: ***These Crane hook is very significant component used for lifting the load with help of chain or wire ropes. Crane hooks are highly liable components that are typically used for industrial purposes. Failure of a crank hook mainly depends upon various geometric variables as well as material properties. In this analysis the material properties of a hook kept constant throughout the analysis and stress is to be reduced by varying different geometric parameters. The selected sections are Circular, Trapezoidal and T-section. The area remains constant while changing the dimensions for the three different sections. The crane hook is modeled using CATIA V5 software. The stress analysis is done by using ANSYS 14.5 workbench Educational version. It is found that T cross section yields minimum stresses at the given load of 50000kN for constant cross section among three cross sections. The stress distribution pattern is verified for its correctness on model of crane hook using Winkler-Bach theory for curved beams.***

Keywords: ANSYS 14.5, CATIA V5, Crane Hook, Static analysis, Winkler-Bach Theory, Stress

1. Introduction

This document Crane hooks are highly responsible components that are typically used for handling material in industries. They are always subjected to failure due to accumulation of large amount of stresses which can eventually lead to its failure. Crane hooks are the components which are generally used to elevate the heavy load in industries and construction sites. A crane is a machine, equipped with a hoist, wire ropes, or chains and sheaves used to lift and move heavy material. Crane hooks are mostly employed in transport, construction and manufacturing industry.

Overhead crane, gantry crane, telescopic, tower crane, mobile crane, jib crane, loader crane are some examples of commonly used cranes. A crane hook is a device used to grabbing and lifting up the loads by means of a crane.

It is basically a hoisting fixture designed to engage a ring or link of a lifting chain or the pin of a shackle or cable socket. Crane hooks with trapezoidal, circular, Square, I-section, T-section and triangular cross section are commonly used. The crane hooks are vital components and are most of the time subjected to failure due to accumulation of large amount of stresses, which are ultimately leading to failure. Cranes are subjected to continuous loading and unloading. This causes fatigue of the crane hook.

If the crack is developed in the crane hook, it can cause fracture of the hook and lead to serious accident. Bending stress, tensile stress, weakening of the hook due to wear, plastic deformation due to overloading, excessive thermal stresses are some of the other so, it must be designed and manufactured to deliver maximum performance without failure. Improper designs of crane hook lead to disastrous accidents.

Every year, incorrect lifting procedures cause injuries, loss of work time and property. People, machinery, loads, methods and work environment, that enough safety measures are fully implemented, lifting accidents can be reduced. Thus the aim of this research is to study stress distribution pattern within a crane hook of various cross sections using analytical, numerical and experimental methods. The general diagram of crane hook is shown in fig 1.1.

Figure 1.1: Crane Hook

2. Literature View

Crane hooks are the components which are generally used to elevate the heavy load in industries and constructional sites. Recently, excavators having a crane hook are widely used in construction work sites. One reason is that such an excavator is convenient since they perform the conventional digging tasks as well as the suspension works. Another reason is that there are work sites where the crane trucks for suspension work are not available because of the narrowness of the sites. In general an excavator has superior maneuverability than a crane truck.

However, there are cases that the crane hooks are damaged during some kind of suspension works. From the view point of safety, such damage must be prevented. Identification of the reason of the damage is one of the key points toward the safety improvement. If a crack is developed in the crane hook, mainly at stress concentration areas, it can cause fracture of the hook and lead to serious accidents. In ductile fracture, the crack propagates continuously and is more easily detectable and hence preferred over brittle fracture. In brittle fracture, there is sudden propagation of the crack and the hook fails suddenly. This type of fracture is very dangerous as it is difficult to detect.

Ajeet Bergaley and AnshumanPurohit [1] describe their work on structural Analysis of Crane Hook using finite elements analysis. The hook was tested on the UTM machine in tension to locate the area having maximum stress and to locate the yield point. The model of hook is prepared in CAE software having dimension and material similar to the crane hook which was purchased from market. The results obtained were compared with theoretical analysis. Then cross section in which minimum stress induced for given load was modified through FEM.

Rashmi Uddaawadikerin [3] discussed on stress analysis of crane hook and validation by photo elasticity. Crane hooks are highly liable components and are always subjected to failure due to accumulation of large amount of stresses which can eventually lead to its failure. To study the stress pattern of crane hook in its loaded condition, a solid model of crane hook is prepared with the help of CAD software. Real time pattern of stress concentration in 3D model of crane hook is obtained. The stress distribution pattern is verified for its correctness on an acrylic model of crane hook using diffused light Polari scope set up. By predicting the stress concentration area, the shape of the crane is modified to increase its working life and reduce the failure rates.

M. Shaban, M. I. Mohamed, A. E. Abuelezz and T. Khalifa [7] studied the stress pattern of crane hook in its loaded condition, a solid model of crane hook is prepared with the help of ABAQUS software. Real time pattern of stress concentration in 3D model of crane hook is obtained. The stress distribution pattern is verified for its correctness on an acrylic model of crane hook using shadow optical method (Caustic Method) setup. By predicting the stress concentration area, the shape of the crane is modified to increase its working life and reduce the failure rates.

Y. Torres, J.M. Gallardo , J. Domínguez , F.J. Jiménez E [11] studied the probable causes which led to a failure of the crane hook in service. The study of accident includes: details of the standards governing the manufacturing and use of lifting hooks, experimental analysis, mechanical behavior of steel of reported hook and simulation of the thermal history of the hook. From the literature survey it is understood by this author that there is a lot of scope for studying the stress analysis with different cross sections. Taking into this consideration, the author has embarked on studying the stress analysis of crane hook with four different cross sections such as rectangular, trapezoidal, triangle and circular sections.
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3. Design of Crane Hook

Machine frames having curved portion are frequently subjected to bending or axial loads or to a combination of bending and axial loads. With the reduction in the radius of curved portions. The stress due to curvature become greater and the results of the equations of straight beams when used to becomes less satisfactory.

For relatively small radii of curvature, the actual stresses may be several times greater than the value obtained for straight beams. It has been found from the results of photo elastic experiments that in case of curved beam, the neutral surface does not coincide with the centroidal axis of but instead shifted towards center of curvature.

It has also been found that the stresses in the fibers of a curved beam are not proportional to the distances of the fibers from the neutral surfaces, as is assumed for a straight beam. The design of crane hook was done by taking the data pertaining to load w. Cross sectional area and curvatures which are used in industrial applications of crane hook.

3.1 Theoretical Analysis

Winkler batch theory is used to calculate the theoretical stress. For the straight beams, the neutral axis of the cross section coincides with its censorial axis and the stress distribution in the beam is liner. But in case of curved beams, the neutral axis of the cross-section is shifted towards the centre of curvature of the beam causing a non-linear distribution of stress. The application of curved beam principle is used in crane hooks. This article uses Winkler - Bach theory to determine stresses in a curved beam.

Bending stress due to load is given by,

$$(\sigma_b)_{outer} = \frac{-M}{A\,X\,R}\left\{1+\frac{R^2}{h^2}\left\{\frac{y}{R+y}\right\}\right\}$$

$$(\sigma_b)_{inner} = \frac{M}{A\,X\,R}\left\{1+\frac{R^2}{h^2}\left\{\frac{y}{R-y}\right\}\right\}$$

Where,
M = Moment about centroidal axis
B = Width of the section on lower portion
A = Area of cross section of member (curved beam)
y = Distance of fibre from neutral axis
h^2 = Sectional constant
R = Radius of curvature

4. Modeling of Crane Hook with Catia V5 R20

Building a model in CATIA V5 usually starts with a 2D sketch. The sketch consist of geometry such as points, lines, arcs, circles, splines etc as we have in all 3D modeling softwares like SOLIDWORKS, CREO, etc. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, concentricity etc according to the possibilities that selected geometries may have, these all relations are collectively available in constraint tool box in CATIA V5. The parametric nature of

CATIA V5 means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

In an assembly the relations are mates. Just as sketch relations define conditions with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. CATIA V5 also includes additional advanced mating features such as gear and cam follower mates, which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, BSI, JIS, SAC).

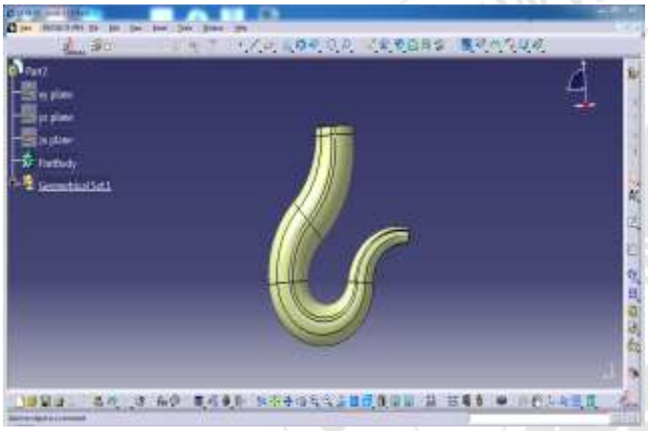

Figure 4.1: Catia V5 Model of Crane Hook with Circular Section

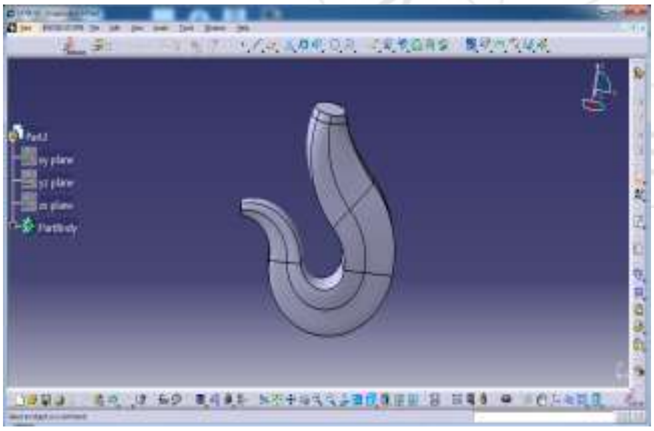

Figure 4.2: Catia V5 Model of Crane Hook with Trapezoidal Section

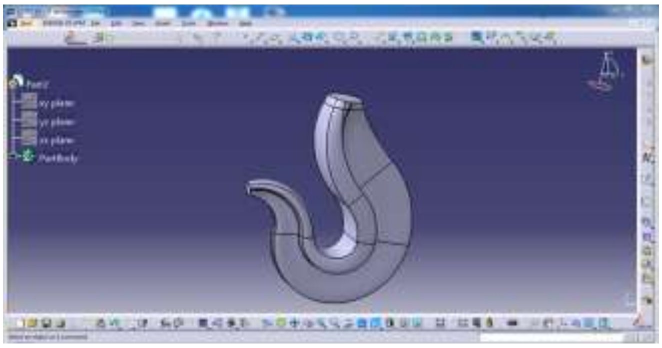

Figure 4.3: Catia V5 Model of Crane Hook with T- Section

5. Meshing

Meshing is probably the most important part in any of the computer simulations, because it can show drastic changes in results you get. Meshing means you create a mesh of some grid points called 'nodes'. It's done with a variety of tools and options available in the software. The results are calculated by solving the relevant governing equations numerically at each of the nodes of the mesh. The governing equations are almost always partial differential equations, and Finite element method is used to find the solutions to such equations. The pattern and relative positioning of the nodes also affect the solution, the computational efficiency and time. This is why good meshing is very essential for a sound computer simulation to give good results.

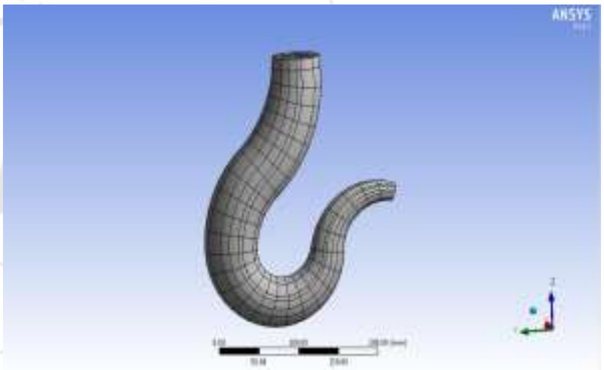

Figure 5.1 Meshing of Circular Cross Section

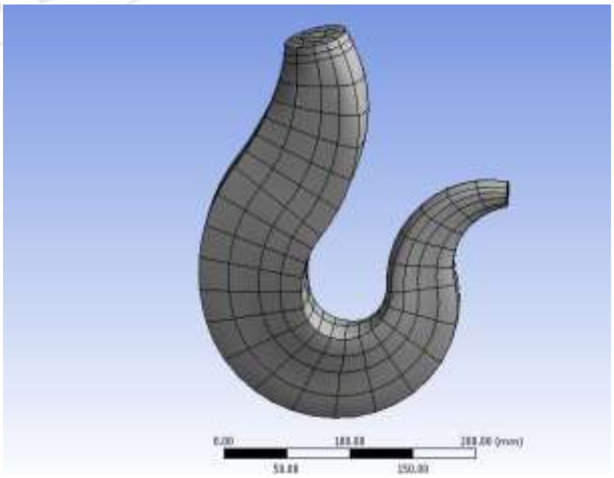

Figure 5.2 Meshing of Trapezoidal Cross Section

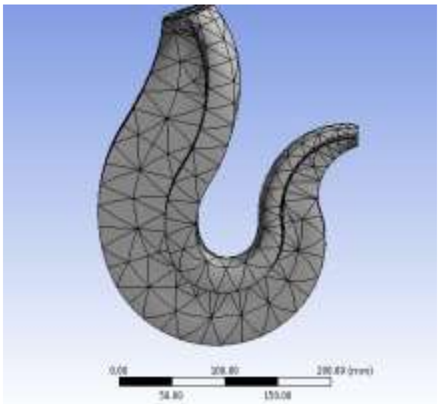

Figure 5.2 Meshing of T Cross Section

6. Load Condition

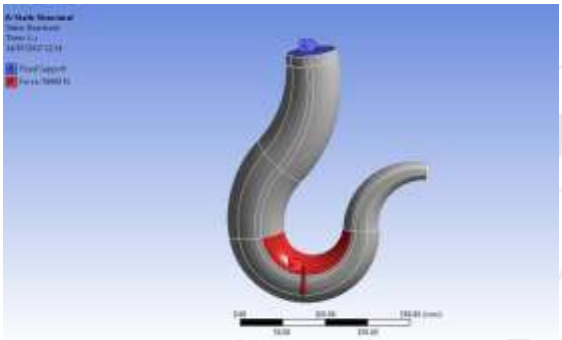

Figure 6.1: Load Condition for Circular Cross Section

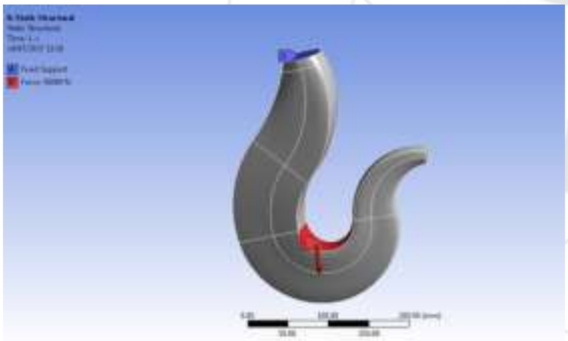

Figure 6.2: Load Condition for Trapezoidal Cross Section

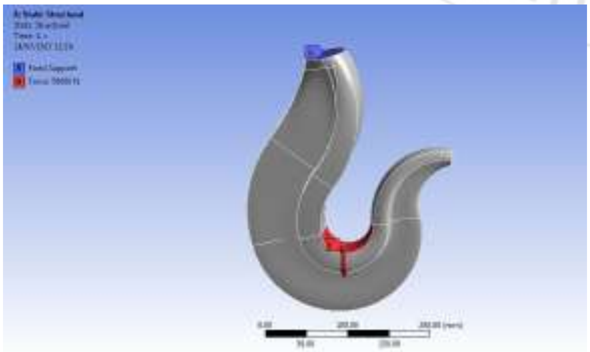

Figure 6.3: Load Condition for T Cross Section

7. Finite element analysis of Crane Hook using ANSYS 14.5 workbench

The finite element analysis method has become a dominant tool for the numerical solution of wide range of engineering problems. Applications range from deformation and stress analysis of automotive aircraft, building and bridge structures with advances in computer technology and CAD systems, complex problems can be modeled with relative alleviate.

In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements. The materials properties and the governing relationships are considered over these elements and considering the loading and constraints, result in a set of equations. Solution of these equations gives us the approximate behavior of the continuum.

8. Results and Discussion

In this dissertation three sections of crane hooks are designed according to curved beam concept. Stresses are found for 50000kN load using curved beam concept.

The model is modeled in CATIA V5 and STEP model is imported into ANSYS 14.5, here top side of crane hook is fixed and at the inner curvature of hook 50000 kN load is applied on nodes and stresses and deformation are plotted.

8.1 Circular Cross Section

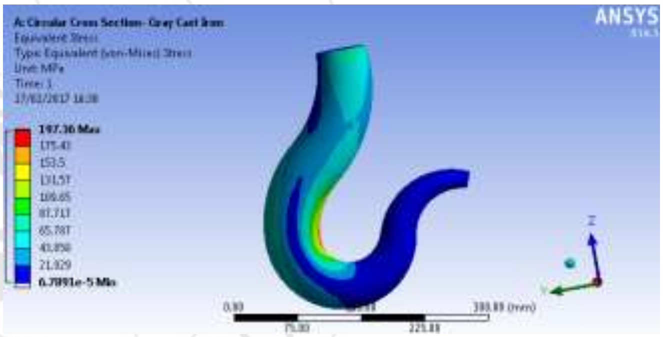

Figure 8.1.1: Equivalent Stresses in Crane Hook of Circular Section made up of Gray Cast Iron

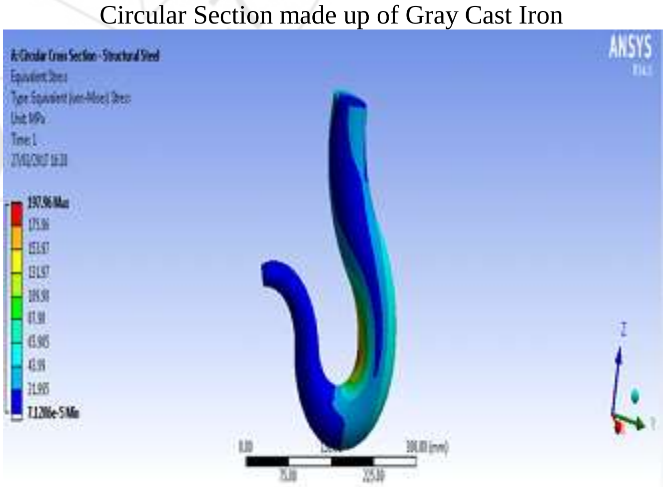

Figure 8.1.2: Equivalent Stresses in Crane Hook of Circular Section made up of Structural Steel

8.2 Trapezoidal Cross Section

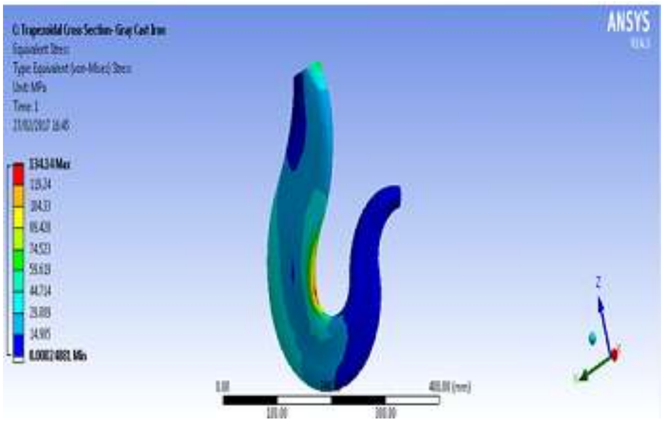

Figure 8.2.1: Equivalent Stresses in Crane Hook of Trapezoidal Section made up of Gray Cast Iron

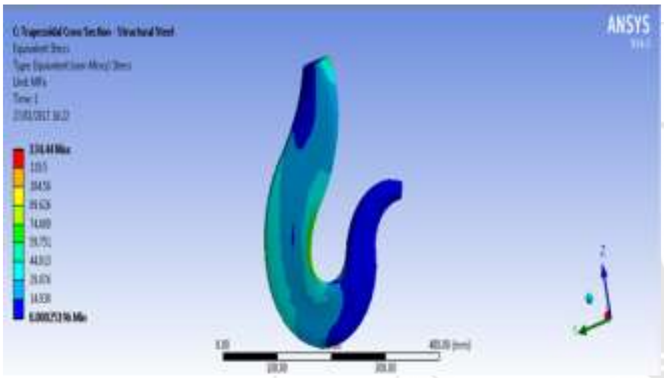

Figure 8.2.2: Equivalent Stresses in Crane Hook of Trapezoidal Section made up of Structural Steel

8.3 T- Cross Section

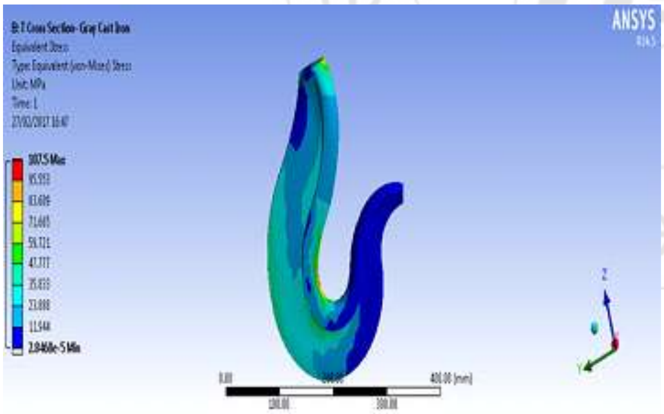

Figure 8.3.1: Equivalent Stresses in Crane Hook of T-Section made up of Gray Cast Iron

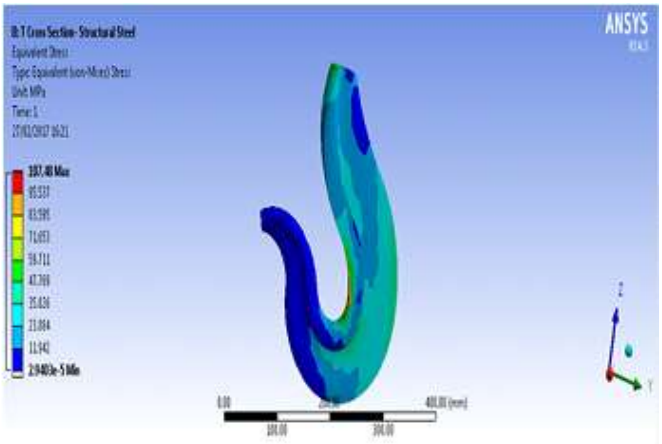

Figure 8.3.2: Equivalent Stresses in Crane Hook of T-Section made up of Structural Steel Table

8.4 Comparisons of Stresses in Different Cross Sections

Section Name	*Area of Cross Section (mm^2)*	*Inner Radius of Curvature (mm)*	*Load (kN)*	*Winkler Theory (The-Rotical) Stresses (N/mm^2)*	*Ansys Stresses (N/mm^2) Structural Steel*	*Ansys Stresses (N/mm^2) Gray Cast Iron*
Circular	3900	62	50	208.28940	197.96	197.36
Trapezoidal	3900	62	50	127.0289464	134.44	134.14
T –Section	3900	62	50	96.25333	107.48	107.50

9. Conclusion

Theoretical stresses calculated based on Winkler-Batch theory and the corresponding crane hook model stresses determined by using ANSYS were tabulated as shown above and found that the deviations are at minimum of 4.9 %. The factor of safety for crane hook under static analysis is 2 based on yield stress value

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