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Modelling and Analysis of C-Hook

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ABSTRACT: In the present work a C-hook assembly used for coil lifting applications is required to be designed based on basic strength of material calculations. The load to be lifted is 30 tons. The position of hinge along with size of counter weights and position the clamp arms to be shaped for optimised design to reduce the weight which in turn reduces the cost of the structure. The possible strengthening rib arrangement needs to be optimised for the requirements along with calculations for lifting pin arrangements. Also the size requirements of crane hook need to be specified for structural stability.

I. INTRODUCTION

The development of science and technology made the standard of living for human beings. The technological developments occurred step by step throughout the twenty first century. Manufacturing and production processes gained a lot in their process design and material handling system etc. The material handling system plays a vital role in the field of manufacturing industries. It is very much required to transfer tons of material from one place to other place through jib cranes etc. These cranes consist of several parts like work holding devices. The work holding devices must be properly designed and analysed in order to put them to work. Since the failure of these devices cause severe problems like destruction of parts, harmful to workers etc.

II. LITERATURE SURVEY

The Clamps have been used in the steel and iron industry for the last two centuries and by early civilizations as far back as the Roman Empire. Steel mills utilize tongs because they can be designed to withstand significant heat are not affected by electromagnetic interference have low maintenance requirements and can withstand significant shock loading. Service centres or fabricators like the fact that the tong requires few operators and can be used at various locations around the plant without concern for electrical or special hook needs. The small end-users embrace the tong for its low cost, flexibility and durability. With minimum (or zero) down time on the process line, the design characteristics of the tong grab make it an appropriate tool for many applications [3].

III. PROBLEM DEFINITION

Manufacturing and production processes gained a lot in their process design and material handling system etc. the material handling system plays a vital role in the field of manufacturing industries. It is very much required to transfer tons of material from one place to other place through cranes. These cranes consist of several parts like work holding devices. The work holding devices must be properly designed and analysed in order to put them to work. In view of the above said facts the C-hook is designed to carry for its maximum load capacity. It is modelled through CATIA V5 and analysed through ANSYS -10 Software.

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V.THEORITICAL CALCULATIONS

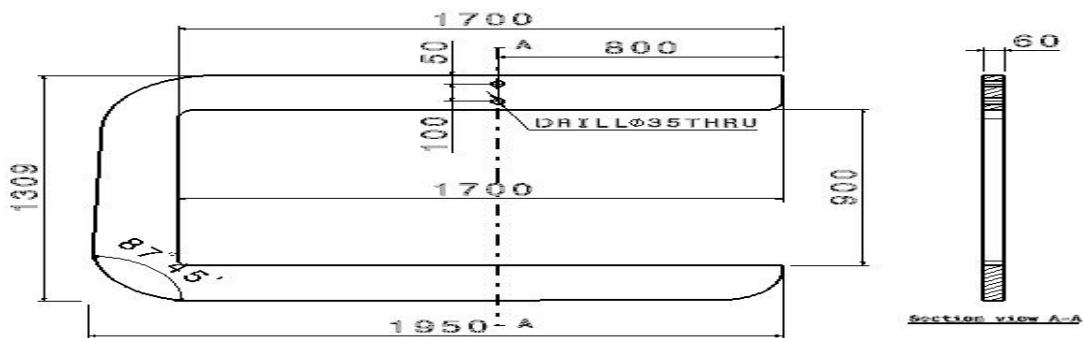


Fig:Frame requirements for the given coil lifting

The figure shows initial dimensions considered for the further calculations to find optimum dimensions of the C-hook. All the dimensions are represented in mm. The fillets are provided at the corners. Hinge position is also represented for lifting applications. Initial position is considered as 800mm from the right edge. Initial thickness of the member is taken as 60mm. The dimensions are considered to accommodate the coil to be lifted. Initially a rectangular section is considered for geometrical built-up.

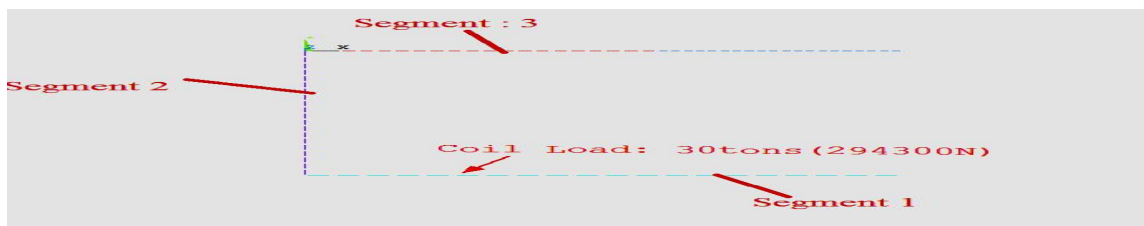


Fig1.1 : Free-body diagram requirement for analysis

The figure1.1 shows free body diagram represents the possible loads and division of the C-hook. Segment 1 is taken as load bearing member and segment 2 height accommodation and segment 3 for crane hook lifting. The top line is split into two parts to indicate the position of crane hook. Converting uniformly distributed load for the coil load

$$W = 294300 / 1950 = 150.9 \text{ N/mm}$$

Considering 3 segments for analysis

$$\text{Maximum Shear force on segment 1: } w \times L = 150.9 \times 1950 = 294300 \text{ N}$$

$$\text{Maximum Bending moment on segment 1} = wL^2/2 = 2.87 \times 10^8 \text{ N-mm}$$

Same moment will be transferred to the segment 2.

Similarly the shear force on segment 1 will work like axial load on segment 2.

Same shear force acts on the segment 3 but creates opposite moment to the initial moment from the segment 1.

So at certain location moment will change from negative to positive. This position can be utilized for support position to reduce the counter weight requirements.

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VI. MATERIAL DETAILS

- Material: Steel
- Young's modulus: 200Gpa
- Density: 7800kg/m³
- Poison's ratio=0.3
- Yield stress: 350N/mm²

VII. DESIGN REQUIREMENTS

- Load of the coil : 30 Tons
- Diameter of the Coil : 1.5meter
- Length of the coil : 3.5meter
- Material to be used : SAILMA450(Structural Steel of Yield stress: 450N/mm²)

VIII. MODELING OF C-HOOK USING CATIA V5

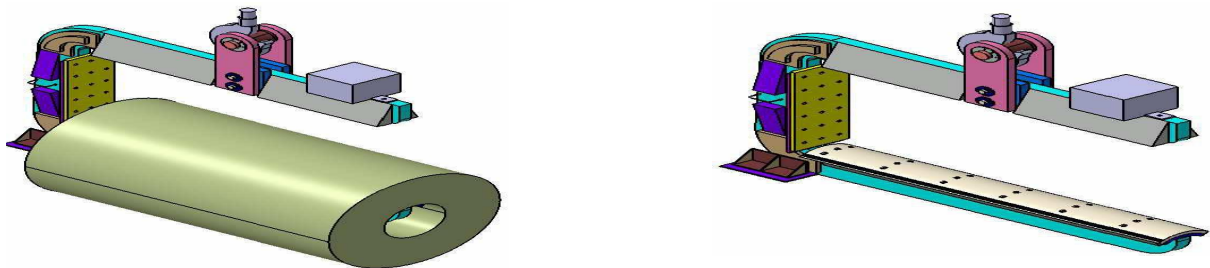


Fig 1.2: Model for Analysis

The figure 1.2 shows three dimensional modelling of the overall C-hook assembly for load lifting applications. Three dimensional modelling is done to verify the structural safety. CATIA V-5, software for three dimensional modelling of the physical object is used to build the geometry.

IX. FINITE ELEMENT ANALYSIS

The figure 1.3 shows ANSYS beam modelling using Beam3 element. For the segment 1 a uniformly distributed load of 150.923N/mm is applied. This load represents the coil load distributed uniformly.

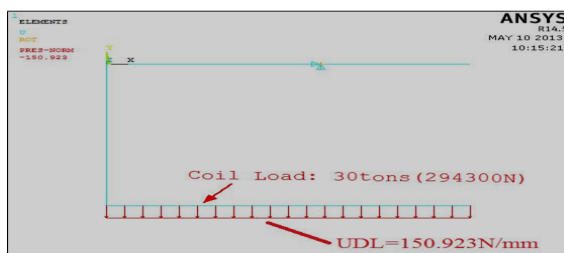


Fig 1.3 Boundary conditions of the problem

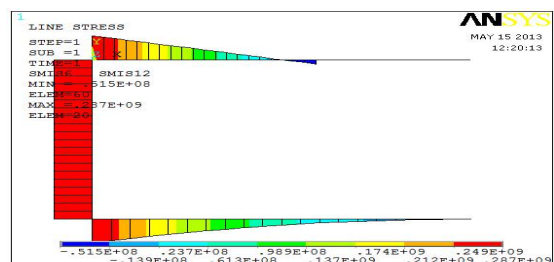


Fig 1.4 Bending Moment Diagram

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Hinge position is also shown. Beam3 element has long been tested for analysis purpose. So these elements gives correct bending and shear calculations along with stress estimates. Beam modelling helps in faster design iterations by which best design can be selected.

The figure 1.4 shows shear force and bending moments. In the segment 1 and 3 maximum shear force is same. No shear force observed on the segment 2 where it is converted as axial load. In the bending moment diagram the variation of moment can be observed from Plus to minus. If this position is taken for support this gives optimum weight for the counter weight.

X.PIN CALCULATIONS

- Pins are designed for shear load
 - Maximum shear load: $F=294300$ N
 - Allowable shear stress $\tau =70\text{N/mm}^2$.
 - Pin is in double shear, allowable shear for stress $\tau =35\text{N/mm}^2$
 - Area of the pin required $A=294300/35=8408\text{mm}^2$
 - Diameter of pin required $d=105\text{mm}$ at the centre
- Considered diameter: 120mm (Considering the variations in loads and bending effects)

XI.LINK DIMENSIONS

- Two lifting links are used.
- Load on each link : $294300/2= 147150$ N
- Minimum area required for the link $A=147150/140$ (140Mpa is allowable stress)
- $A=1051\text{mm}^2$.

XII.MINIMUM SECTIONAL REQUIREMENT FOR THE SEGMENT 2

Since same moment is acting on this structure for full length same section considered for segment 1 can be considered.

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XV.OPTIMUM POSITION FOR LIFTING

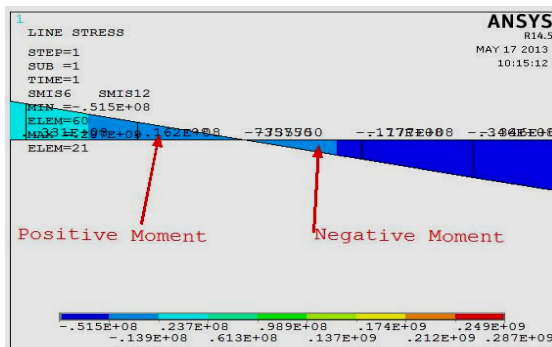


Fig 1.5 Point of Contraflexure

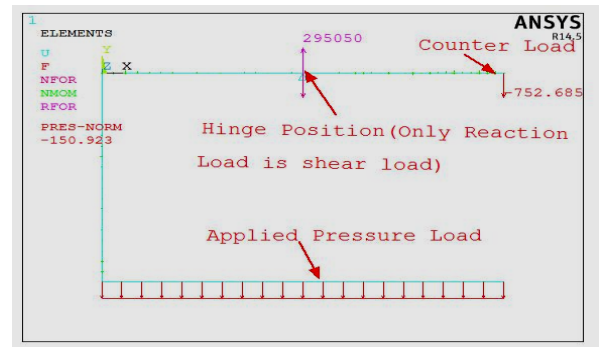


Fig 1.6 New Hinge position (977.5mm from the right edge)

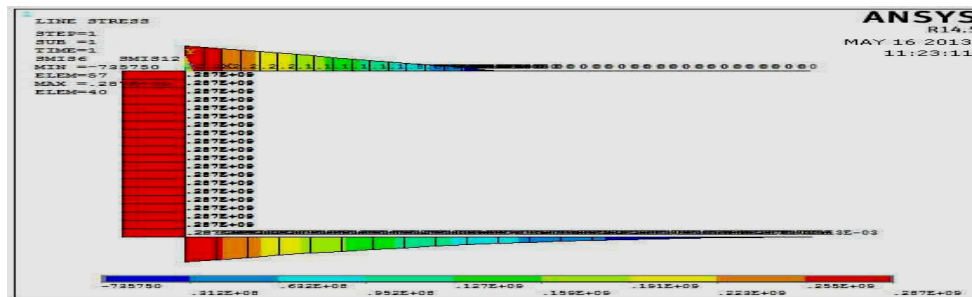


Fig 1.7 Bending Moment diagram with change of hinge position

The above fig1.5,fig1.6, fig1.7 show location of point of Contraflexure where sign change is taking place, new hinge position and B.M. diagram for change of hinge position respectively. This position shows zero value of moment. So if this position is selected properly counter weight requirement will reduce. So here the position of Contraflexure is also important for design of the structure.

XVI. MESH PICTURE

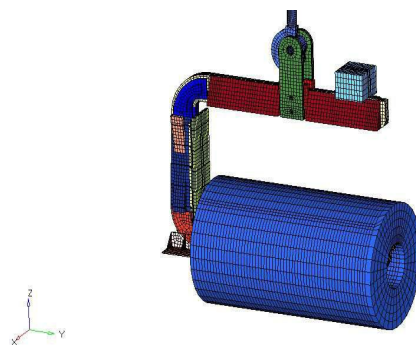


Fig 1.8 Three Dimensional mesh of the C-hook

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Fig1.8 is exported from CATIA V5 to ANSYS for good quality mesh. Total of 20966 elements and 27693 nodes are used for representation of the whole problem. Even though coil meshed it is not used in the analysis. Instead a load of 30tons is distributed on the segment1.

XVII.RESULTS AND DISCUSSION

Analysis has been carried out for three dimensional problems for the given coil lifting loads. The objective of the analysis is to find the structural safety and satisfaction of the sections considered for the different members.

Vonmises is the most popular theory for finding the structural failure of the members. It is a distortion energy based theory which represents all combination of stresses like stresses in orthogonal directions and stresses in rotational directions. Even Tresca's theory also can be used. But the literature says Vonmises match with 90% failure of the ductile structure. Since the entire structure is made of mild steel Vonmises theory is enough to predict the failure of safety margin in the problem.

Since the structure weight is more self weight analysis is also carried out. The analysis is done for three cases.

CASE1: SELF WEIGHT ANALYSIS

Many times self weight plays important role in structural stress generation. Many structures fail by self weight itself. This can be avoided by proper rib design for the structure. So initial estimation of self weight effect is also important in the problem.

CASE 2: FULL LOADING CONDITIONS

This condition is required as the full loading structure has the maximum stresses and strains. It helps in factor of safety in the problem. It gives guarantee for working condition of the problem.

While loading due to rotation generated by counter weight which is fixed to the member stresses will generate in the system. To balance the system a horizontal block is added to the clamp during unloading. So stress condition is important to check for this also.

STATIC ANALYSIS RESULTS

The crane hook is fixed in the position and gravity load is applied. The total problem is converted to meters for better self weight results. Gravity load of 9.81m/sec^2 is applied through loads>Gravity option. The self weight results are as follows.

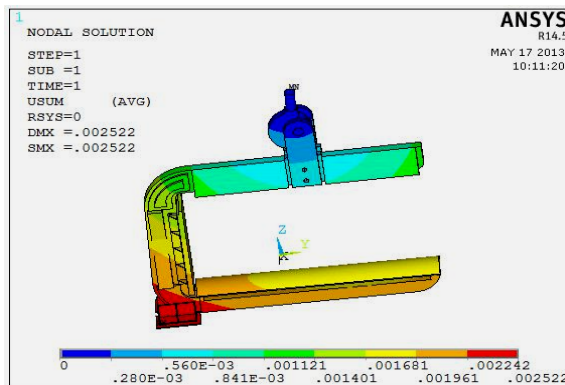


Fig 1.9 Displacement Plot

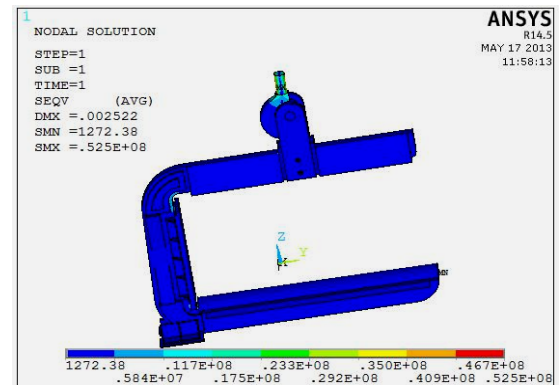


Fig 1.10 Vonmises Stress Plot

The figure1.9 shows maximum displacement of 2mm or (0.002522m). Maximum allowable deformation for this beam for structural safety as per the IS code is $1800/250=7.2$ mm. So the developed deformation is lesser than allowable

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deformation of the problem. So structure is safe for the given self weight. Generally deflection represents stiffness of the structure, lesser the deflection higher the stiffness of the structure and vice-versa

The figure1.10 shows developed Vonmises stress in the structure. Maximum Vonmises stress is around 52.5Mpa as shown in the figure. Maximum stress is observed at the crane hook. The stress is maximum at the crane hook as the section of resistance for the load is less. Vonmises stress is the stress corresponding to stored energy of the system. Once this stress is more than allowable or criticalstresses the structure is said to be under failure as per the structural analysis terminology.

FOR FULLY LOADED CONDITION:

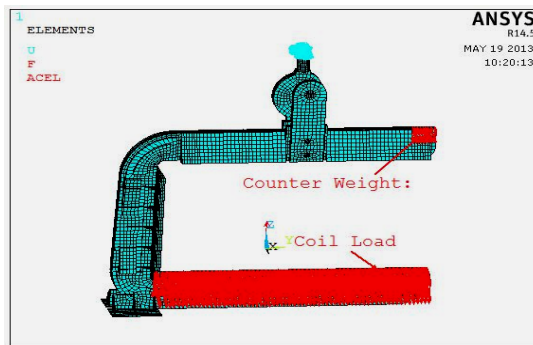


Fig 1.13 Boundary Conditions plot

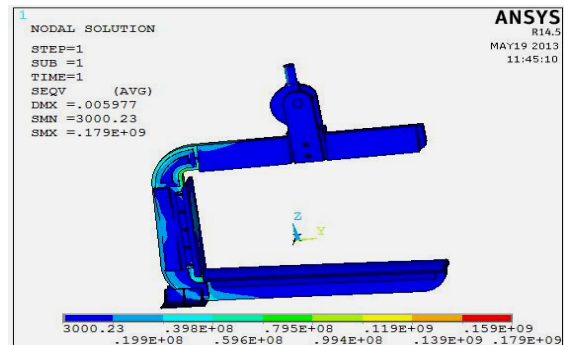


Fig 1.14 Vonmises Stress plot

The figure 1.13 shows applied load 30 tons on segment1 and counter weight on the segment 3 along with self weight effect. The 30tons load is distributed to the whole structure after finding the area of the loading plates. In the figure the elements shows applied loads. Here ‘u’ means applied displacements. The crane hook top end is completely constrained and ‘F’ means force which is applied to the nodes related to loading plates. ‘ACEL’ means applied gravity load. This activates the self weight effects.

The figure1.14 shows developed Vonmises stress in the structure. Maximum stress is around 179Mpa. This stress is less than the allowable stress of the structure. Here allowable stress is on the basis Factor of safety 2.5. For the given yield stress of 450Mpa, allowable stress= $450/2.5=180$ Mpa.

Here also maximum stresses are observed at the curvature regions. Since more stresses are expected at the curvature regions due to stress concentration higher ribbing is done at these regions. Except the curvature regions stresses are limited in the other regions as shear stress is the major contributor to the stress compared to the bending stress

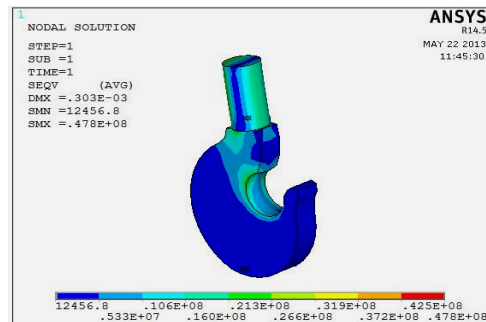
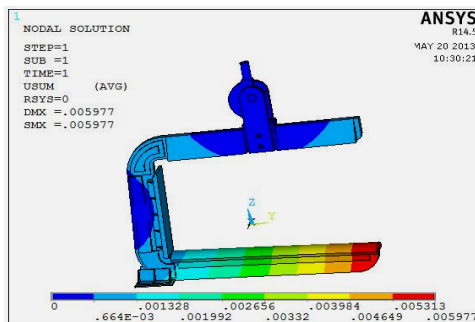


Fig1.15 Overall displacement plot

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The figure1.15 shows developed deformation in the problem. Maximum of 5.877mm or 0.005977meters displacement can be observed in the problem. This deformation is less than the allowable deformation of 7.2mm. So the structure is safe for the given loads.

Maximum deformation can be observed at the segment 1 right end. This can be attributed to cantilever effect. (Cantilever free end has higher deformation and other end has minimum deformation).

CASE3: UNLOADING CONDITION

The analysis is carried out for unloading conditions. Once the coil load is removed there is possibility of the C-hook may be unbalanced and it may harm the bottom segment left corner. So analysis is carried out to find the effect of this unloading. Only counter weight load and self weight effect will act on the structure. The results are as follows.

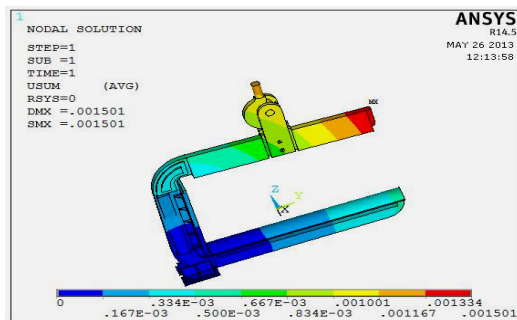
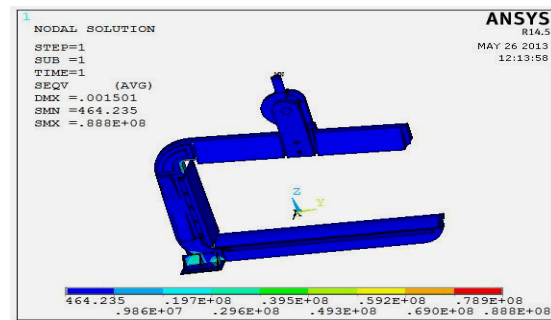


Fig 1.16 Deformation Plot



Figs 1.17 Vonmises Stress in the Structure.

The figure1.16 shows maximum deformation of 1.5mm or 0.001501m in the structure during unloading. Maximum deformation is observed at the segment 3 right ends. This is due to higher self weight compared to the downward counter weight loads. But this deformation is in the safe limits and lesser than the allowable deflection of 7.2 mm. So the structure is safe for the given loading conditions.

The figure 1.17 shows stress development at rest pad. This analysis is mainly done to check the rest pad stresses for structural safety. Maximum stress development is around 88.8MPa which is less than the allowable stress of the structure. The stresses except at the corner regions are almost negligible. So the structure is completely safe for the unloading condition.

XVIII.CONCLUSIONS

The C-hook has been modelled and analysed for coil lifting applications of capacity 30 tonns. The finite element analysis along with theoretical calculations are used for proper estimation of structural stability of the C-hook is carried out.

XIX. FUTURE SCOPE

- The analysis can be carried out for dynamic stresses due sudden dropping of the C-hook from certain height.
- The Design optimisation carried out for the components of assembly for further minimisation of material.
- Topology optimisation can be carried out
- Composite usage can be checked for the application

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- Possible Thermal effects can be considered for further stress calculations
- The similar study may be carried out for other parts for which there exist applied loads.

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