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Stress Analysis of Different Geometries of Crane Hook Using Diffused Light Polariscope

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Abstract: **In this project, we use diffused light polariscope for studying various complex geometries of crane hook. For this entire study, we select four different types of hooks which are used in crane for lifting purpose. 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, the different acrylic models of crane hook are loaded in diffused light polariscope. The stress distribution pattern is verified for its correctness on ANSYS software. By predicting the stress concentration area, the shape of the crane is modified to increase its working life and reduce the failure rates. By observing the stress pattern in acrylic models, we calculate the stress concentration factor for different geometries. After comparing the acrylic models on the basis of stress concentration factor, we find that which one is best geometry out these four selected geometries for various lifting load conditions.**

Keywords: **Diffused light polariscope, photoelasticity, stress concentration factor, acrylic hooks.**

1. INTRODUCTION

In the field of present engineering development, stress / strain analysis by photoelastic methods play an important role. Photoelasticity is an experimental technique for stress and strain analysis that is particularly useful for members having complicated geometry, complicated loading conditions, or both. For such cases, analytical methods (that is, strictly mathematical methods) may be cumbersome or impossible, and analysis by an experimental approach maybe more appropriate. While the virtues of experimental solution of static, elastic, two-dimensional problems are now largely overshadowed by analytical methods, problems involving three-dimensional geometry, multiple component assemblies, dynamic loading and inelastic material behaviour are usually more amenable to experimental analysis. Unlike the analytical methods of stress determination, photoelasticity gives a fairly accurate picture of stress distribution, even around abrupt discontinuities in materials. The method is an important tool for determining critical stress points in a material, and is used for determining stress concentration in irregular geometries. We use the photoelasticity to determine the stress concentration factor of different crane hooks.

2. PRINCIPLE OF PHOTOELASTICITY

The method is based on the property of birefringence, as exhibited by certain transparent materials. Birefringence is the phenomenon in which a ray of light passing through a birefringent material experiences two refractive indices.

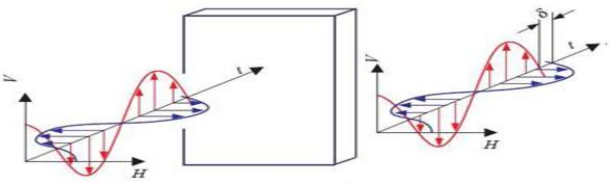

Fig. 1 Principle of photoelasticity

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When a ray of light passes through a photoelastic material, its electromagnetic wave components are resolved along the two principal stress directions and each component experiences a different refractive index due to the birefringence. The difference in the refractive indices leads to a relative phase retardation between the two components. Assuming a thin specimen made of isotropic materials, where two-dimensional photoelasticity is applicable, the magnitude of the relative retardation is given by the stress-optic law

$$\delta = \frac{2\pi t}{\lambda} c(\sigma 1 - \sigma 2)$$

Where,

δ is the induced retardation,

c is the stress-optic coefficient,

t is the specimen thickness,

σ_1 and σ_2 are the first and second principal stresses, respectively.

The retardation changes the polarization of transmitted light. The polariscope combines the different polarization states of light waves before and after passing the specimen. Due to optical interference of the two waves, a fringe pattern is revealed. The number of fringe order *N* is denoted as

$$N = \frac{\delta}{2\pi}$$

3. EXPERIMENTAL SETUP OF DIFFUSED LIGHT POLARISCOPE

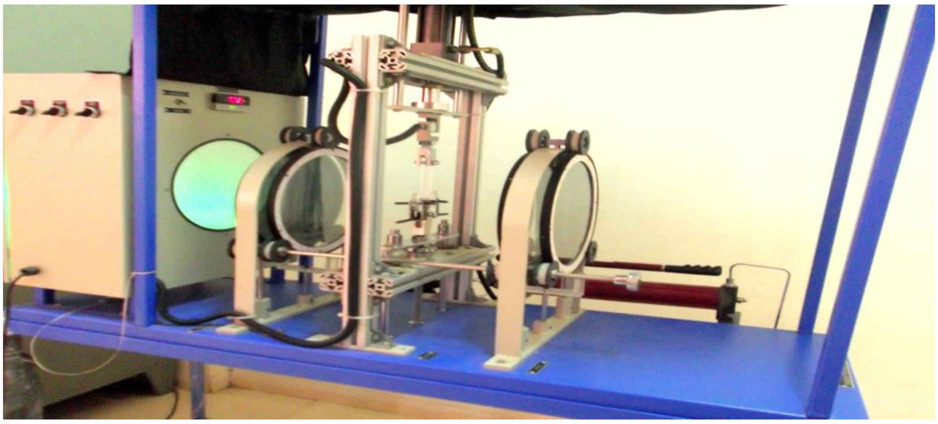

Fig. 2 Diffused Light Polariscope

The polariscope incorporates two such assemblies, first set containing polarizer and quarter wave plate Q1 and second set containing quarter wave plate Q2, and analyzer knob is used to rotate quarter wave plates. Out of these two assemblies, user's side assembly allows the rotation of analyzer within the assembly. Assembly on light box side does not permit the rotation of polarizer. A scale is fixed on user's side assembly. The scale is graduated for fractional fringe order values. When knob on the front side plate, which is fixed to synchronizing bar, is rotated, all the plates that are polarizer, both quarters wave plates and analyzer rotate keeping their relative position with each other the same.

Plane Polariscope:

In plane type Polariscope, the light source may be mercury or a sodium vapour lamp, an incandescent filament or sodium vapour lamps are used as monochromatic light source and incandescent filament lamp is used as white light source for the lens type Polariscope. For the diffused light Polariscope a bank of bulbs is used in an opaque box with a ground glass on one side to give diffused light. In plane Polariscope, two types of set up are possible, first bright, when polarizer and analyzer are parallel and dark when polarizer and analyzer are crossed.

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Circular Polariscope:

In addition to all the elements of a plane polariscope, the circular polariscope has two or more quarter wave plate, the first between the polarizer and model and second between the model and the analyzer. The first and slow axes of the quarter wave plate are inclined at 45˚ with the polarizer or the analyzer. The quarter wave plate are made of Polaroid film and produce a path difference of λ/4 or a phase difference of 90˚ in the two light vector passing through them.

There are two possible arrangements in circular polariscope to obtained dark field background-

- First the two- quarter wave plates are kept crossed, i.e. the fast axis of the first quarter wave plates is kept parallel to the slow axes of the second quarter wave plate. The polarizer and analyzer are kept crossed.
- In second type, the element is kept parallel. In both case, dark field background can be easily understood.

4. VALUES AND COLOUR PRODUCED IN A DARK FIELD WHITE LIGHT SOURCE

COLOURS	FRINGE ORDER
Black	0
Grey	0.28
White	0.45
Yellow	0.60
Orange	0.79
Red	0.90
Tint of passage 1*	1.00
Blue	1.06
Blue green	1.20
Green yellow	1.38
Orange	1.62
Red	1.81
Tint of passage 2*	2.00
Green	2.33
Green yellow	2.50
Pink	2.67
Tint of passage 3*	3.00
Green	3.10
Pink	3.60
Tint of passage 4*	4.00
Green	4.13

NOTE –

The tint of passage is a sharp dividing

- Zone occupying between red and blue in the first order fringe,
- Red and green in the second order fringe
- Pink and green in the third, fourth, and fifth order fringes.

5. STRESS CONCENTRATION FACTOR DUE TO TENSION IN VARIOUS TYPES OF HOOKS

The presence of holes, keyways, grooves, notches, etc. in a machine member result in an abrupt change in the geometry. Under these conditions, the stresses in the member do not follow the elementary equations. High stresses are induced locally and the material nearest to the abrupt change in geometry is the most affected. Such phenomenon is called as stress concentration is measured by the stress concentration factor is defined by

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$$K\sigma = \frac{\sigma max}{\sigma nom.}$$

In various hook, stresses occurs at different points. The stress concentration factor ‘Kσ’ is a ratio of maximum stress developed due to sudden change in shape at the given point under consideration. The following models are referred for our experiment:

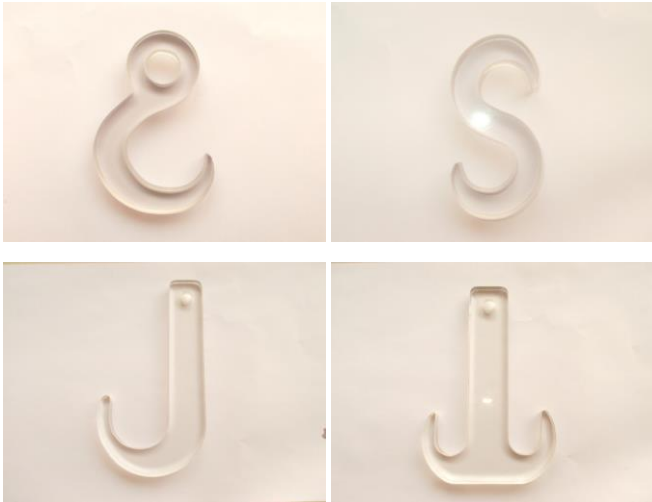


Fig. 3 Various geometries of crane hook

For the model referred, the value of stress concentration factor ‘Kσ’ is defined as

$$K\sigma = \frac{\sigma max}{\sigma nom.}$$

$$K\sigma = \frac{NA}{NB}$$

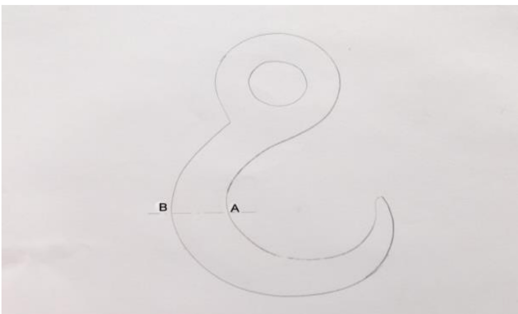
Where,

NA is Fringe order in intrados,

NB is Fringe order in extrados.

6. DETERMINATION OF STRESS CONCENTRATION FACTOR

A) C-Hook:



- **Observation:**

P = Load in Kg,

A = Fringe Order in intrados,

B = Fringe order in extrados,

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NA and NB = Fringe order at point A & B respectively.

- **Observation Table:**

Fringe Order (N)		Load
Inside NA	Outside NB	(P)
3	2	5
5	3	7
9	5	10

- **Calculation:**

$K\sigma$ = Stress Concentration Factor

$$K\sigma = \frac{\sigma max}{\sigma nom.}$$

For P = 5 kg

$$K\sigma = \frac{NA}{NB}$$

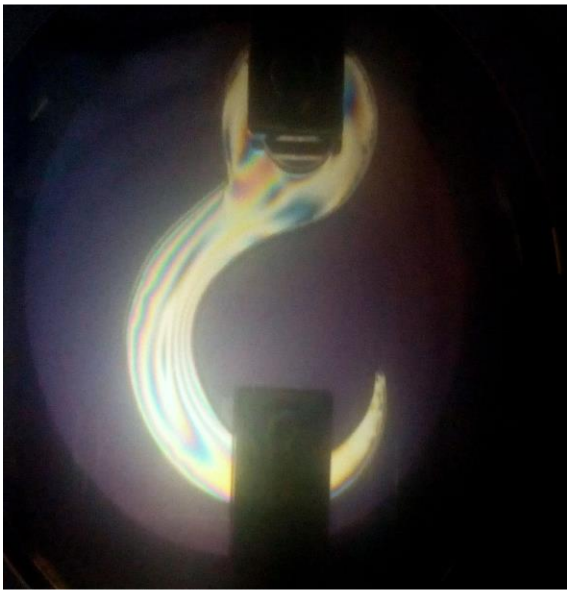
$$K\sigma = \frac{3}{2}$$

$$K\sigma = 1.5$$

- **Result Table:**

Load (P) Kg	Stress Concentration Factor
5	1.5
7	1.66
10	1.8

Fringe pattern for C-Hook:



P= 5kg

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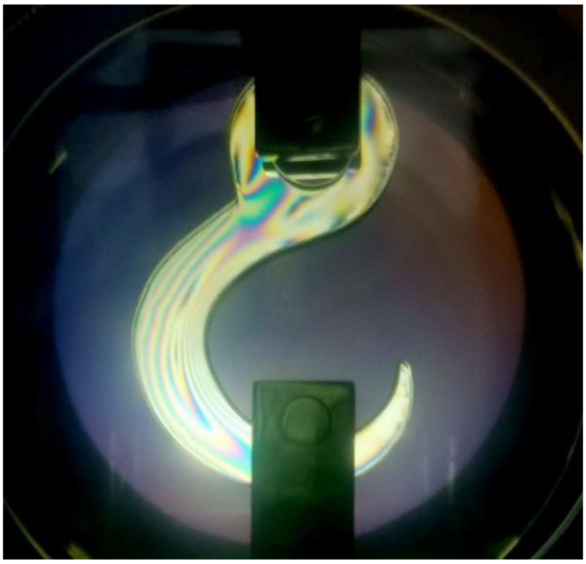
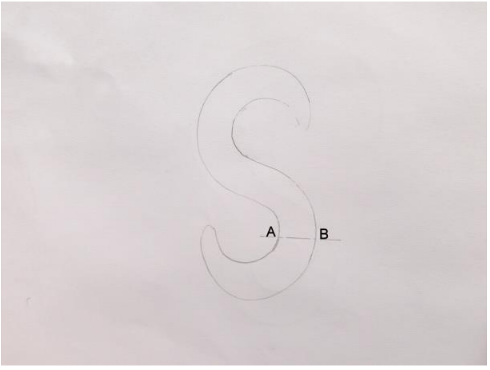


P= 7kg

B) S-Hook:



- **Observation Table:**

Fringe Order (N)		Load
Inside NA	Outside NB	(P)
5	3	5
7	4	7
9	5	10

- **Calculation:**

$K\sigma$ = Stress Concentration Factor

$$K\sigma = \frac{\sigma max}{\sigma nom.}$$

For P = 5 kg

$$K\sigma = \frac{NA}{NB}$$

$$K\sigma = \frac{5}{3}$$

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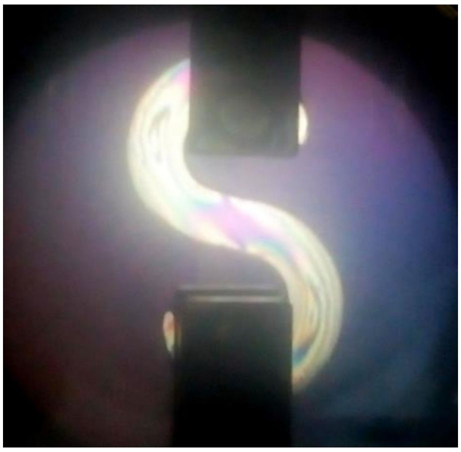
$$K\sigma = 1.66$$

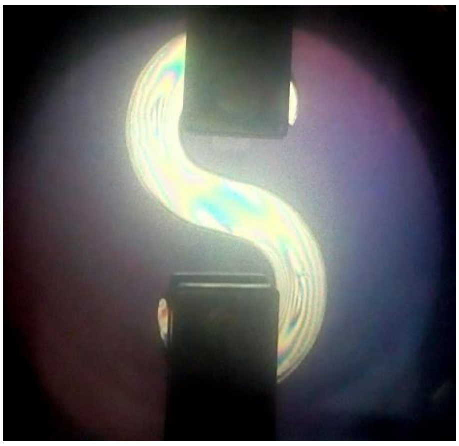
- **Result Table:**

Load (P) Kg	Stress Concentration Factor
5	1.66
7	1.75
10	2

Fringe pattern for S-Hook:

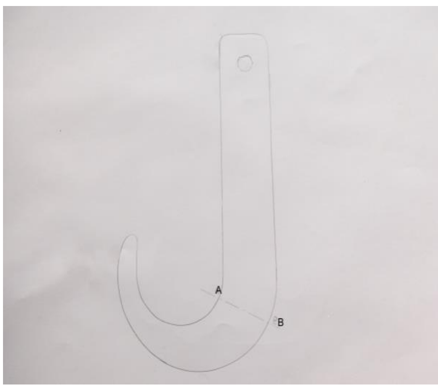


P= 5kg



P= 7kg

C) J-Hook:



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- **Observation Table:**

Fringe Order (N)		Load (P)
Inside NA	Outside NB	
2.50	0.79	50
2.67	0.79	60
3	0.90	70

- **Calculation:**

$K\sigma$ = Stress Concentration Factor

$$K\sigma = \frac{\sigma max}{\sigma nom.}$$

For P = 50 kg

$$K\sigma = \frac{NA}{NB}$$

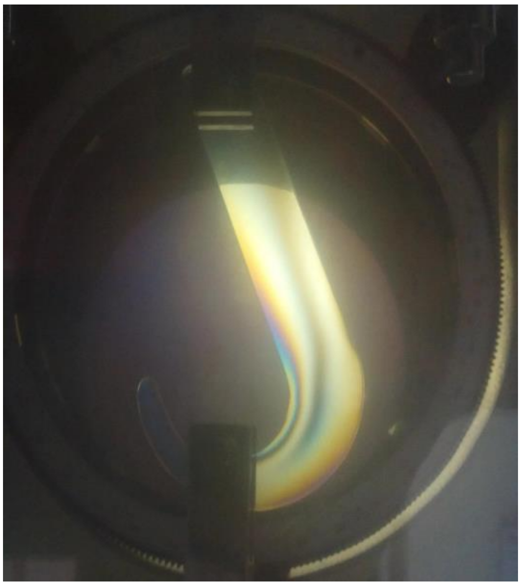
$$K\sigma = \frac{2.5}{0.79}$$

$K\sigma = 3.16$

- **Result Table:**

Load (P) Kg	Stress Concentration Factor
50	3.16
60	3.33
70	3.37

Fringe pattern for J-Hook:



P= 50kg

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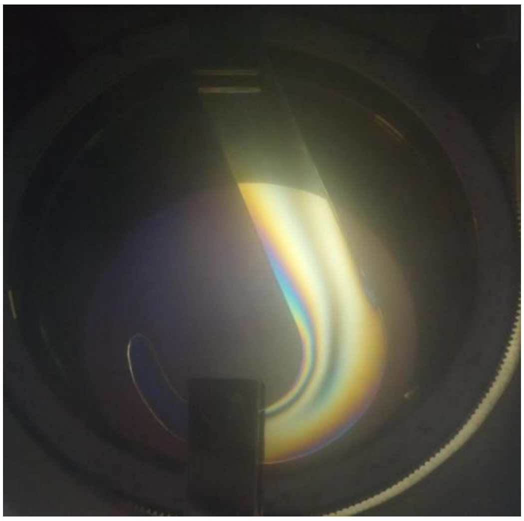
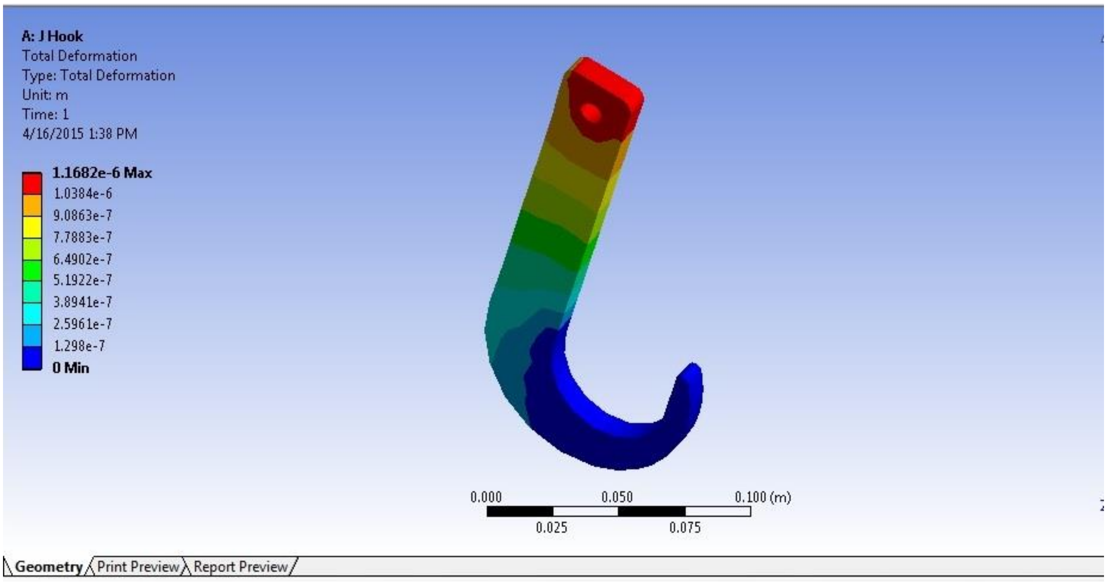


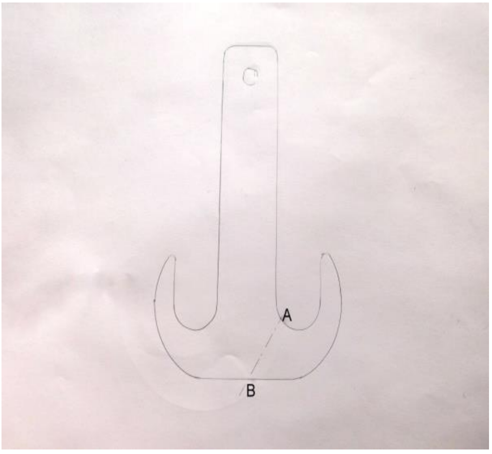
P= 60kg

J-Hook analysis by using Ansys:



Stress pattern using Ansys

D) Double J-Hook:



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- **Observation Table:**

Fringe Order (N)		Load
Inside NA	Outside NB	(P)
0.45	0.45	50
0.60	0.45	100
0.79	0.45	150
1.20	0.60	200

- **Calculation:**

$K\sigma$ = Stress Concentration Factor

$$K\sigma = \frac{\sigma max}{\sigma nom.}$$

For P = 50kg

$$K\sigma = \frac{NA}{NB}$$

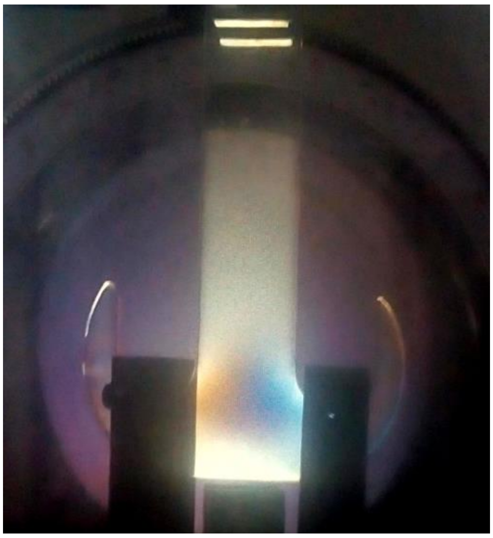
$$K\sigma = \frac{0.45}{0.45}$$

$K\sigma$ =1

- **Result Table**

Load (P) Kg	Stress Concentration Factor
50	1
100	1.33
150	1.75
200	2

Fringe pattern for Double J-Hook



P= 50kg

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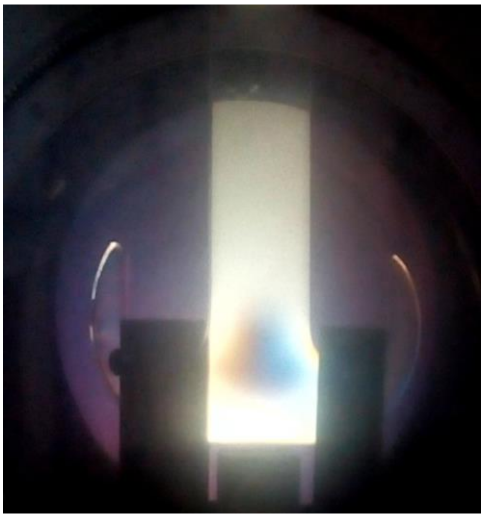
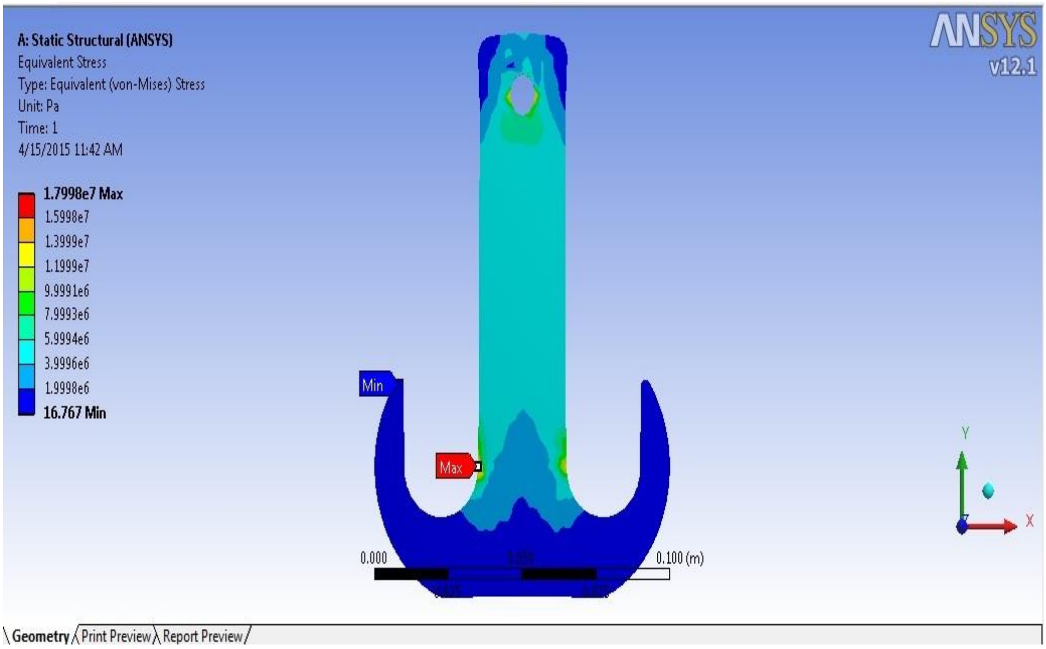


P= 100kg

Double J-Hook using Ansys:



Stress pattern using Ansys

7. CONCLUSION

In the stress analysis of the different crane hook geometries, the stress pattern of different geometries of various hooks was observed on diffused light polariscope at same loading conditions. The fringes occurred in S hook is more than C hook. Thus we concluded that, the stress concentration in S hook is more than C hook which was confirmed from the calculation of stress concentration factor. Also the load carrying capacity of C hook is more than S hook.

Load (kg)	Kσ for C hook	Kσ for S hook
5	1.5	1.66
7	1.66	1.75
10	1.8	2

Similarly, at same loading conditions between J and double J hook, it is observed that the stress concentration in J hook is more than double J hook. Hence the load carrying capacity of double J hook is more than J hooked. Also the stress pattern in J and double J hook is observed using Ansys workbench.

Load (kg)	Kσ for J hook	Kσ for double J hook
50	3.16	1

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