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Optimization of location, size of opening hole in a pressure vessel cylinder

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Abstract

A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The main objective the thesis work is to make an analysis and optimize the location and size of opening hole in a pressure vessel cylinder. For the purpose of analysis and optimization, three thick-walled cylinders with different internal diameters and having same height and thickness are chosen. Further hole diameter is varied and positioned at the center of each cylinder for hole size optimization, also hole of particular size is placed at different pressure vessels surface locations. It is found that with the increase in diameter of hole, Von Misses initially decreases and then becomes constant with hole size. Finally optimum locations of the hole was found.

Keywords: Pressure vessel; Optimization; Von misses stresses

1. Introduction

Pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The pressure vessels may be thin or thick. When the ratio of the plate thickness to mean radius of the pressure is less than 1/15 then the pressure vessel is termed as a thin pressure vessel, otherwise, a thick pressure vessel. Failure of pressure vessels may cause an economic loss and fatal to human life. Most of the pressure vessels are incorporated with the openings in the main body for various reasons like fluid transfer, instrumentation, manhole openings, gauges etc. These holes, the geometric discontinuity for the pressure vessels cylinder caused the stress distribution alteration near the vicinity of discontinuity.

In this work, main emphasis is put on to analyze the stress levels in the pressure vessel cylinders, further optimization of the size of hole and location in the pressure vessel cylinders is carried out. In order to design the pressure vessels, it is necessary to concentrate on the four major factors: (1) Most likely mode of failure, (2) Stress generated due to pressure and temperature in the pressure vessel, (3) Suitable material, which can withstand the produced stresses, (4) Stress concentration due to the geometric discontinuities present in the pressure vessel. Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and fluid supply systems in industries. The main purpose of this work is to perform a stress analysis on a thick - walled pressure vessel and optimize the location and size of opening using finite element analysis.

Pressure vessels are subjected to several unusual conditions of pressure, temperature and environment during their operation life. Hence, it is necessary to put a special attention on the operating stresses produced in the pressure vessel. Analytical, experimental and numerical techniques are the methods used for the determination of operating stresses. C. R. Calladine (1966) [1] applied plastic design approach for the design of reinforcement for openings in thin spherical pressure vessels. The essence of the approach is to adjust the thickness and shape of the vessel in the vicinity of the opening so that the full limit pressure of the vessel may be carried with relatively little bending action. It is concluded that pad-reinforced nozzle represents major advantage over other forms of reinforcement is that its general form enables the forces on the nozzle and its surround due to pressure loading to be carried almost entirely by membrane stresses; and this in turn results in low stress concentration effects.

R. Kitching (1970) [2] compared the experimental limit pressures for cylindrical shells with unreinforced openings for different shapes and sizes. It was observed that the limit pressures similar for openings of the same overall dimensions and is not dependent of the shape. M. N. Bapurao (1971) [3] studied stresses around a small elliptic hole in an infinitely long circular cylindrical shell subjected to torsion. C. Gwaltney (1973) [5] compared theoretical and experimental stresses for spherical shells having single non-radial nozzles. J. W. Bryson (1977) [7] presented work on parametric study on stresses in reinforced nozzle-to-cylinder attachments under internal pressure loading as analyzed by the finite-element method. Dennis Martens (1996) presented a method which allows the vessel engineer to more accurately evaluate the flexibility and stresses in vessel nozzles within the time and expense parameters associated with the normal design process. Kang Soo Kim (1999) [8] presented work on opening distance patterns on the stress distribution of the pressure vessel head, using IDEA FEM code. Result indicated that the stress values of head parts between the adjacent nozzles increases according to the reduction of the distance between them.

The main objective of the present work is to optimize the location and size of opening hole in a pressure vessel cylinder.

2. Methodology

To design a pressure vessel, the selection of codes (ASME VIII div 1) is important to achieve the safety of pressure vessel.

1. Selection of Pressure Vessel

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2. Material Selection
(Carbon Steel SA 516 Gr. 70)

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3. Simulation

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4. Optimization

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5. Analysis

Fig 1: Flow Chart

3. Results & Discussions

3.1 Specification of pressure vessels

A solid wall vessel consists of a single cylindrical shell, with closed ends. Due to high internal pressure and large thickness the shell is considered as a 'thick' cylinder. In general, the physical criteria are governed by the ratio of diameter to wall thickness and the shell is designed as thick cylinder, if its wall thickness exceeds one-tenth of the inside diameter. Design data of the pressure to be simulated is given below

Design Pressure	P - 5 N/mm^2
Design Temperature	T - 20^{0}C
Design Code	- ASME (Sec. VIII Division-1)
Inside Radius of vessel	R_i- 200 mm
Safety Factor	F.S- 0.3

3.2 Simulation of pressure vessel

As per the above design specifications model was simulated using CATIA. Initially 2 D model of a cylindrical vessel is developed. The model is extended to 3 D is shown in Fig.2. The developed model is considered for the further analysis explained in the following section.

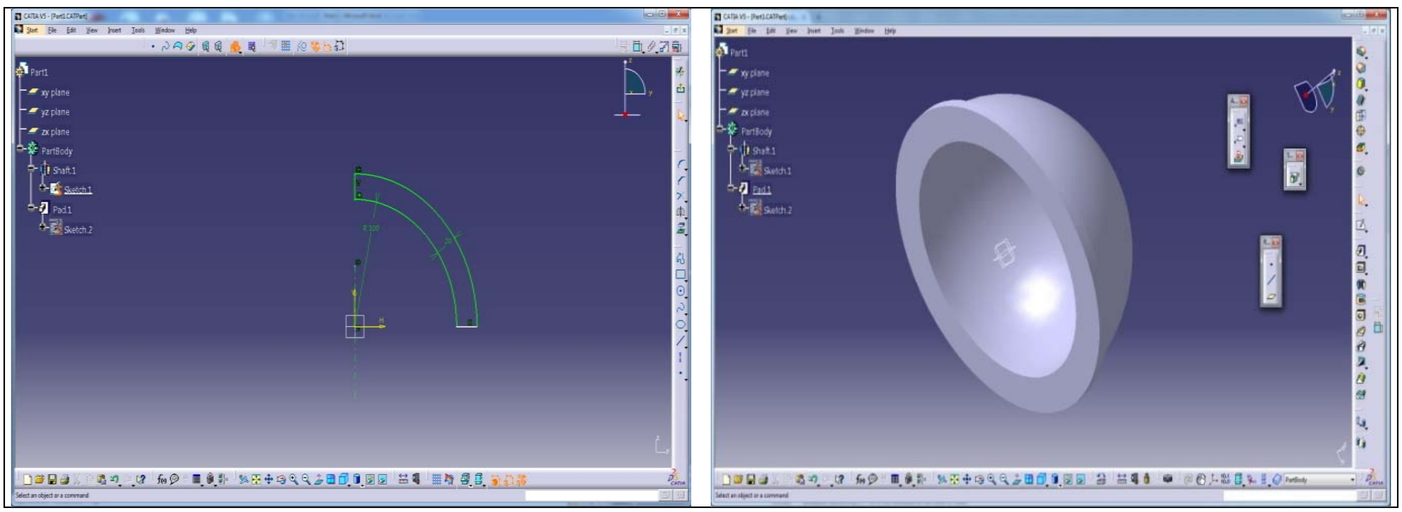


Fig 2: 2D and 3D Modal of end dish

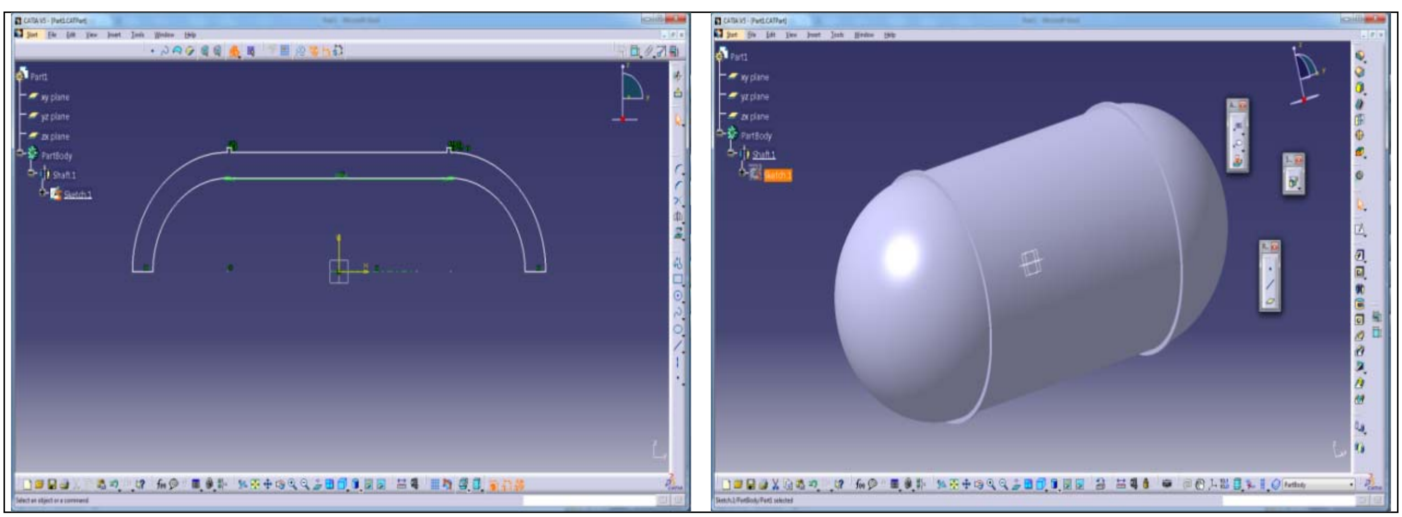


Fig 3: 2Dand 3D model of hemisphere end dish

3.3 Analysis of pressure vessel cylinder without and with hole

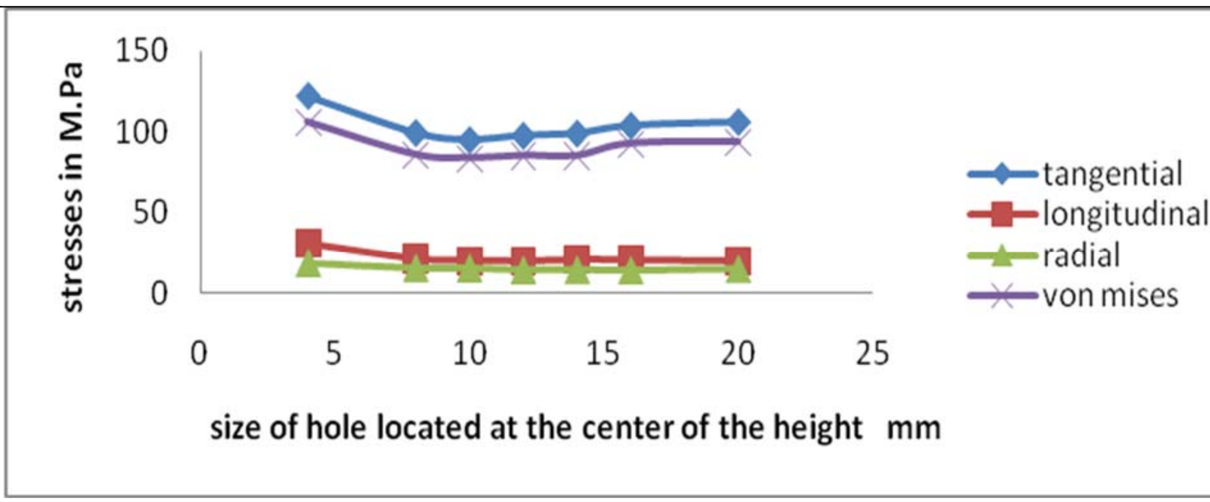
In the present work optimization of the location and size of opening in a pressure vessel cylinder without hole has been done analytically studied. The cylinder dimensions are considered for three various models and three different internal diameters, namely 20, 25 and 30 cm were used. Flanges (upper and lower) at the end of the cylinder were attached with 20 mm height and 40 mm and total height 300 cm with pressure is 5mpa. numerical result s are generated for (σ_t) tangential stress, and (σ_r) radial stress, and (σ_l)

Table 1: Comparison of stresses of cylindrical Vessel (Analytical and Ansys) Without Hole

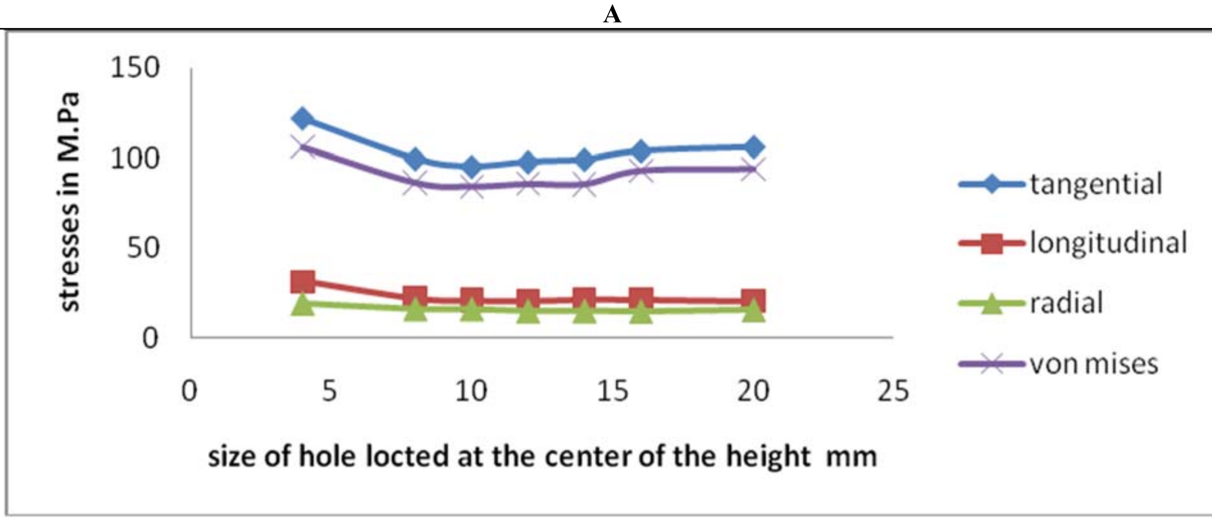
Cylinder Diameter	Φ = 20		Φ = 25		Φ = 30	
Stresses	**Analytical**	**Ansys**	**Analytical**	**Ansys**	**Analytical**	**Ansys**
Tangential stress (σ_t)	27.72	34.71	33.93	49.49	40.15	30.38
Longitudinal stress (σ_l)	11.36	14.17	14.46	19.12	17.57	23.95
Radial stress (σr)	-5	9.361	-5	14.26	-5	18.91
Von misses stress (σ_{eqv})	26.25	29.86	25.54	36.89	30.84	43.79
Deformation	-	0.014	-	0.0214	-	0.0304

Table 2: Von Misses stresses with different size hole located at the center of the height With Hole

Cylinder Diameter	Φ = 20		Φ = 25		Φ = 30	
Stress Von-misses	**Analytical**	**Ansys**	**Analytical**	**Ansys**	**Analytical**	**Ansys**
4	80.87	80.90	100.33	102.30	118.71	122.00
6	78.34	78.72	97.30	97.81	98.58	99.31
8	78.64	97.42	98.70	99.01	98.78	99.51
9	77..84	78.97	79.80	88.79	93.98	94.30
10	76.08	77.67	88.02	88.79	94.98	95.23
11	74.47	75.00	81.27	83.67	95.10	97.78
12	75.47	76.00	82.27	84.07	96.10	97.78
14	74.86	75.00	80.52	82.21	98.22	99.16
16	74.36	75.40	84.91	86.14	100.49	103.92
18	75.20	75.90	87.52	87.97	104.85	105.17
20	74.23	75.90	88.52	88.77	105.80	106.17



A



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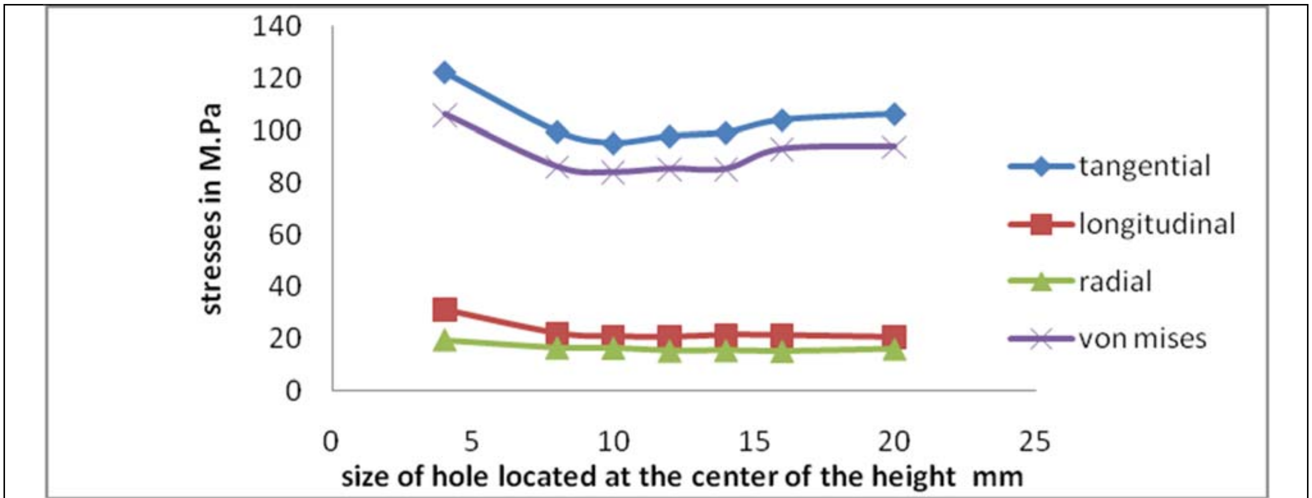


C

Fig 4: Comparison of theoretical and ANSYS result of hoop, longitudinal, radial, and Von Misses stresses in all cylinder with hole

3.4 Analytical analysis of stress distribution around a hole in the cylinder Comparison of stress dish end angle location with Hole

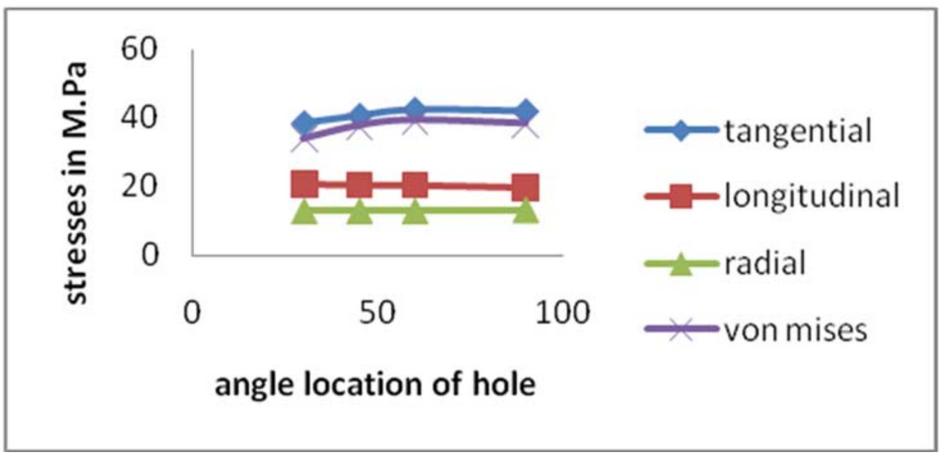
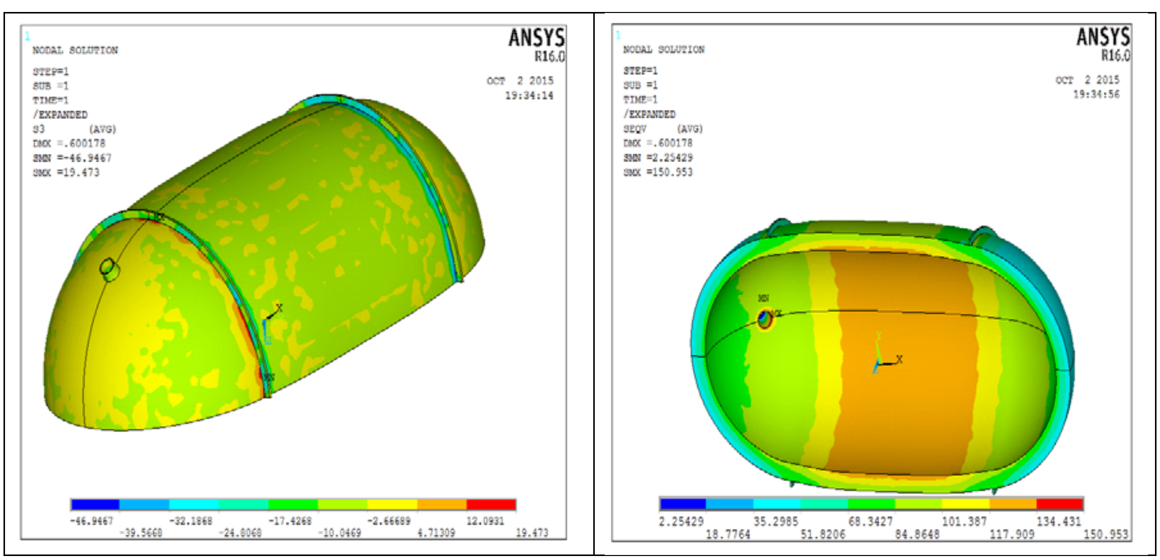


Fig 5: Comparison of theoretical and ANSYS result of hoop, longitudinal, radial, and Von Misses stresses in all dish end cylinder with hole

3.5 Analysis of Hemisphere pressure vessel cylinder without and with hole Analysis of Hemisphere Pressure Vessel with hole



(a) Radial stress (b) Von-misses stress

Fig 6: Stresses hemisphere cylinder with hole

Table 3: Comparison of stress hemi sphere cylinder vessel with and without hole

Parameter	Tangential	Longitudinal	Radial	Von Misses	Deformation
Without Hole	130.2	95.83	16.03	132.08	0.5981
With Hole	148.67	110.25	19.47	150.95	0.600

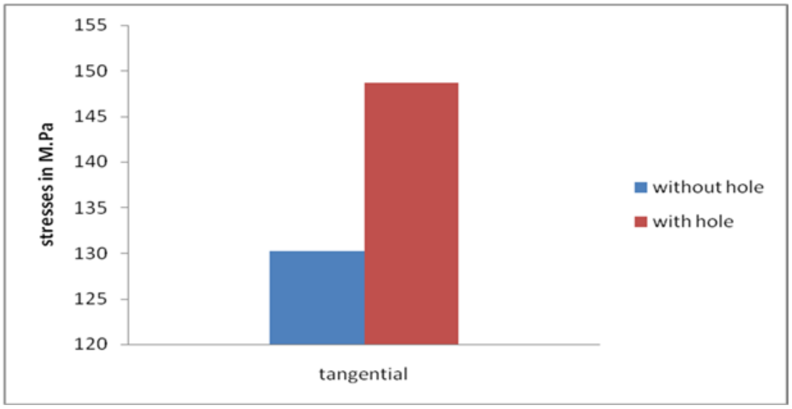


Fig 7: Comparison of theoretical and ANSYS result of hoop, longitudinal, radial, and Von Misses stresses in all hemisphere cylinder without and with hole

4. Conclusions

By doing stress analysis for the optimization of hole presence in pressure vessel, following conclusions can be drawn Size and location of the hole in pressure vessels depends on its size of pressure vessel. The optimum hole size is the one for which the value of Von Misses is minimum around the vicinity of hole. The optimum location of the hole is the one where minimum Von Misses stress is obtained. The hole with 10 mm diameter on cylindrical vessel having minimum stresses and which is best size to provide the hole and 1/8 th of cylinder height is best location.

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