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Design and Analysis of Schmidt Coupling

Koppalavijayalakshmi[1], Dr. C. Vijaya Bhaskar Reddy[2]
[1]PG Scholar, Dept. of MEC, Sri Venkateswara College of Engineering & Technology (Autonomous), R.V.S. Nagar, Chittoor-517127
[2]Professor, Dept. of MEC, Sri Venkateswara College of Engineering & Technology (Autonomous), R.V.S. Nagar, Chittoor-517127

***Abstract*- A Coupling may be a device that is answerable for the operative power transmission between 2 shafts rotating at explicit revolution. It is designed to accommodate large radial displacement between two shafts. Consisting of an arrangement of links and discs three discs rotating in unison, interconnected in series by six or more links a Schmidt coupling can adapt to wide variations in radial displacement while running under load. In operation, all three discs of a Schmidt coupling rotate with equal velocity. The bearing-mounted connections of links to discs are spaced 120° apart on same-diameter pitch circles. The constant-velocity relationship between input and output shafts joined by a Schmidt coupling is unaffected by changes in radial displacement. This relationship is equally unaffected by initial radial reaction forces that might otherwise imbalance the system. Mainly this Project enables a variable parallel offset between two shafts. They provide constant speed rate with extraordinarily low backlash, and their compact styles give giant floor area savings.**

In this project we conduct static structural analysis by using ANSYS workbench and study the various stresses and strain. For these purpose modelling of the Schmidt coupling is carried out in Solid works and analysed in ANSYS Workbench.

Index terms- Solid works, CATIA, ANSYS workbench, Schmidt coupling, Finite element method

I. INTRODUCTION

A Schmidt coupling may be a variety of coupling designed to accommodate massive radial displacement between 2 shafts. Consisting of an arrangement of links and discs three discs rotating in unison, connected in series by five or more links a Schmidt coupling can modify to wide discrepancy in radial displacement while running under load. In operation, all three discs of a Schmidt coupling rotate with same velocity. The bearing-mounted connections of links to discs have equi-spaced 120° apart of same-diameter pitch circles. The shafts can be varied between the minimum value and a maximum of twice the length of the links. While the coupling in undulating, there is no phase change between shafts. The relationship between input and output shafts are constant as joined by a Schmidt coupling is unaffected by changes in radial displacement. This relationship is equally unaltered by initial radial reaction forces that may otherwise variance the system. Schmidt couplings maintain input and output shafts at constant velocity.

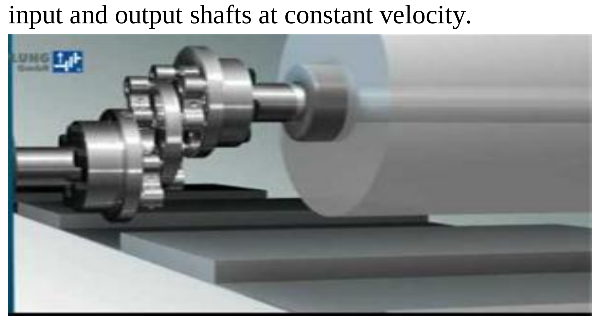

Fig 1.1 Schmidt Coupling

The Fig 1.1 shows the diagram of Schmidt coupling. In these coupling have different types of alignments. The different as shown below fig.

1.3 TYPES OF SCHMIDT COUPLING:

States man couplings have been classified as different types. They are:

1.3.1 statesman Helmut Heinrich Waldemar Offset Couplings: Schmidt couplings that transmit constant angular speed and torsion during a big selection of parallel shaft placement.

1.3.2 Semi flex Couplings: Semi flex coupling could be a torsionally stiff and restoring-force-free exactitude coupling. In addition to the compensation of axial and angular displacements, it provides high radial displacement capacity together with compact design

1.3.3 States man In line Couplings: Schmidt couplings which accommodate small parallel shaft misalignment at constant angular velocity.

1.3.4 Management flex Couplings: Management flex could be a exactitude coupling designed to satisfy the mechanical and scientific discipline needs of encoders. Through its unique function element, the compact shaft encoder coupling combines extremely low restoring force and low stress on the encoder bearings with constant angle-synchronous transmission of the rotary movement.

1.3.5 statesman Helmut Waldemar and national leader 5-D Couplings: Schmidt couplings which give parallel shaft placement and a ±5° angular placement with moderate axial shaft displacement capabilities.

Fig 1.2 Offset Alignment of Schmidt Coupling

The Fig 1.2 shows the diagram offset alignment of Schmidt coupling. In these coupling have different types of alignments. Offset alignment also one of the alignment in Schmidt coupling

Gearless transmission that operates using the mechanism of rotary and kinematic chain principle. Couplings supply giant shaft placement capabilities and constant angular rate. The acting forces within the coupling can be precisely calculated, assuring a sound coupling design which is especially important for heavy-duty applications.

II. LITERATURE SURVEY

The work on the Schmidt coupling has started in the late of 1984 and but in the early, the work has been started on the design and analysis of Schmidt coupling has been explained below. In these couplings, subsequent works by various researchers and their behind it will be discussed.

[1] Ding ming: Journal on wear behavior of Gear steel under coupling of Rolling and sliding. In this journal discussed about mechanical properties of steel and wear resistance can be explained. In this paper mainly discussed about power transmission through gears and life span of gear. Mainly the load under sliding and rolling operation is a complicated process.

[2] Richard Helmut Heinrich Waldemar et.al: Journal on Schmidt coupling and parallel offset. In this work design of coupling, in 1960, NASA authorize Richard Schmidt of Madison, Alabama, to develop a propulsion system for rockets in Zero- Gravity environments. Schmidt coupling used for rotating slider cranks, it is used to transmission of power to the wheels of a steam locomotive. Schmidt couplings change a variable offset between 2 shafts. They are pliable to wide variations in radial displacement whereas running beneath load.

Invented within the early Sixties by Richard Helmut Heinrich Waldemar Schmidt, and supplementary to the Zero-Max line of versatile shaft couplings in 1984, Helmut Heinrich Waldemar Schmidt couplings were originally developed beneath commission from NASA for use in propulsion systems for rockets in zero-gravity environment .

Similar disc and link arrangement had done by German engineers, but engineers could not make the theory work in practice because the disc requires its own bearing. Schmidt coupling centre disc rotates from its own axis. Design of coupling system completes angle of rotation for all times. In these coupling eliminates the external forces.

[3] A.J. Mazzeia, and R.A. Scottb: In this work, Effects of internal viscous damping on the stability 0f a rotating shaft driven through a universal joint. Design and fabrication of universal joint for applying different loads on a shaft with both outer and inside. A Scientific model on arrangement of coupled, direct incomplete differential mathematical statements with time sub coordinate coefficients. In these journal experiments can done by different time subordinate coefficients. In Galerkin’s system is used to find arrangement of coupled straight differential mathematical statements with time coordinate coefficients. By utilization of differential mathematical statements, inner damping on parametric zones can be examined by using lattice method. In that zones are acquired on disposing of time- subordinate coefficients in differential

comparisons which prompts an Eigen value Examination.

[4] Richard Schmidt and Walter Harmaan Schmidt-Kupplung Gmbh: In this work, May 1963, Schmidt applied for a patent for his coupling for precise angular transmission of rotation of shaft at the Munich, Germany. The company Schmidt-Kupplung Gmbh was established in 1965. Richard Schmidt and Walter Harmaan to sell the patented coupling. The patent was granted by 1967. Schmidt coupling enters the united states market in 1984. When Zero-max, Inc. acquired Schmidt coupling.

[5] G. Pantazopoulos et.al: In this work, Torsional failure of a Universal steel coupling system. In this study can done by 2006. In this paper tells the disappointment of a cracked knuckle joint of a general coupling frame work is done. In this coupling works transmit rotational movement to the moves down of an aluminum sheet straightening machine. Survey of operational conditions iof coupling and capacity to transmit power capacity was noted.

[6] Siraj MohammadAli Sheikh: In this journal, Analysis of universal coupling under torque condition. Drive shafts are one of the most important components in vehicles. Mainly this paper focused on Torsion and bending stress due to weight of parts. These rotating components are susceptible of fatigue by the nature of their operation. Mainly drive shaft having failure because of vibration or shudder during running condition. Driver shaft mainly works on steering operation of vehicle. Drivers will lose control of their vehicle if the driver shaft broke during speed cornering. Because human life can be in danger if we don't know when, where the driven shaft will fail. It is very important to accurate prediction of driven shaft failure.

[7] Chandra Sekhar Katta: It has studied about the circularly coupled oscillator system that consist of many locally connected subsystems, especially oscillators, that produce linear state relations. The relations are defined between two connected subsystems, where their references are also assigned as a goal behavior simultaneously. A mathematical description of the subsystem interactions are clarified by extending a method based on the gradient dynamics. As an example of this formulation, the relative phase control of the circularly coupled oscillator system is considered, where the oscillation with the uniform phase lag should be achieved.

III. THEORITICAL ANALYSIS

Mainly couplings are used to connect two shafts for Torque transmission in different applications. Mainly affecting factor in Schmidt coupling is torque, and stress. The design calculations as follows

3.1 DESIGN CALCULATIONS:

Depending up on material properties and parameters are changed and part number speed, and power are constant for these project. In this data can be taken in design data book author, i.e., Bandhari. The parameter values as shown below:

Performance Factor : 17.135

Part No : L312C

Speed (N) : 900rpm

Power(P) : 15kw

: 15x10^3 W

1. Torque transmitted by the shaft:

By using theoretical formulas, we find the torque transmitted by the shaft. The equation as follows:

$\mathbf{T = \frac{60P}{2\pi N}}$ Nm …..(1)

Where

P is the power transmitted by the shaft, W;

N is the speed of the shaft, rpm;

2. Shear stress induced in the shaft:

By using below formula, Shear stress induced in Schmidt coupling were calculated and equation as follows

$\boldsymbol{\tau = \frac{16T}{\Pi d^3}}$ N/m 2 …..(2)

Where

T is the torque transmitted by the shaft, N-m;

d is the diameter of shaft, mm;

3. Angular Velocity of the shaft:

The rate of change of angular position of a rotating shaft. The equation as below:

$\boldsymbol{\omega = \frac{2\pi N}{60}}$ rad/s2 …..(3)

Where

N is the speed of the shaft, rpm;

4. Axial force acting on the shaft:

By using formula, axial force acting on the shaft in Schmidt coupling were calculated and as follows

$\mathbf{F = \frac{2T}{d}}$ N …..(4)

Where

T is the torque transmitted by the shaft, N-m

d is the diameter of the shaft, mm

5. Stress induced in the shaft:

The stress induced in coupling are force per unit area. The formula as below

$\boldsymbol{\sigma} = \frac{\mathbf{F}}{\mathbf{A}}$N/m2 …..(5)

Where

F is the axial force acting on the shaft, N;

A is the area of the shaft, m2;

A=π/4 d2

6. Maximum principal stress:

According to the maximum principal stress, the equation as follows:

$\frac{1}{2}[\boldsymbol{\sigma} + \sqrt{\boldsymbol{\sigma}^2 + 4\boldsymbol{\tau}^2}]$ N/m2 ..…(6)

Where

$\boldsymbol{\sigma}$ is the normal stress acting on the shaft, N/m2

$\boldsymbol{\tau}$ is the shear stress acting on the shaft, N/m2

7. Maximum shear stress :

According to the maximum shear stress theory, the maximum shear stress equation can be written as below

$\mathbf{1/2}[\sqrt{\boldsymbol{\sigma}^2 + 4\boldsymbol{\tau}^2}]$N/m2 …..(7)

3.2 SAMPLE CALCULATIONS:

Based on the design conditions, a sample calculation has been done.

1. Torque transmitted by the shaft is given by

$\mathbf{T} = \frac{\mathbf{60P}}{\mathbf{2\pi N}}$ Nm

$= \frac{\mathbf{60x1000x15}}{\mathbf{2\pi x900}}$

= 159.15 N-m

2. Shear stress induced in shaft is given by

$\boldsymbol{\tau} = \frac{\mathbf{16T}}{\mathbf{\Pi d^3}}$ N/m2

$= \frac{\mathbf{16x159.15}}{\mathbf{\Pi x300^3}}$

= 30Mpa

3. Angular velocity of the shaft is written by

$\boldsymbol{\omega} = \frac{\mathbf{2\pi N}}{\mathbf{60}}$ rad/s2

$= \frac{\mathbf{2\pi X900}}{\mathbf{60}}$

= 94.24rad/s^2

4. Axial force acting on the shaft in these coupling is given by

$\mathbf{F} = \frac{\mathbf{2T}}{\mathbf{d}}$ N

$= \frac{2X159.15X1000}{300/2}$

= 1061N

5. Normal stress acting on the shaft as below

$\boldsymbol{\sigma} = \frac{\mathbf{F}}{\mathbf{A}}$N/m2

$= \frac{\mathbf{1061}}{\mathbf{70685}}$

= 0.015 N/m2

6. Maximum principal stress acting on the coupling is given by

$= \frac{\mathbf{1}}{\mathbf{2}}[\boldsymbol{\sigma} + \sqrt{\boldsymbol{\sigma}^2 + 4\boldsymbol{\tau}^2}]$ N/m2

= 0.016246.1 N/m2

7. Maximum shear stress induced on the shaft is given by

$= \mathbf{1/2}[\sqrt{(\boldsymbol{\sigma}^2 + 4\boldsymbol{\tau}^2)}]$N/m2

= 11362N/m^2

These process is repeated for different diameters. We get more stress values. So this diameter getting minimum stress value. Finally Schmidt coupling is suitable for this diameter only. Following these formulas, we find suitable diameter only.

IV. NUMERICAL RESULTS

In this Numerical analysis, Schmidt coupling can done by different materials such as Steel, Aluminum, Titanium, copper etc., For this project, analysis can done by three materials. They are

1. Steel
2. Aluminum
3. Titanium

Properties of Outline Row 11: Stainless Steel

	A	B	C
1	Property	Value	Unit
2	Density	7750	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	1.7E-05	C^-1
5	Reference Temperature	22	C
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and P...	
8	Young's Modulus	1.93E+11	Pa
9	Poisson's Ratio	0.31	
10	Bulk Modulus	1.693E+11	Pa
11	Shear Modulus	7.3664E+10	Pa
12	Tensile Yield Strength	2.07E+08	Pa
13	Compressive Yield Strength	2.07E+08	Pa
14	Tensile Ultimate Strength	5.86E+08	Pa
15	Compressive Ultimate Strength	0	Pa

Depending upon material properties the above details can be varied. For example Stainless Steel material having different Properties and Titanium having different properties. The Stainless Steel Properties as shown in above table.

In this Stainless Steel material, Numerical analysis can be done by two methods such as static structural analysis, Temperature analysis. These analysis as shown in below figures.

STATIC STUCTURAL ANALYSIS FOR STEEL:

(a) Total Deformation Results:

A deformation theory of plasticity is proposed wherein the deformation paths for material elements are assumed and the plastic work becomes dependent on displacements. Among the infinite possible ways to assume deformation paths, one has been chosen that has several advantages when materials harden isotropically.

Earlier, this path was shown to require the minimum work path to achieve a desired strain. Here, a mathematical description of a constitutive law of deformation plasticity is developed based upon this path for rigid-plastic and for Elasto-plastic materials. The proposed deformation theory provides a convenient theoretical basis for FEM applications involving analysis, and especially design, of forming processes.

In Static Structural analysis, total deformation of Steel as shown in below fig.]

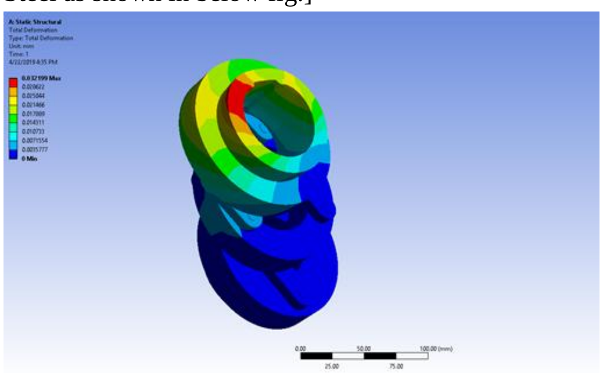

Fig 4.1 Total deformation for Steel

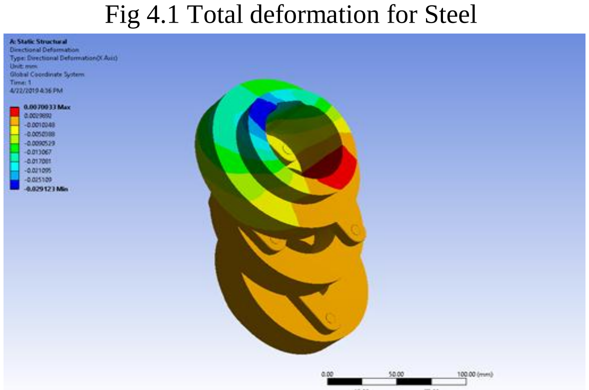

Fig 4.2 Directional deformation for steel

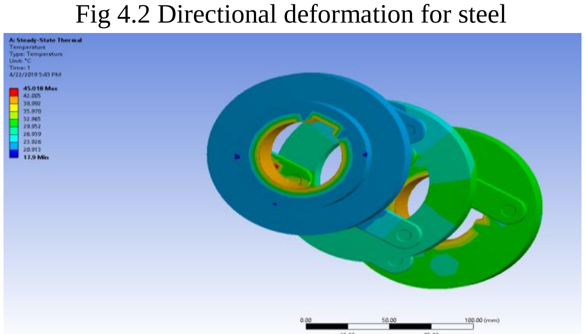

Fig 4.3 Steady State Thermal Analysis for steel

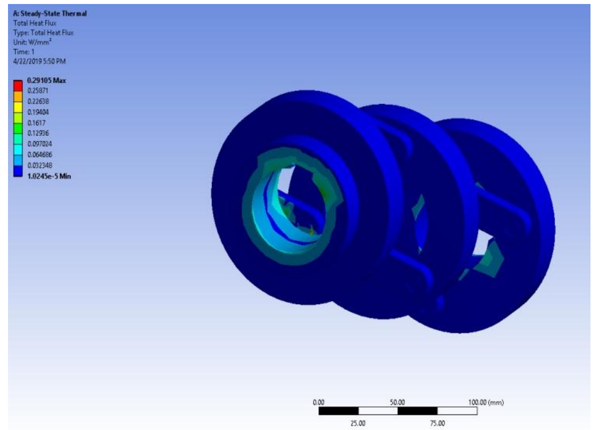

Fig 4.4 Total Heat Flux for Titanium

The design and analysis of Schmidt Coupling has done based on different assumptions. All the design and analysis of Schmidt Coupling parts has done based on the properties of the material. The results are tabulated based on the design condition and assumptions.

All the designed results are calculated from the data are compared with the analysis results. As observed the below graphs, Analysis results are more than that of theoretical results why because, in analysis of model we have some assumptions and conditions. But theoretical we don't need that conditions.

COMPARISON RESULTS FOR PRINCIPAL STRESS OF STEEL:

The comparison results as shown in below table

Table 6.1 comparison data between theoretical and simulation principal stress results for Steel

S.No.	Theoretical principal stress(MPa)	Simulation principal stress(MPa)
1	162.46	164.02
2	142.8	143.58
3	122.6	123.6
4	101.9	102.72
5	81.9	82.28
6	60.6	61.85
7	40.4	41.42
8	19.68	20.99

The above represented data shows the graphical representation of principal stress results for steel as shown below.

From the below Fig 6.1, we can take Theoretical principal stress on X-axis and Numerical stress on y-axis. From that graph, we understood that Theoretical principal stress decreases as compared to Numerical principal stress.

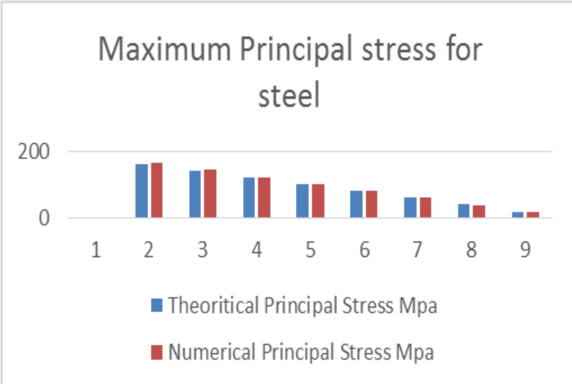

Fig 5.1 Theoretical and numerical representation of principal stress (MPa) for Steel

COMPARISON RESULTS FOR PRINCIPAL STRESS OF ALUMINUM:

The comparison results as shown in below table

Table 6.2 comparison data between theoretical and simulation principal stress results for Aluminum

S.NO.	Theoretical principal stress (MPa)	Simulation principal stress (MPa)
1	162.46	165.07
2	142.8	144.29
3	122.6	123.51
4	101.9	102.74
5	81.9	81.958
6	60.6	61.181
7	40.4	40.404
8	19.68	19.626

The above data can be represented in graph as shown in below Graph.

From the below Fig 6.2, we can take Theoretical principal stress on X-axis and Numerical stress on y-axis. From that graph, we understood that Theoretical principal stress decreases as compared to Numerical principal stress for Aluminum.

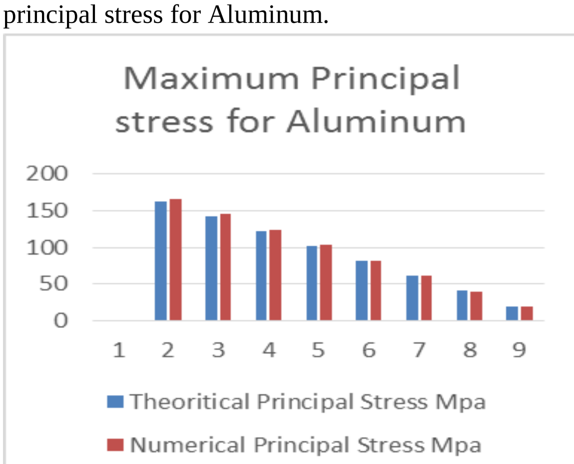

Fig 5.2 Theoretical and numerical representation of principal stress (MPa) for Aluminum

COMPARISON RESULTS FOR PRINCIPAL STRESS OFTITANIUM:

The comparison results as shown in below table

Table 5.3 comparison data between theoretical and simulation principal stress results for Titanium

S. No	Theoretical principal stress(MPa)	Simulation principal stress(MPa)
1	162.46	166.29
2	142.8	145.14
3	122.6	123.99
4	101.9	102.84
5	81.9	81.694
6	60.6	60.5
7	40.4	39.39
8	19.68	18.248

The above data can be represented in graph as shown in below Graph.

From the below Fig 6.3, we can take Theoretical principal stress on X-axis and Numerical stress on y-axis. From that graph, we understood that Theoretical principal stress increases as compared to Numerical principal stress.

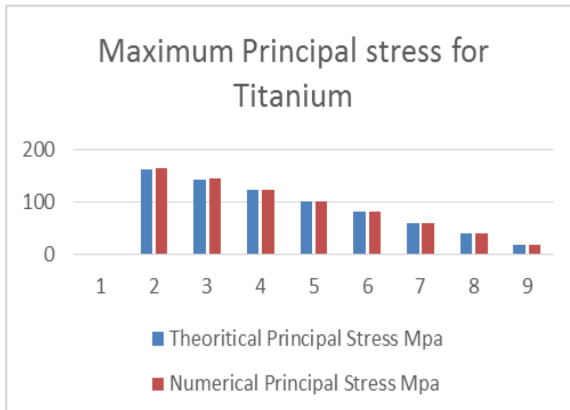

Fig 5.3 Theoretical and numerical representation principal stress (MPa) for Titanium

V.CONCLUSION

Based on experimental observations and modeling analysis, the possible geometries are plotted & results are critically discussed. It can be concluded from the results that the proposed conceptual design can be applied for the transmission of power between two parallel shafts having proper shift and off-set by employing different geometries of Z-pins. Finally for these Schmidt coupling is suitable for diameter 300mm, theoretically calculated in chapter3. The weight calculations for all materials can done but aluminum having less weight but that having more breaking nature. So, in these coupling is suitable for

Titanium material. These material having high strength and low weight ratio. It can withstand high and low temperatures. Titanium has Non magnetic and anticorrosive material. So, Finally Titanium is suitable for this Schmidt coupling.

Future scope of work may include:
Fabrication of Schmidt coupling enables a variable parallel offset between two shafts with low backlash. Increase Diameters will definitely lead to higher transmission of power. Different materials are used to design definitely lead to better results.

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