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FAULT DIAGNOSIS OF FEED WATER PUMP USING ORDER ANALYSIS

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Abstract
Faults like unbalance, mechanical looseness, misalignment, bearing fault and bent shaft etc. causes vibration in rotating machinery. Detection of these faults in machines is required to avoid serious and significant economic losses. In this paper, implementation of order analysis technique in feed water pump in sugar factory for fault diagnosis. Order analysis technique is based vibration. In order analysis technique, both amplitude and phase are obtained. It is observed that the motor drive end (MDE) and drive end bearings of the pump found excess vibration. The result shows the presence of unbalance and parallel misalignment in pump. Order analysis can detect faults effectively and precisely before the failure occurs. It helps the maintenance engineer of the sugar factory for planning the maintenance activities well in advance.
*Keywords:*Sugar Factory; Faults diagnosis; Feed water pump; Order analysis

1. Introduction

Boiler feed water pump is a critical machine in sugar factory, nuclear power plant and thermal power plant. It is used to feed the water to the boiler. The overall efficiency of the plant depends on the operating conditions and efficiency of boiler feed water pump. Therefore, accurate pump problem diagnostics becomes essential. Vibrations in machines can be caused by a variety of faults, including unbalance, misalignment, looseness, and other faults.These faults become very severe, then result in unexpected shut down. As a result, vibration-based condition monitoring has been employed recently to diagnose faults in critical rotating machines. The simplest approach to keep track of a machine health, ensure that it is effective throughout time, and increase factory productivity is through vibration analysis. Thus, vibration condition monitoring reduces the overall operating cost and down time period.
Misalignment and unbalance faults are identified using Model based technique, which is based on residual generation technique. The fault location and condition of fault are effectively detected by using model based technique [1]. Misalignment and unbalance faults of rotor using equations of motion; the resolution of equation of motion by spectral method permits the analysis of dynamic response of flexible rotor subjected to unbalance and misalignment [2]. The effects of unbalance and clearance on the bearings of an overhung rotor is identified. Finite Element method is used to discretize the system and Assumed Modes is used to reduce the system. They performed a Fast Fourier Transform (FFT) analysis on a time signal, they show that an overhung rotor high unbalance caused many harmonics to appear in the frequency spectrum. [3]. In the presence of rotor fault such as unbalance and rotor stator rub, the cracked rotor shows vibration response. Experimental investigations of several faults are conducted, and full spectrum analysis is used to examine vibration data[4]. Artificial neural network design

for identification unbalance, misalignment, coupling looseness and pedestal looseness fault in rotating machinery is discussed. A back-propagation learning algorithm and multilayer network were applied [5].

Case study is particularly of a deep groove ball bearing used to support non drive end (NDE) of centrifugal pump is presented. Theoretical formulation of response parameters such as vibration velocity and frequency using dimensional analysis is carried out. Experiments is performed using vibration analyzer [7]. Condenser system repair and failure data are collected and examined for reliability analysis. Using coordinated condition monitoring, fault detection of the condenser cooling water pump.They shows that coordinated condition monitoring improves the accuracy of fault diagnosis [8]. Algorithm is developed for identification and confirmation of fault in thermal power plant machines using condition monitoring technique [9].

In order to diagnose faults in monoblock centrifugal pumps, decision tree algorithms are utilised to extract statistical features from vibration signals in both healthy and faulty conditions [10].For water pump fault diagnostics, an adaptive neuro-fuzzy inference system based on vibration signal is adopted. They extracted feature parameters from frequency domain to create feature vectors and fault pattern classification is carry out [11].For the categorization and diagnosis of centrifugal pump faults, an Artificial Neural Network (ANN) model based on vibration signals is used.More data samples is required for the greatest network for generalization [12].For the purpose of diagnosing centrifugal pump faults, frequency domain analysis is utilised.Several fault conditions of centrifugal pump are considered and frequency domain of faults are obtained [13].Petri net theory is implemented to creat the fault model for this fault signal. Feed water pump fault reasons and reasons probability using model [14].

Most of researchers, FFT spectrum is used for fault diagnosis. FFT spectrum shows multifault as per the frequency component peaks, but some faults have same frequency components. So the present work presents the order analysis techniques for fault diagnosis of forced draft fans which helps to confirm the fults in pump.

2. Fault diagnosis Methodology

Flow chart of fault diagnostic system by order analysis as shown in Fig. 1. Vibration data are usually taken as velocity on bearing housing, in all three directions, i.e., Vertical (V), Horizontal (H) and Axial (A). Velocity reading in V, H and A directions are taken and if overall velocity-rms amplitudes are within acceptable limits as per ISO standard chart, then the machine would be accepted. If the overall velocity-rms amplitude is greater than the acceptable limit as per ISO standard, i.e., just tolerable (restricted) or not permissible (critical) condition, then check for other faults using order analysis.

In order analysis both amplitude and phase are obtained. Evaluation of amplitude and phase is done by order analysis at a machine speed frequency (rotation). Order analysis is based on synchronized sampling of time signal with the machine speed. Order analysis requires an external trigger, which matches both the zero time sample in the time domain buffer and the sample clock such that the 1x frequency component is always the first order. Firmware corrections of the analyser are canceled out the tracking filter phase errors. First order (1x frequncy) shows phase value. Hence, It should be highlighted that phase analysis is the relative movement of different parts of the machine at a given frequency, and is not restricted to a specific frequency. Order analysis is to hold the display to the machine rotating speed under test. This ensures that even if the machine operating speed (frequency) changes, the order components will still be shown on the display. Thus, whenthe speed changes 1x frequency component is not shift. A phase verses orders display provides phase relationships with respect to the trigger.

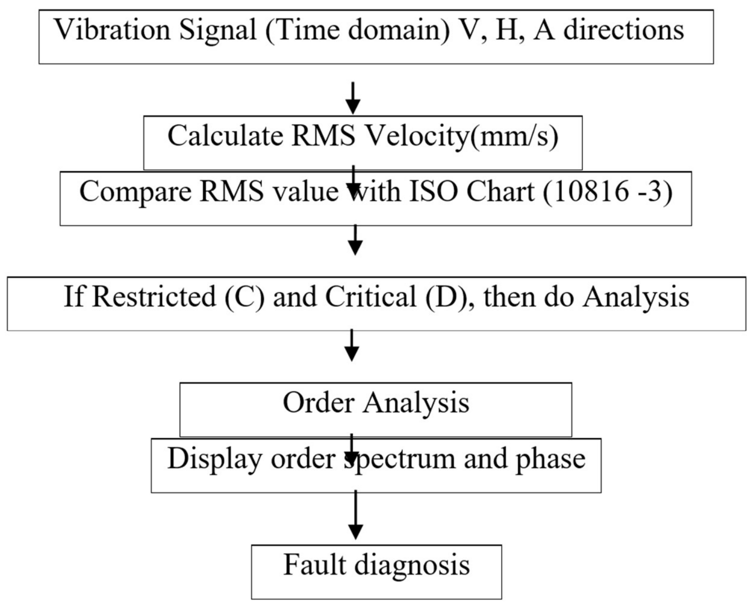

Fig.1 Flow chart of fault diagnostic system by order analysis

3. Specification and features of boiler feed water pump

Fig. 2 shows the photograph of boiler feed water pump. Specifications of boiler feed water pump in Table 1.

Table 1 Specification of boiler feed water pump

Make	KSB pumps Ltd.
Speed	2900 rev/min
Driven	Induction Motor
No. of impeller	7
Power	55 HP
Speed	2900 rev/min

Fig. 2. Photograph of boiler feed pump

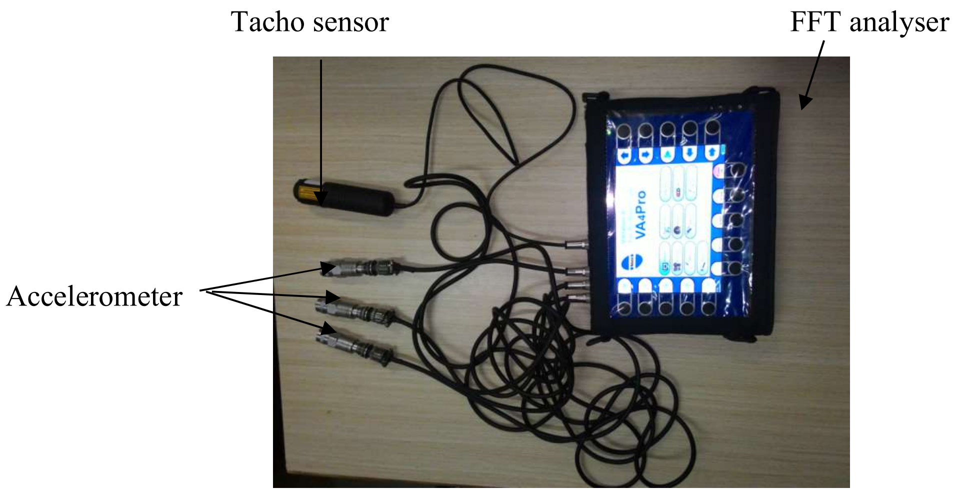

Fig. 3. Photograph of vibration analyser

The three piezoelectric accelerometers are used to collect the vibration signals in vertical (V), horizontal (H) and axial (A) direction at bearing. Vibration data is collected and analysis using four channel vibration analyser. Vibration is measured in terms of velocity. Table 2 shows the standard vibration levels for class III as per ISO 10816 -3.

Table 2 Standard vibration levels for class III machines. (As per ISO 10816 -3)

Standard Vibration Level (RMS) mm/s	Machine condition
0 -2.3	Good (A)
1.8- 4.5	Normal (B)
4.5-7.1	Restricted (C)
Above 7.1	Critical (D)

3.1. Order analysis of Boiler feed water pump

The vibrations are measured in the vertical (V), horizontal (H), and axial (A) directions at the motor drive-end (MDE), drive-end (DE) bearing, and non drive-end (NDE) bearing of the boiler feed water pump. Table 3 shows the overall RMS amplitude in the V, H, and A directions at DE and NDE bearing.It is clear from Table 3 that the RMS values of amplitude in V and H directions at DE bearing and MDE bearing are greater than the acceptable limit as per ISO 10816-3 (Table 2). Overall RMS amplitude of DE bearing in V and H directions is in a restricted zone (alarm) as per ISO 10816-3 (Table 2). Therefore, the Order spectrum is obtained.

Table 3 Overall RMS values of amplitude in V, H and A directions at DE and NDE bearing of the rotor

Speed (rev/min)	Vibration parameter RMS Amplitude (mm/s)			
	Bearing end	Direction		
		V	H	A
2940	MDE	3.39	**7.43**	3.40
	DE	**7.11**	**12.1**	1.42
	NDE	2.30	2.92	1.14

Figures 4-6 illustrate the order spectrum and phase of the motor drive-end bearing in the vertical, horizontal, and axial directions, respectively. The order spectrum and phase of drive-end bearing in vertical direction, DE-V (Fig. 7), horizontal direction, DE-H (Fig. 8) and axial direction, DE-A (Fig. 9) are shown. The order spectrum and phase of drive-end bearing in vertical direction, NDE-V (Fig. 10), horizontal direction, NDE-H (Fig. 11) and axial direction, NDE-A (Fig. 12) are shown. Order spectral analysis reveals a high amplitude peak at first order, i.e. 1480 rev/min in vertical direction, axial direction and high amplitude at second order in horizontal direction of MDE bearing. In the vertical, horizontal, and axial directions of the DE and NDE bearing, the order spectra show high amplitudes at first order.

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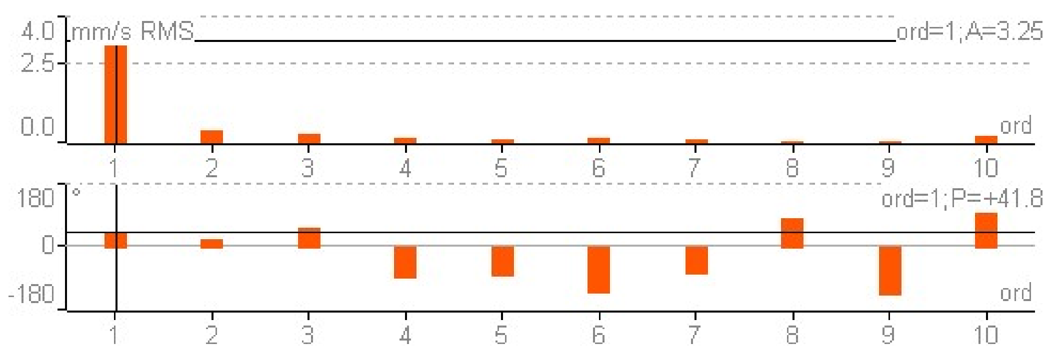

Fig. 4. Order spectrum and Phase at Motor Drive End (MDE) bearing in Vertical direction

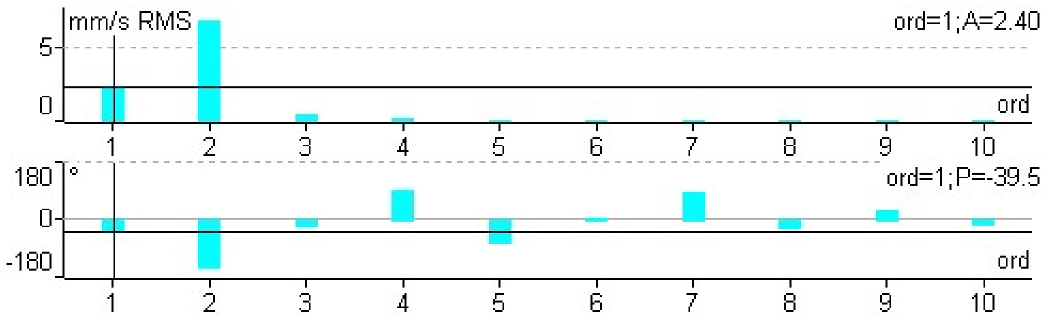

Fig. 5. Order spectrum and Phase at Motor Drive End (MDE) bearing in Horizontal direction

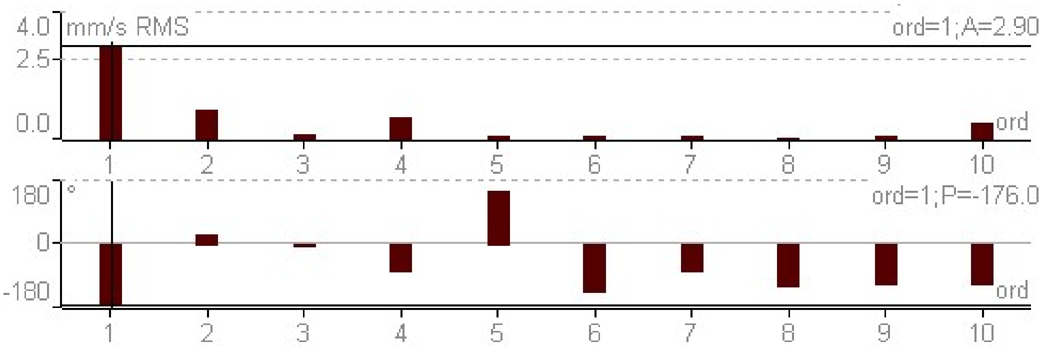

Fig. 6.Order spectrum and Phase at Motor Drive End (MDE) bearing in Axial direction

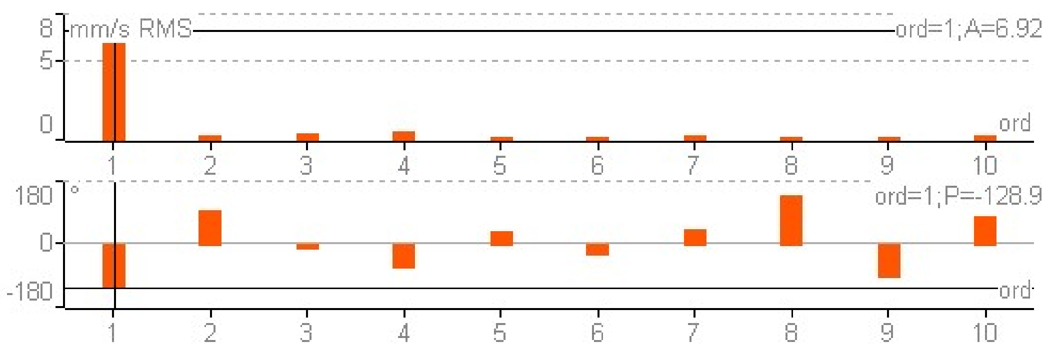

Fig. 7. Order spectrum and Phase at Drive End (DE) bearing in Vertical direction

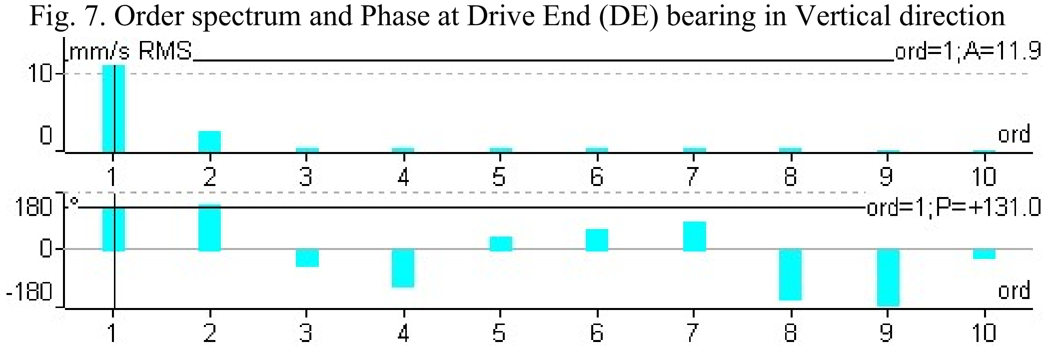

Fig. 8.Order spectrum and Phase at Drive End (DE) bearing in Horizotal direction

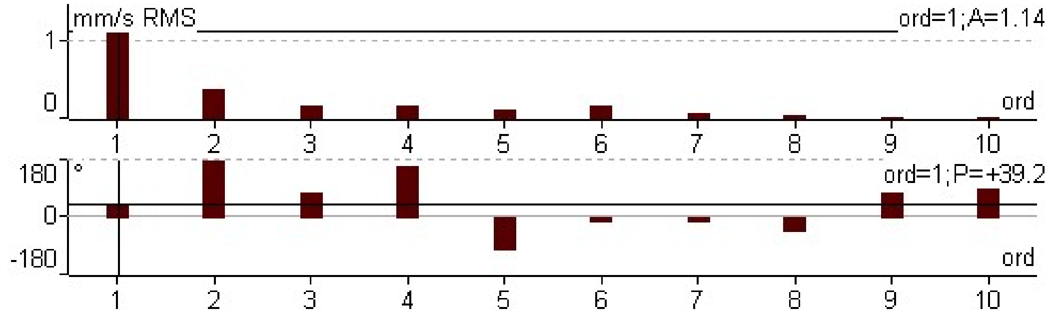

Fig. 9.Order spectrum and Phase at Drive End (DE) bearing in Axial direction

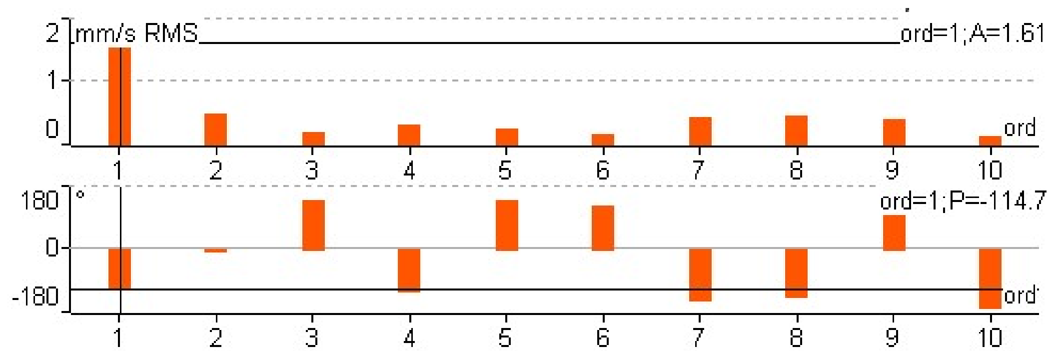

Fig. 10. Order spectrum and Phase at Non Drive End (NDE) bearing in Vertical direction

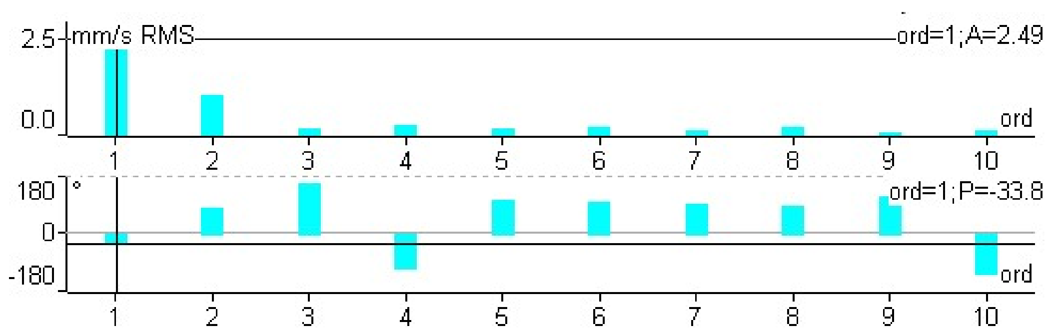

Fig. 11. Order spectrum and Phase at Non Drive End (NDE) bearing in Horizontal direction

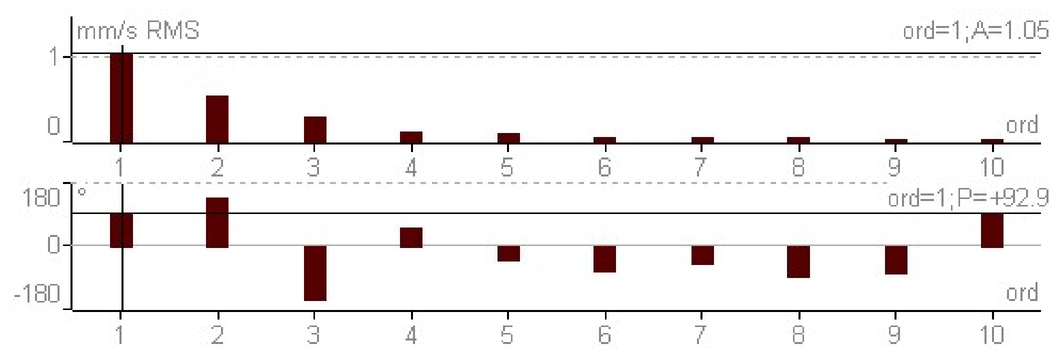

Fig. 12. Order spectrum and Phase at Non Drive End (NDE) bearing in Axial direction

From order spectrum and phase analysis is carried out for confirm fault. To identify a particular fault, phase analysis is carried out for confirming fault. Table 4 shows phase values in V, H and A directions at MDE, DE and NDE bearing.

Table4 Phase values in V,H and A directions at MDE,DE and NDE bearing

Direction	MDE	DE	NDE
V	41.8 º	-128.9 º	-114.7 º
H	-39.5 º	131 º	-33.8 º
A	-176 º	39.2 º	92.9 º

The phase difference, calculated between DE-V and DE-H, is 101°, between NDE-V and NDE-H is 80.9°, i.e., 90° ± 30° [6]. Further, the phase difference calculated between DE-V and NDE-V is 14.2°, i.e., 0° ± 30°. Phase difference results confirm that the unbalance is present in pump.

Vertical phase difference at motor drive-end (MDE) bearing and rotor drive-end (DE)bearing, across coupling, are measured and shown in Table 4; a phase difference between vertical direction at motor drive-end (MDE) and DE bearings is obtained as 170.7°, and between horizontal direction at MDE and DE bearings is obtained as 170.5°, i.e., 180 ± 30°[6]. Thus, the result confirms the parallel misalignment present in the pump.

4. Conclusion

With the appropriate implementation of vibration diagnosis techniques, boiler feed water pump can operate with higher reliability and effectiveness.The result shows unbalance and parallel misalignment fault is diagnosed. Order analysis is the most effective for fault diagnosis of pump. Phase analysis allows to differentiate which of the several possible machine problems dominates. Phase analysis provides deep information related to machine diagnostics in combination with the information primarily provided by the order spectrum. Phase and amplitude data are typically used to determine the type and location of faults. Using order spectrum and phase analysis, the industry can overcome several promising faults.

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