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Condition Monitoring And Parametric Analysis Of Planetary Gearbox

Pravin K. Khamkar[1],Shubham G. Ahire[2], Prof. S.H.Patil[3]
[1,2,3]Mechanical Engineering, Government College of Engineering Karad, Maharashtra, India-415124.
Email ID- pravinkhamkar23@gmail.com

Abstract: Vibration analysis is a non-destructive testing method for condition monitoring of machines such as gearboxes. The fault on gear tooth can be identified with the help of this technique. In this work, vibration signature analysis is used to rectify the presence of gear tooth malfunction like crack, misalignment. An Experimental investigation was carried out on the three-stage planetary (epicyclic) gearbox. Results obtained from this performed testing gives the parameters of vibration analysis event, Vibration frequency, amplitude changes at different stages of the gearbox for healthy (normal) as well as faulty gear. It was hypothesized that vibration analysis technique is capable of diagnosing the crack and another malfunctioning in the gear tooth at no load condition. Hence vibration analysis technique has a notable potential for evaluation of condition monitoring of gearbox.
Keywords: condition monitoring, vibration, epicyclic, gearbox.

1. INTRODUCTION

Planetary gearboxes are commonly used to transmit power in many applications like automobile, aircraft, marine applications and wind turbines. Epicyclic gearbox has many advantages some of them are a large speed/torque ratio in a compact gearbox. In planetary gearbox input and output shafts lie on the same axis, this means that the input shaft delivering drive to the gearbox and the output shaft from the gearbox, coaxial with each other. Gearbox can be mounted on the same axis without having an offset. [1] This property of an epicyclic gearbox simplifies the design. It is well known that epicyclic gearboxes have less noise and vibration properties. Different speed and torque ratios from the same planetary set can be varied. This ability of the epicyclic gearbox makes it suitable for use in automatic transmissions, as well as other machines such as four-wheel drive, transfer cases and differentials. Epicyclic gearboxes are also widely used in crane and lifting devices where high speed to torque ratio is required in a compact space. An epicyclic gear train (also known as planetary gear) consists of the sun gear, planet gear, planet carrier cage and ring gear. Coaxial sun gear and planet gears rotating at same centres along with the planet carrier. The ring gear held stationary and sun gear drive motion to the planet carrier via planet gears. The appropriate reduction ratio is obtained by contact between planet gears with the ring gear. It is possible to obtain various gear ratios are by varying number of teeth on planet and sun gear at different stages. Multistage gearbox can be obtained by connecting individual stages in series.

As compare to fixed-axis gearboxes, work on condition monitoring and fault diagnosis of epicyclic gearboxes are not many. But in recent years there is tremendous growth in research regarding this topic. Many researchers have published their work in journals, conferences. Similar to parallel shaft spur gear transmissions, planetary systems are also not immune to the problems arising from the gear malfunctions. The prediction of noise and vibration and detection of faults by machine condition monitoring (MCM) techniques are vital for the smooth operation of planetary gearboxes in industrial applications. Epicyclic gearboxes are extensively used in industries and thus it requires precise condition monitoring capabilities for these gearboxes. This aim to avoid accidents and provide savings in cost of planetary gearboxes. This hypothesis aims to conclude the research and development of monitoring techniques and fault diagnosis of planetary gearboxes. It tries to segregate the information on this topic and thus providing a complete reference for researchers by helping them in developing advanced research work in this field. The analysis is presented in the form of different techniques used in fault diagnosis of planetary gearboxes like intelligent diagnosis methods, modelling tools and signal processing techniques.

The complete paper comprises following sections. In section 2 complete working structure, experimental setup and data acquisition system is discussed. Section 3 includes result and discussion, various output responses are depicted in the form of graphs. The conclusion lies in Section 5.

2. EXPERIMENTAL INVESTIGATION

2.1 Experimental Setup And Data Acquisition System

The experimental study was performed on the three-stage planetary gearbox test ring as shown in fig.1. The setup includes three-stage planetary gearbox with horizontal mounting hollow input foot mounted with open end shaft. The test ring assembly comprises two magnetically mounted accelerometers with SKF FFT analyzer. Accelerometers connected to each stage in the vertical and horizontal direction shown in fig. 2. The test gearbox is of spur gears planetary and specification are detailed in table 1. Gearbox is filled with lubricating oil number 220. All the tests are carried out with no load condition.

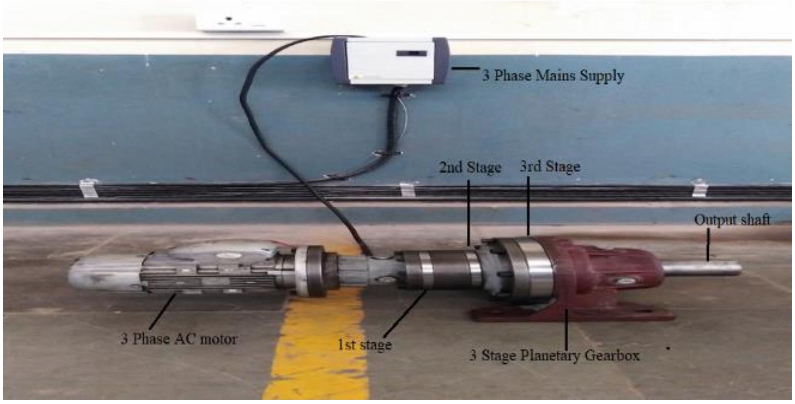


Figure 1 Three-stage planetary gearbox

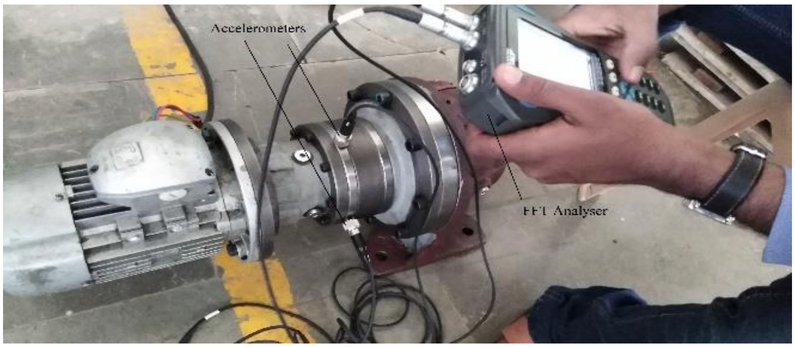


Figure 2 Test ring with FFT analyzer

The vibration signals were measured close to the test gear. The measurements for the vibration signals performed for the good condition healthy gearbox and gear with artificially induces fault with no load condition. Table 1 incorporates the gearbox specifications.

Parameters	Gear ratio	Planet gear teeth	Sun gear teeth	Ring gear teeth
1^{st} stage	3.82	23	22	83
2^{nd} Stage	4.26	21	19	80
3^{rd} Stage	5.77	24	13	74

Table 1 Test gearbox specifications

Accelerometer (SKF CMSS 2111) was used for the measurements of vibration signals. The sensor was placed on the gearbox at each of the stages progressively as shown in Fig. 2. The vibration signature at each stage was captured and saved with the help of FFT analyser. The vibration signal was post-processed in mainframe SKF analysis and reporting module. The basic components in the mainframe are the main amplifiers and threshold which are adjusted to identify the test sensitivity.

2.2 Measurement Analysis

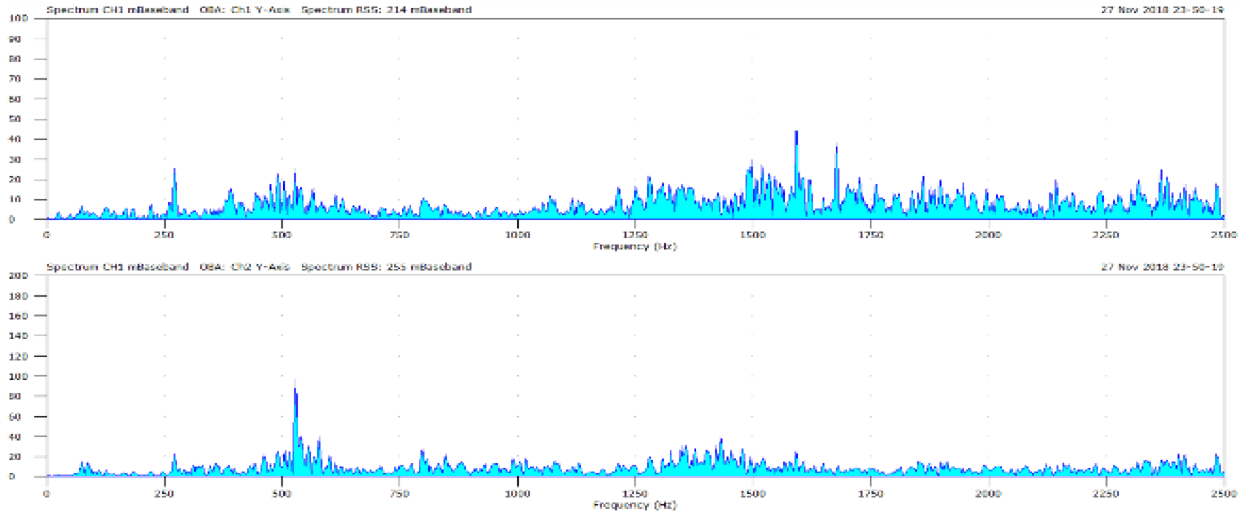
The experimental analysis was conducted to predict the value of Vibration signature Hz with healthy as well as the faulty gear of crack in planet gear at no load condition. All the experiment were conducted at a constant input speed of 1440 rpm. The fault in the planet gear was introduced by means of misalignment at one of the planet gear. Appropriate frequency level of detection and level of post-amplification was set up to get maximum vibration signature sensitivity. The vibration parameters measured was frequency of amplitude of vibration data.

3. RESULT AND DISCUSSION

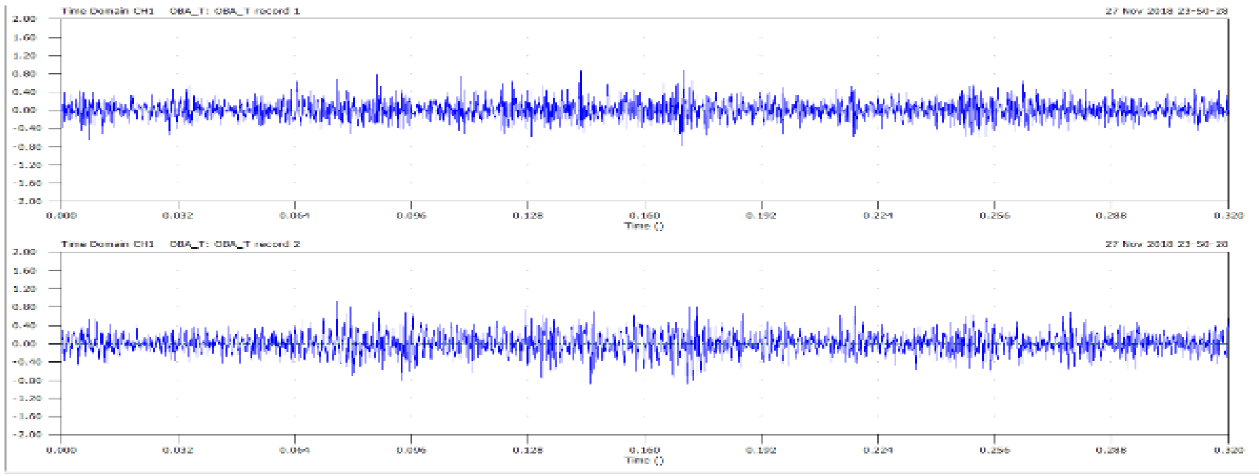
The experimental analysis was conducted at different stages of gearbox also at input and output bearings. Two accelerometers were connected at each stage at a time to get a vibration signature in two directions viz. vertical and horizontal. Vibration signature in the frequency domain, as well as time domain, were recorded in FFT analyser. The comparative study of obtained vibration values for healthy normal conditioned gearbox and faulty gear was represented. It is all clear from the readings of experimental investigation that change in vibration signature values for normal and faulty gear.

The experimental observations of vibration signature for normal and faulty gearbox are shown in the form of a graph in fig. 3 (a) (b) (c).

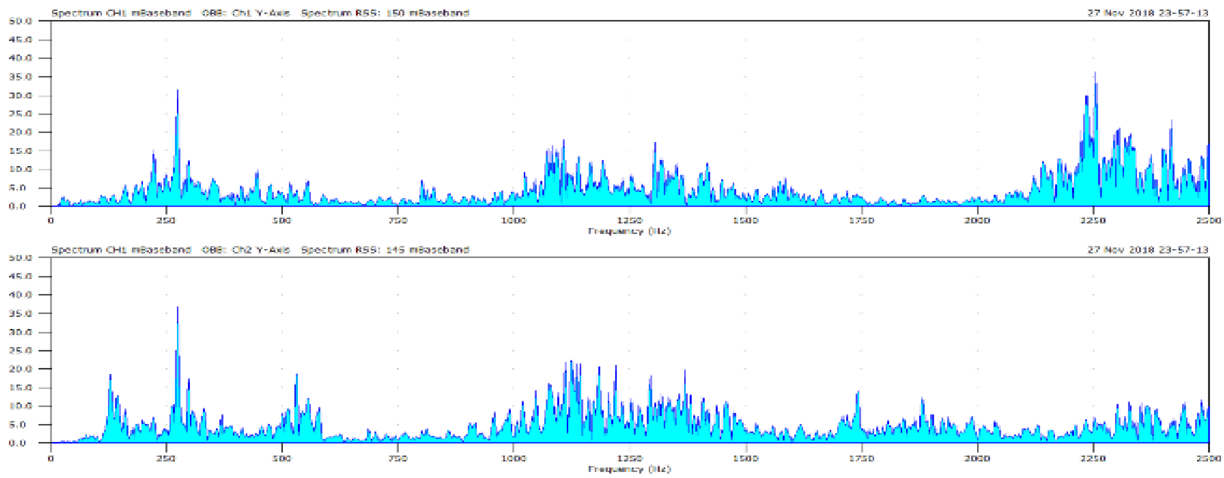
3.1 Normal Vibration Signature Is As Follow (Gearbox With Oil)



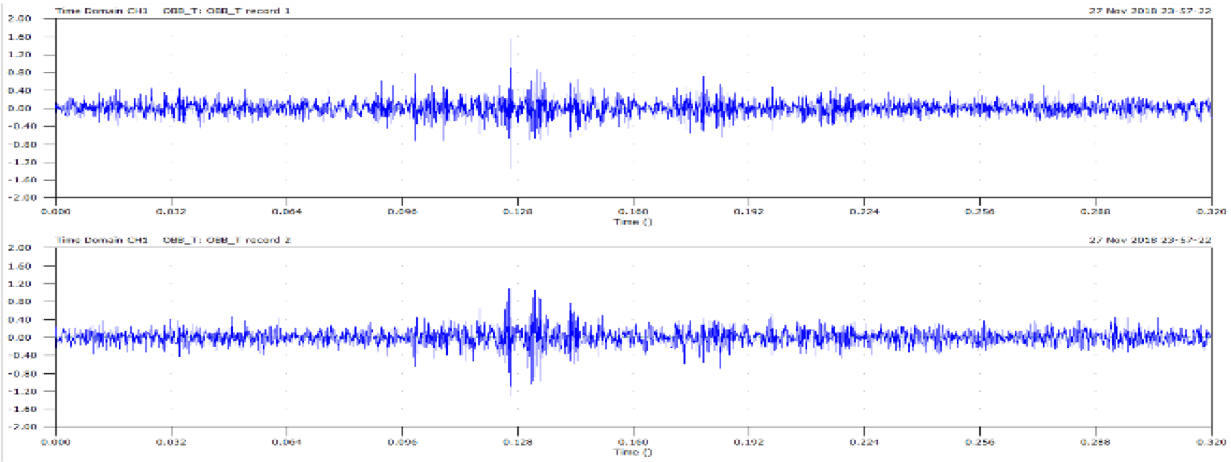
(a) Frequency domain signal at input shaft bearing.



(b) Time domain signal at input shaft bearing.

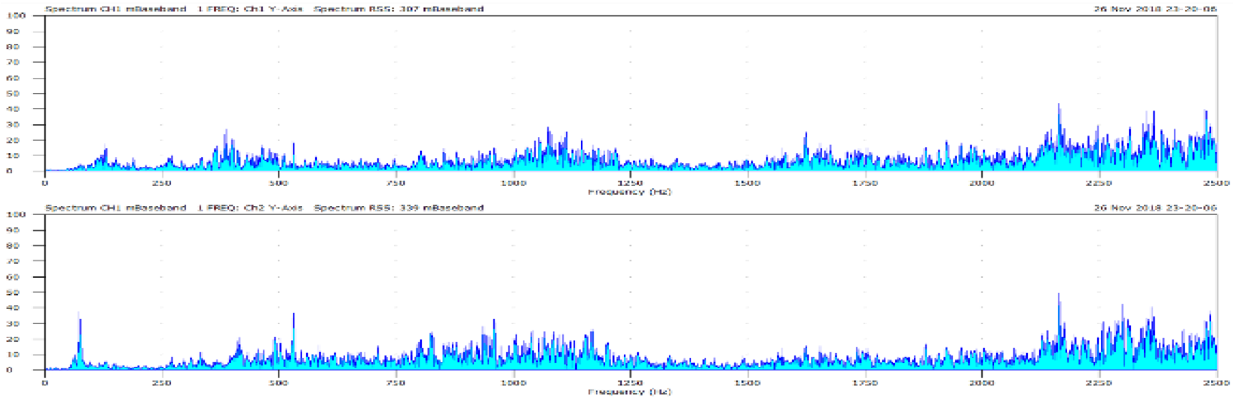


(c) Frequency domain signal at output shaft bearing.

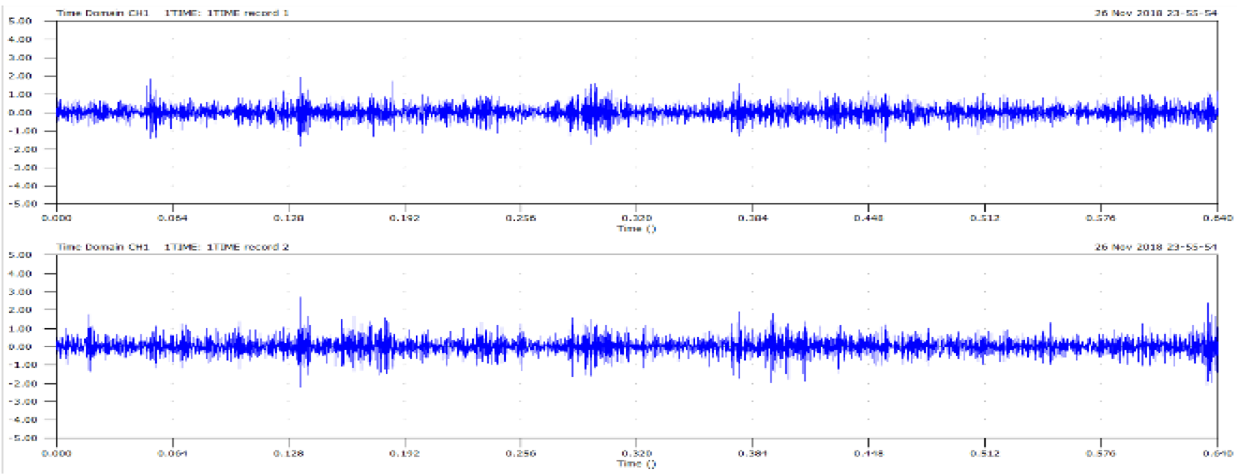


(d) Time domain signal at the output shaft.

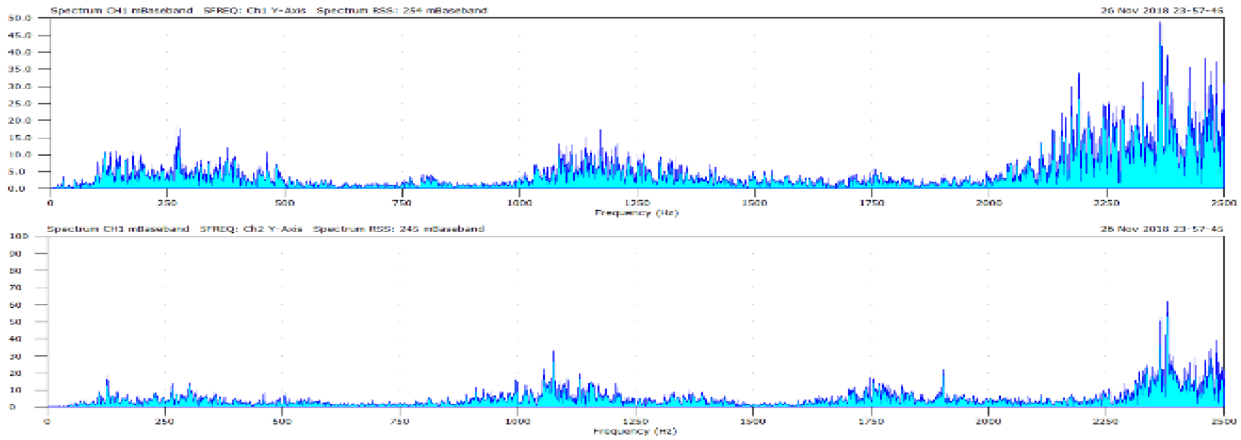
3.2 Faulty Gear Vibration Signature Is As Follows (Gearbox Without Oil)



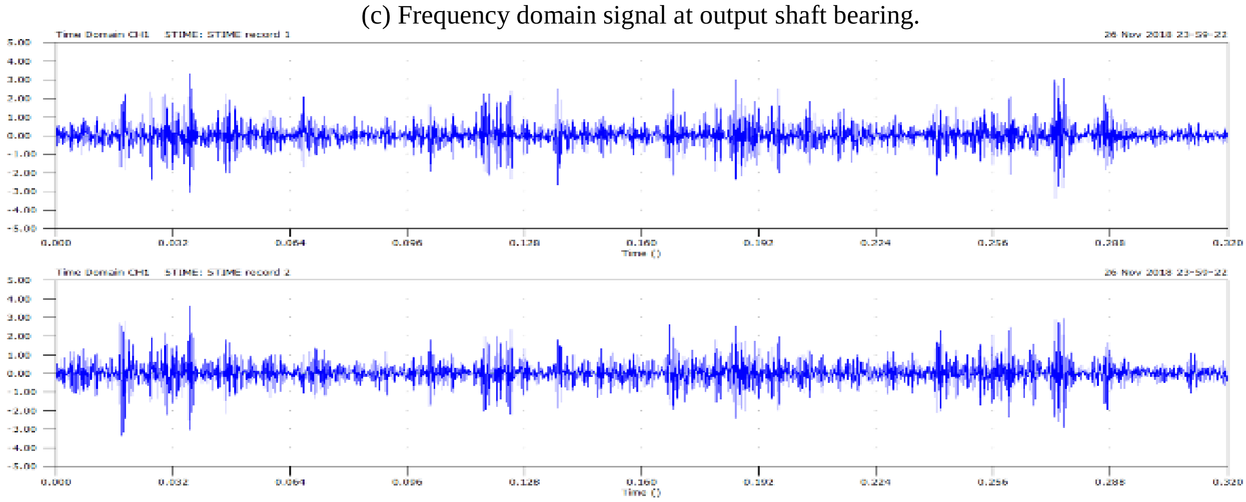
(a) Frequency domain signal at input shaft bearing.



(b) Time domain signal at input shaft bearing.



(c) Frequency domain signal at output shaft bearing.



(d) Time domain signal at the output shaft.

The experimental observations for frequency deviation on vibration frequency value for healthy (normal) and faulty gear during the test are summarized in Table 2. From these experimental data, which clearly implies that frequency increases during faulty gear meshing. It is also investigated that the value of vibration frequency for faulty gear is higher than the value of frequency for healthy (normal) gear at no load condition. This variation in values of vibration frequency clearly indicates the presence of a crack or gear malfunction.

4. CONCLUSION

As planetary gearbox are seldom used to transmit power in many applications such as automobile, aircraft, marine ships and wind turbines etc. The main concern in the condition monitoring of planetary gearbox is to identify the presence of defect to avoid sudden failures and to prevent disastrous actions. The presence of gear crack in the tooth has been predicted in the present study by using vibration analysis technique. Experimental analysis has been carried out on vibration generated during meshing of gears for normal as well as faulty gears to examine the reliability and effectiveness of vibration technique also to make sure this technique allow us early warning failure indication of gear. These results reveal the capability of the vibration analysis technique in the diagnosis of the presence of a crack in gearbox and effective condition monitoring of gearbox.

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