Bearing fault diagnosis based on signal processing

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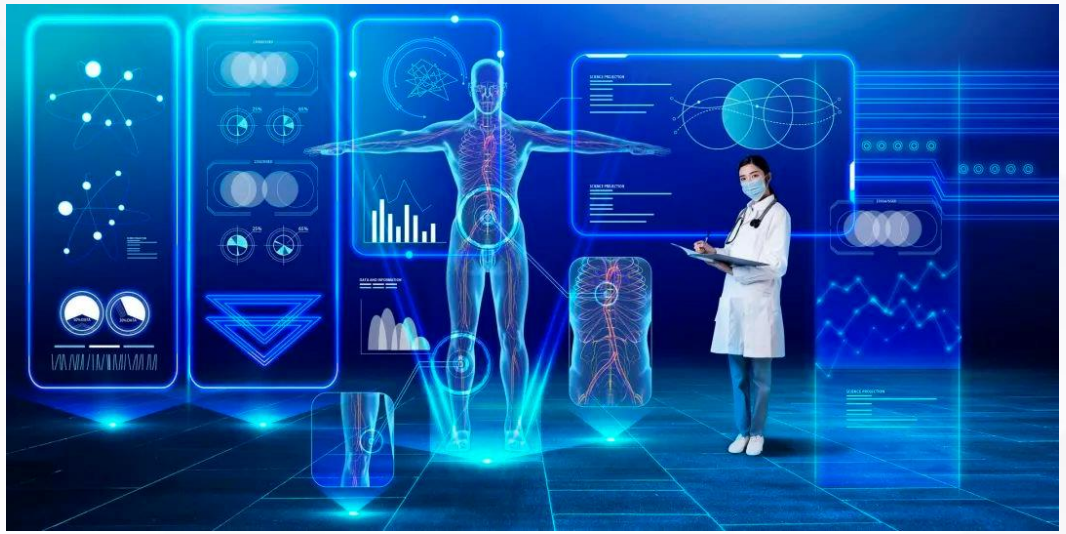
Background

- Human diseases can be reflected in the health indicators of various organs.



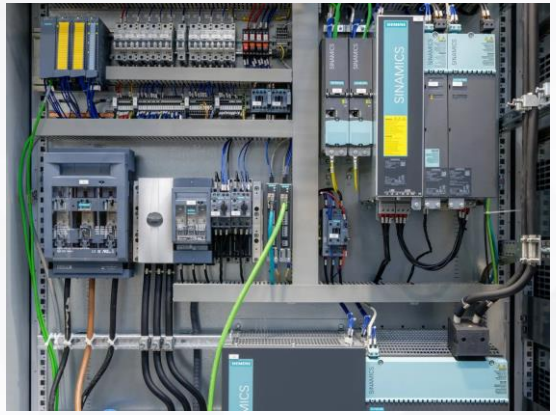
1) Collect data using medical equipment

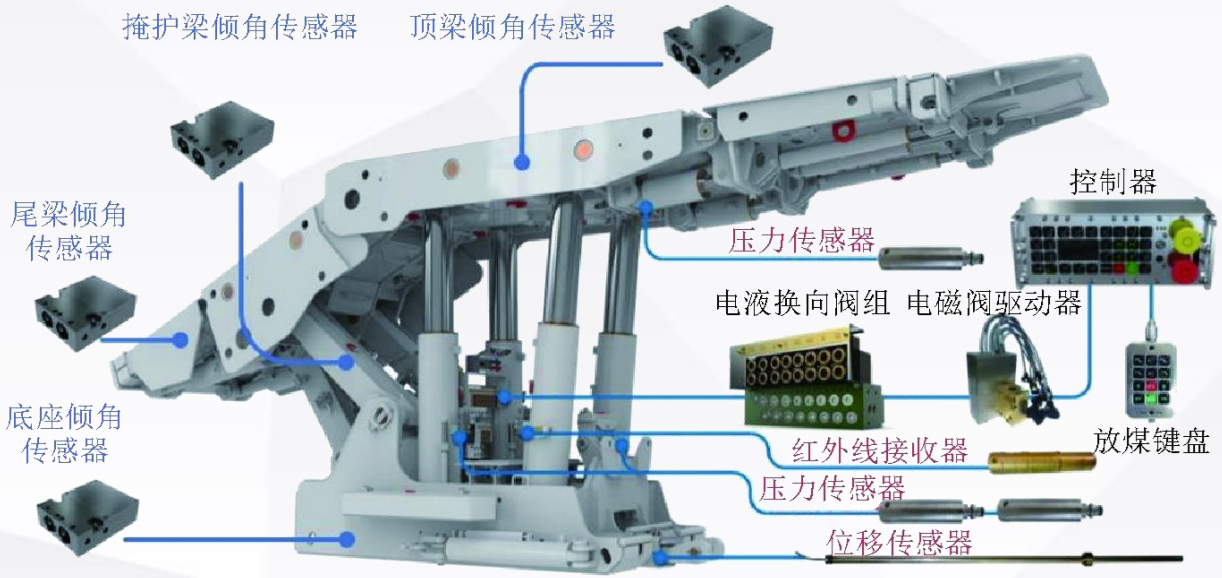
2) Monitor health indicators of various organs

3) Diagnose a variety of diseases

Background

- Device failures can also be reflected in the operational data of various parts.





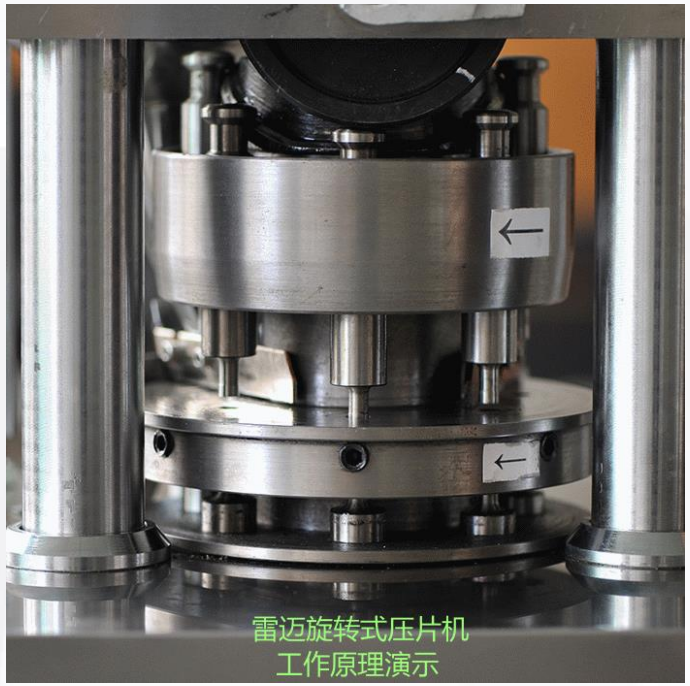
1) Collect data using sensors

2) Monitor operational data of various parts

3) Diagnose a variety of failures

Requirement

Rotating machinery



Rolling bearing

Failure mode

Outer race fracture

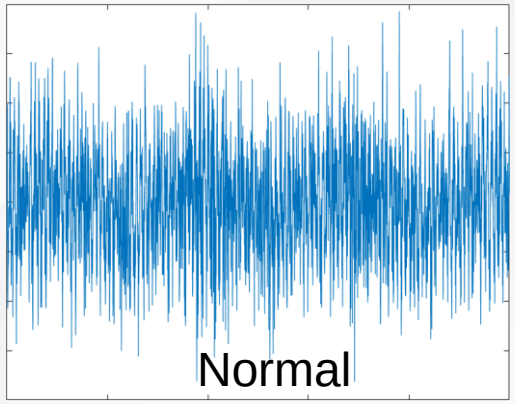
Inner race wear

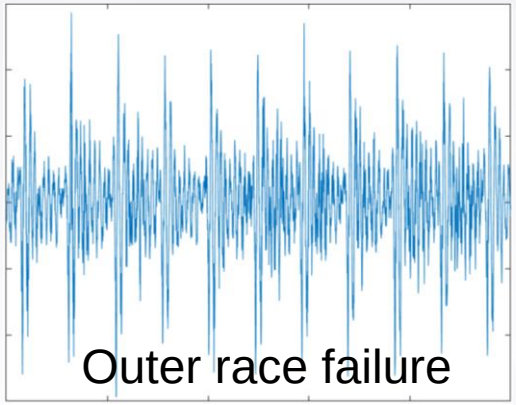
Cage fracture

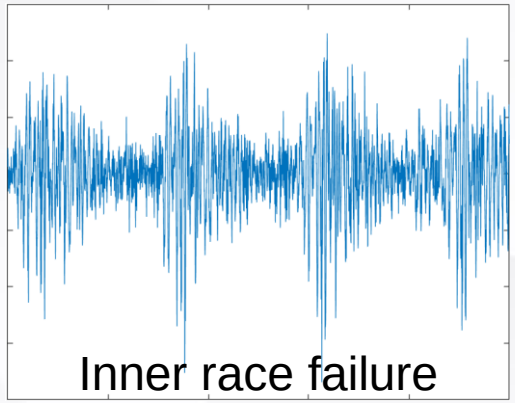
Ball wear

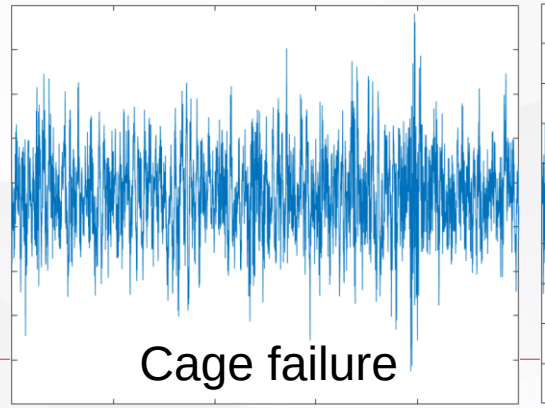
Requirement

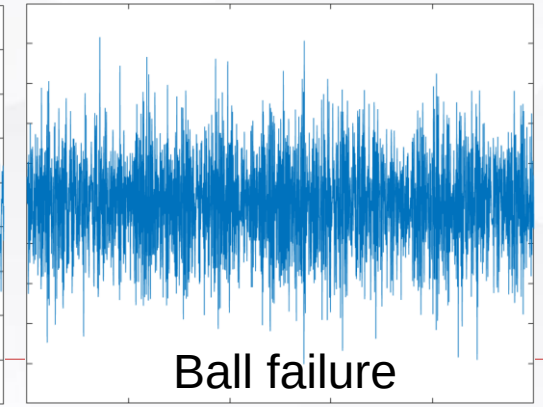
Raw vibration signal











Fault characteristic frequency

Ball Pass Frequency on Outer race

$$BPFO = n * \frac{fr}{2} * \left(1 - \frac{d}{D} * \cos A\right)$$

Ball Pass Frequency on Inner race

$$BPFI = n * \frac{fr}{2} * \left(1 + \frac{d}{D} * \cos A\right)$$

Ball Spin Frequency

$$BSF = \frac{fr}{2} * \frac{D}{d} * \left(1 - \left(\frac{d}{D} * \cos A\right)^2\right)$$

Fundamental Train Frequency

$$FTF = \frac{fr}{2} * \left(1 - \frac{d}{D} * \cos A\right)$$

n: number of balls
fr: rotating speed (rps)
d: Ball diameter
D: Bearing mean diameter
A: Contact angle

Requirement

- Use demodulation resonance analysis to identify the failure modes of the following 8 faulty samples.

Data File	n	fr (rps)	d (mm)	D (mm)	A	Failure mode
100.csv	8	35	7.92	34.55	0	
110.csv		35				
123.csv		35				
144.csv		35				
161.csv		37.5				
486.csv		37.5				
2365.csv		40				
2538.csv		40				

Requirement

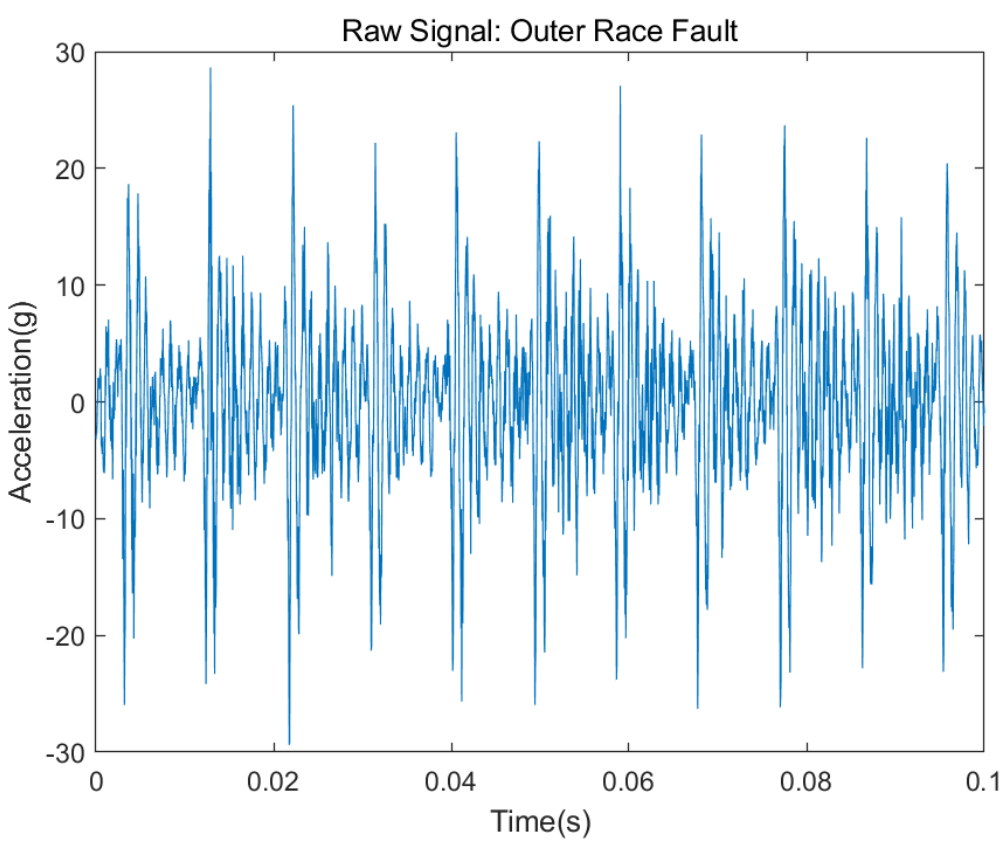
共振解调法原理

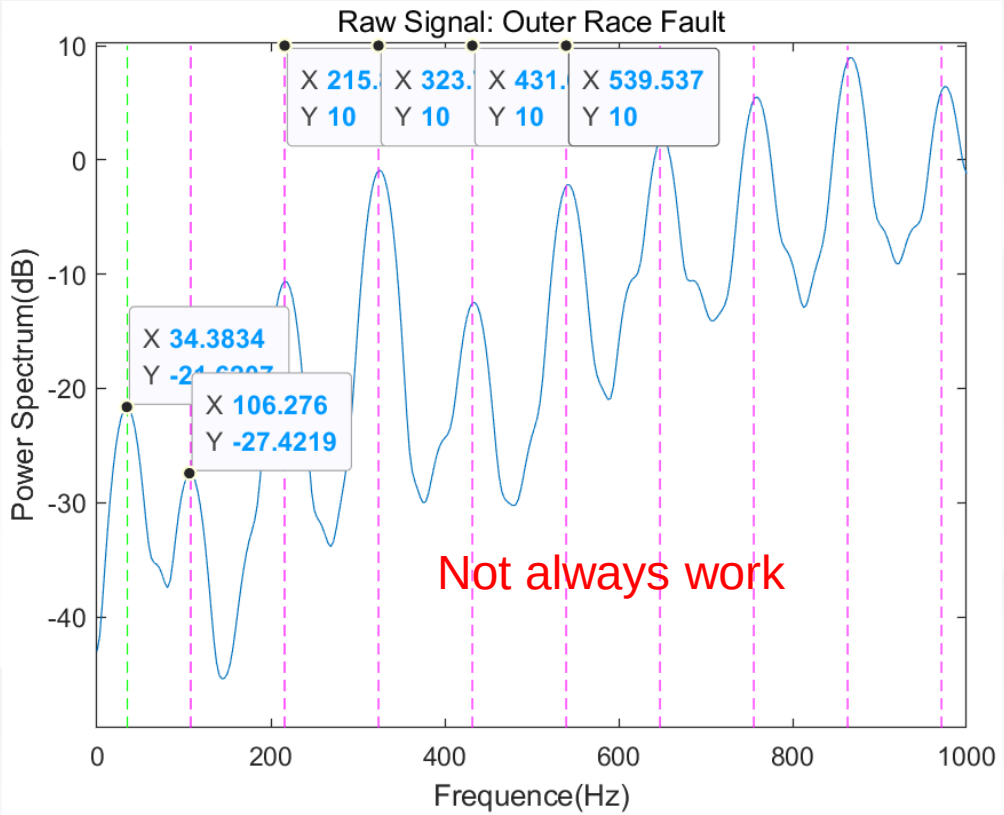
- 当轴承工作表面上出现局部损伤时，在循环工作中，轴承必将和其他相接触的零部件产生碰撞冲击，而这些能量较为集中的冲击脉冲由于持续时间极短，频带范围较宽，会引发设备发生高频共振，使得故障脉冲增强。

- 从频谱分析轴承故障时，往往难以从高频信号中识别出低频信息，因此就需要使用包络分析技术对信号的高频段进行带通滤波，将高频振动信号去除。通过谱峭度分析可以确定高频共振脉冲的频带，通过特定中心频率和带宽的带通滤波器将需要着重分析的频段分离出来。

- 带通滤波后进行幅度解调形成包络信号，通过观察包络信号的频谱就可以发现较低频的轴承故障特征频率，进而直观地判定和识别故障。

Example



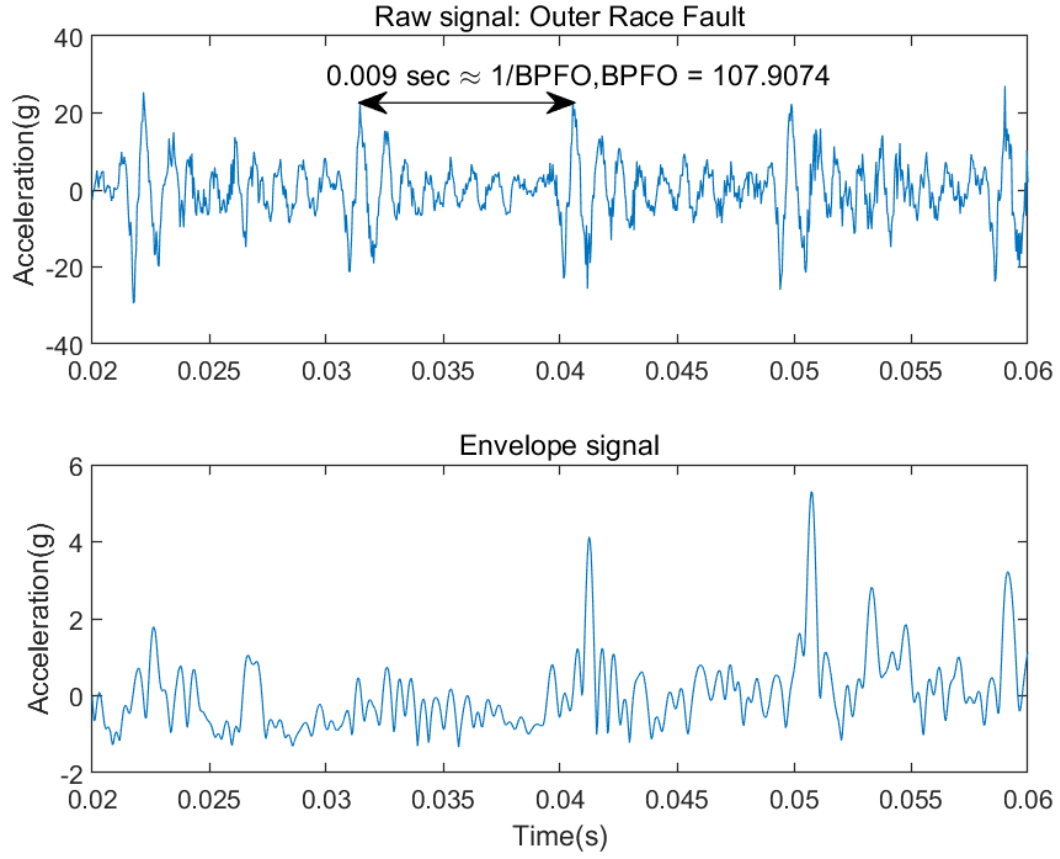


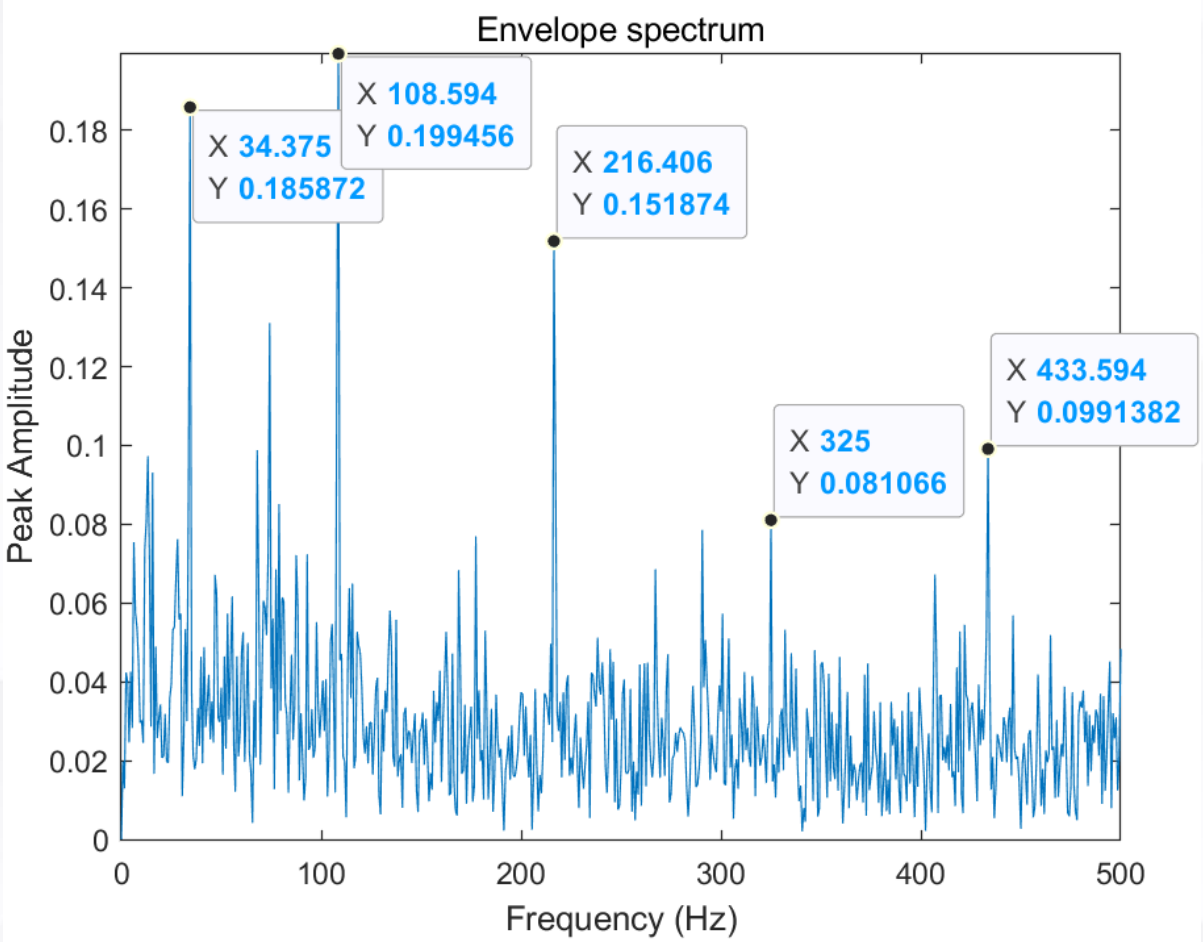
fr = 35 Hz

BPFO = 107.9 Hz BPFI = 172.1 Hz

BSF = 72.3 Hz FTF = 13.5 Hz

Example





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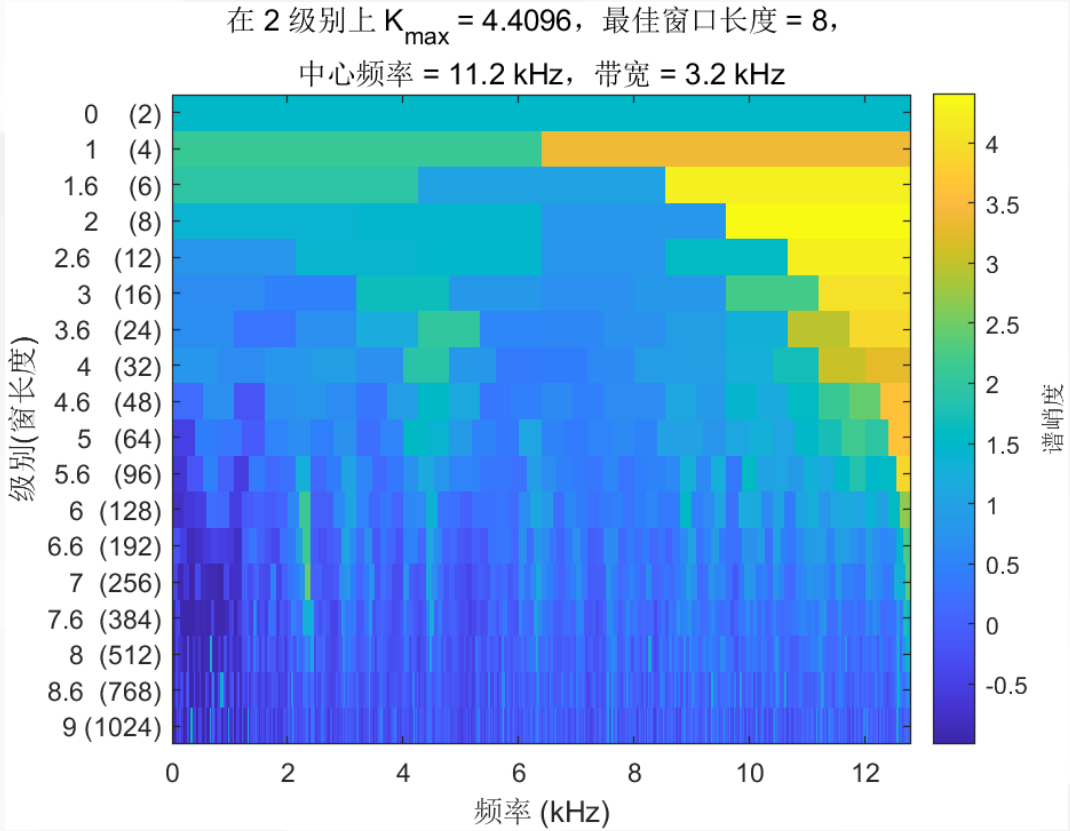
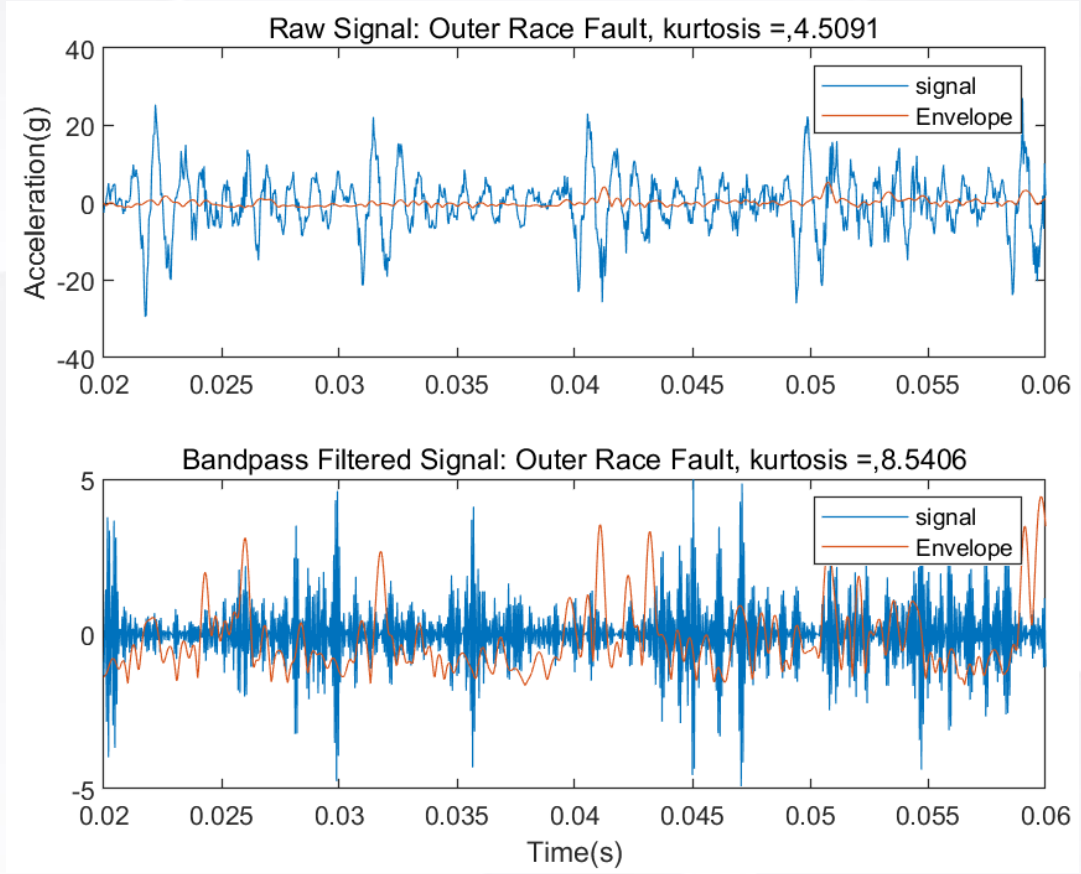
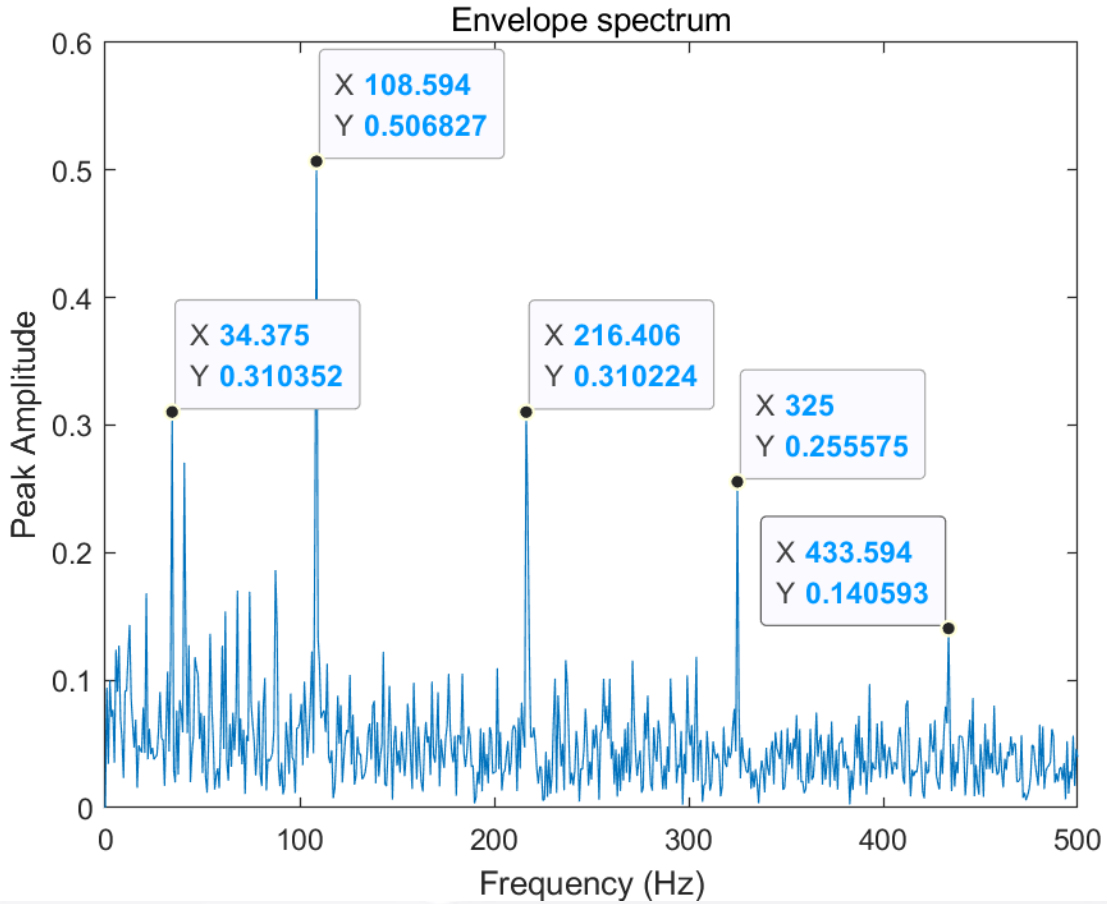

在 2 级别上 K_{max} = 4.4096，最佳窗口长度 = 8，
中心频率 = 11.2 kHz，带宽 = 3.2 kHz
0 (2)
1 (4)
1.6 (6)
2 (8)
2.6 (12)
3 (16)
3.6 (24)
4 (32)
4.6 (48)
5 (64)
5.6 (96)
6 (128)
6.6 (192)
7 (256)
7.6 (384)
8 (512)
8.6 (768)
9 (1024)
级别(窗长度)
0 2 4 6 8 10 12
频率 (kHz)
4 3.5 3 2.5 2 1.5 1 0.5 0 -0.5
谱峭度

Example





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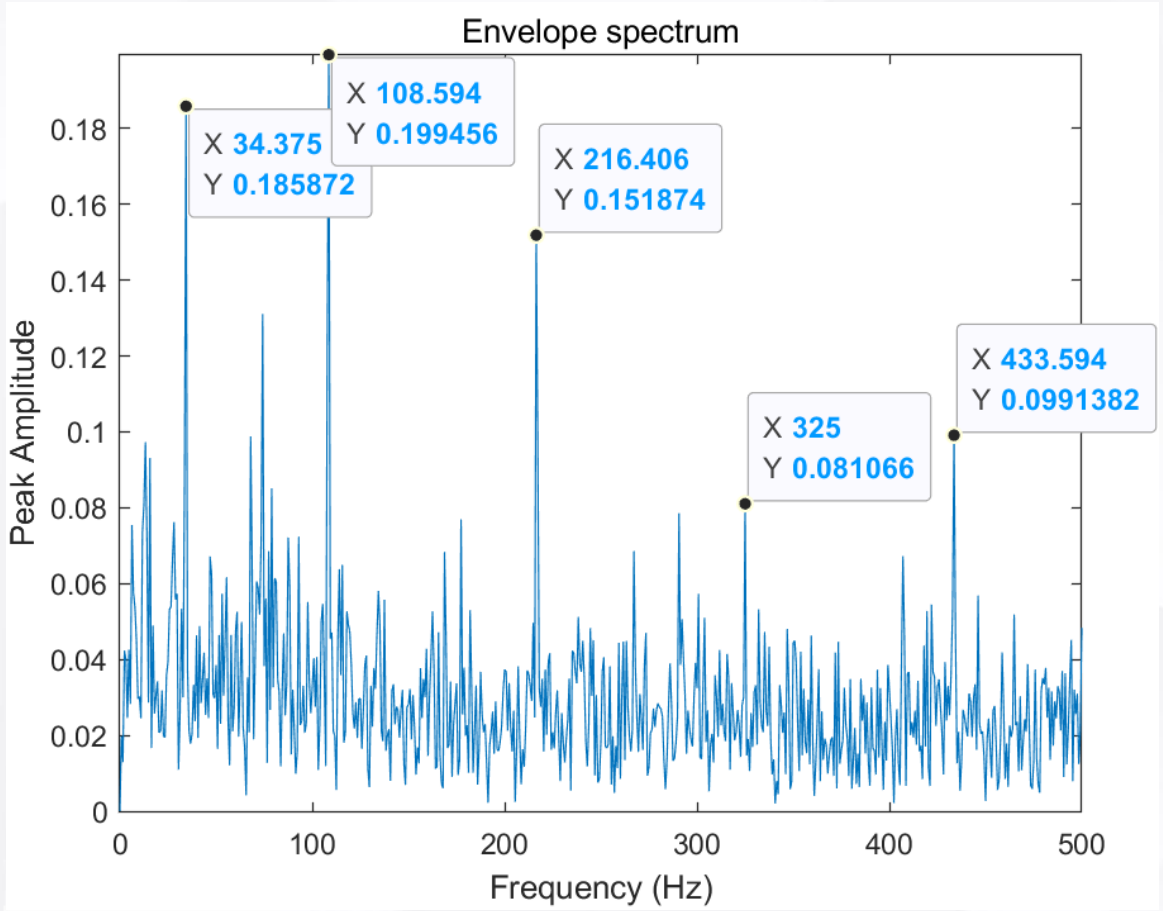
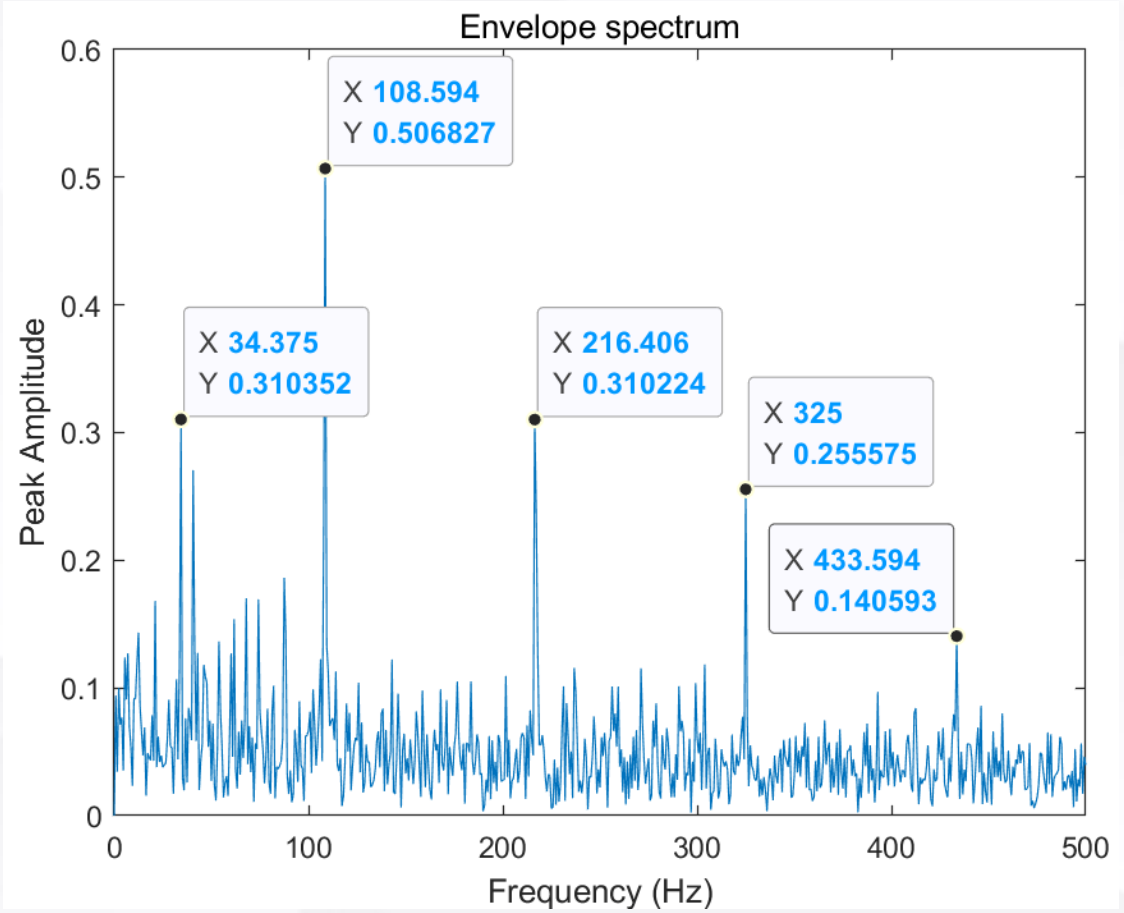
→ Outer race failure

Example



Before filtering



After filtering