Adikari Wisesa
INDONESIA

Adikari Wisesa INDONESIA

WEBINAR MAINTENANCE SERIES ADVANCED VIBRATION ANALYSIS

Outline

Sesi Pertama

- **Pengantar vibrasi**
- ***Fault condition* yang dapat diidentifikasi menggunakan analisa vibrasi**
- **Contoh kasus**
- **Summary**

Sesi Kedua

- ***Operating deflection shape***
- **Contoh Kasus**
- **Summary**

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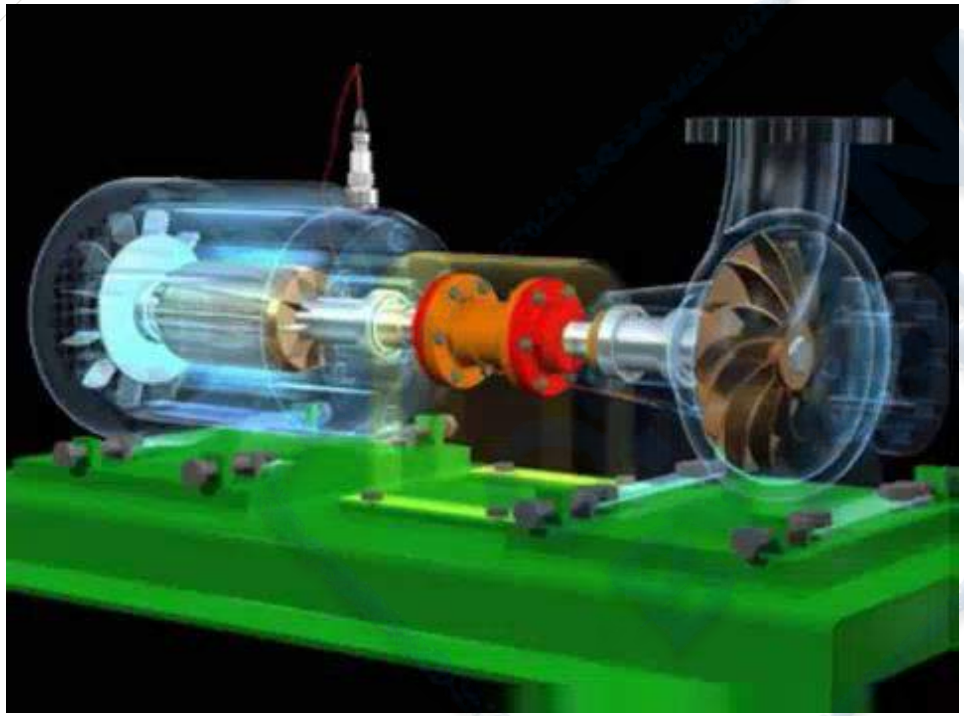
Sesi Pertama

Pengantar vibrasi



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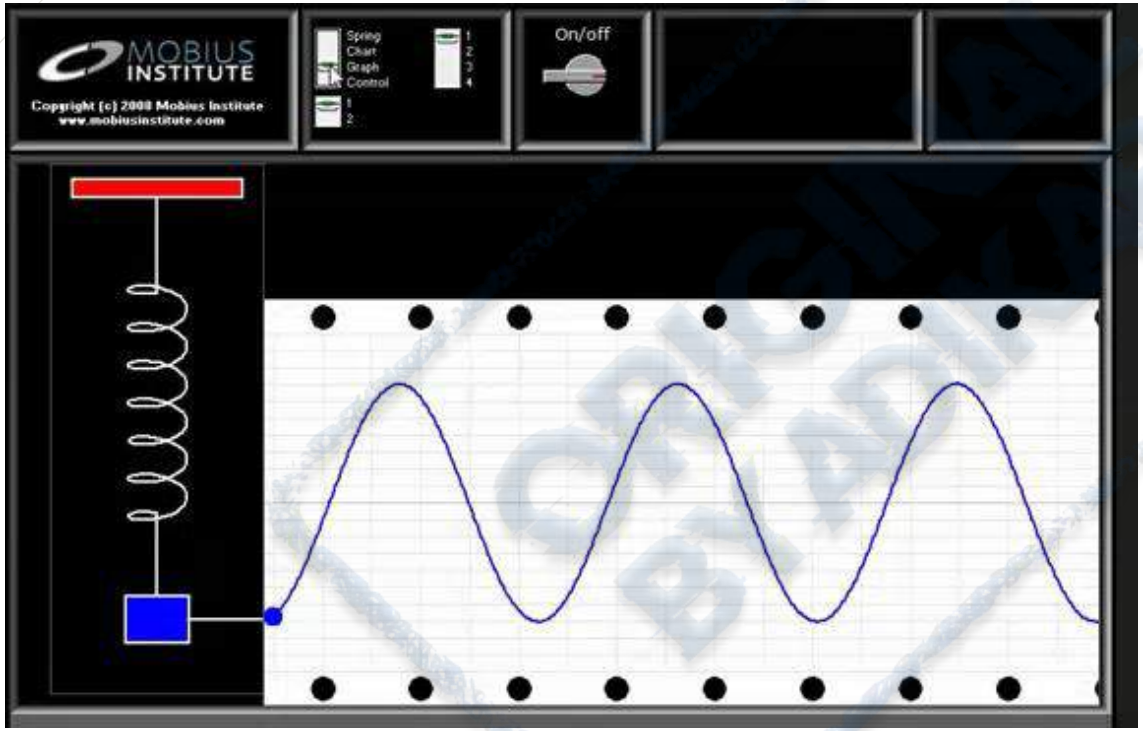
Pengantar vibrasi



Karakteristik Vibrasi

Amplitudo → Seberapa besar

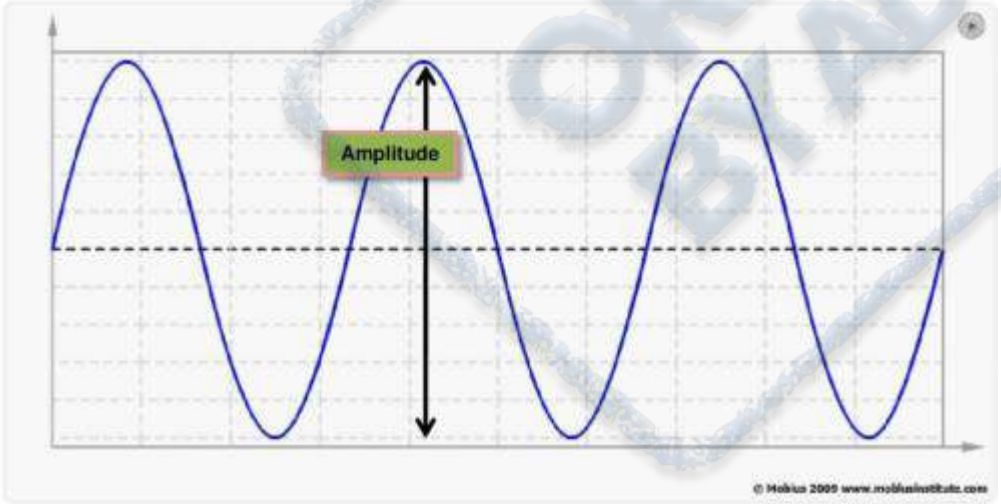
Frekuensi → Seberapa sering

Fasa → Kapan

Karakteristik Vibrasi

Amplitudo

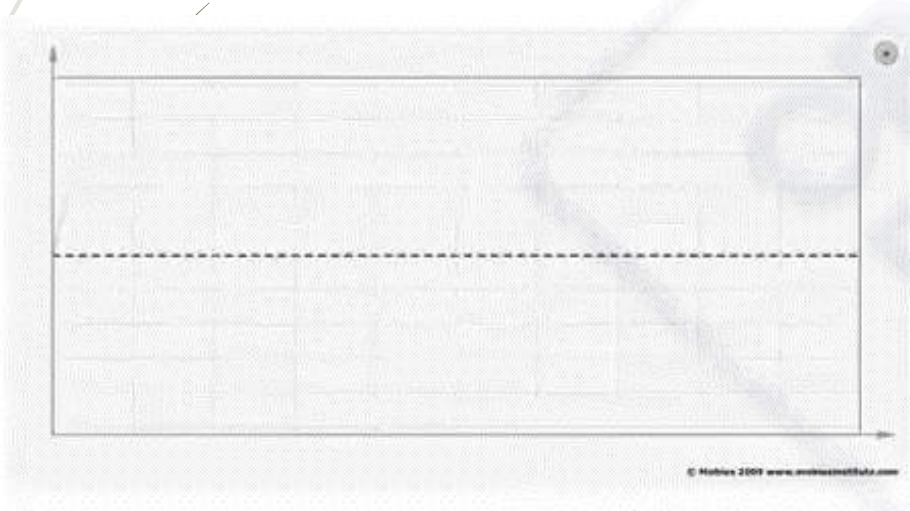
Besar nilai vibrasi yang berbanding lurus dengan kuatnya sinyal (millivolts atau milliamps) dalam satuan engineering (in/s, mm/s, mils)



Karakteristik Vibrasi

Amplitudo (bersambung)

Ada banyak cara dalam mengukur amplitudo dari vibrasi.
Paling umum adalah: peak to peak, zero to peak, root mean square (RMS), dan average.



Karakteristik Vibrasi

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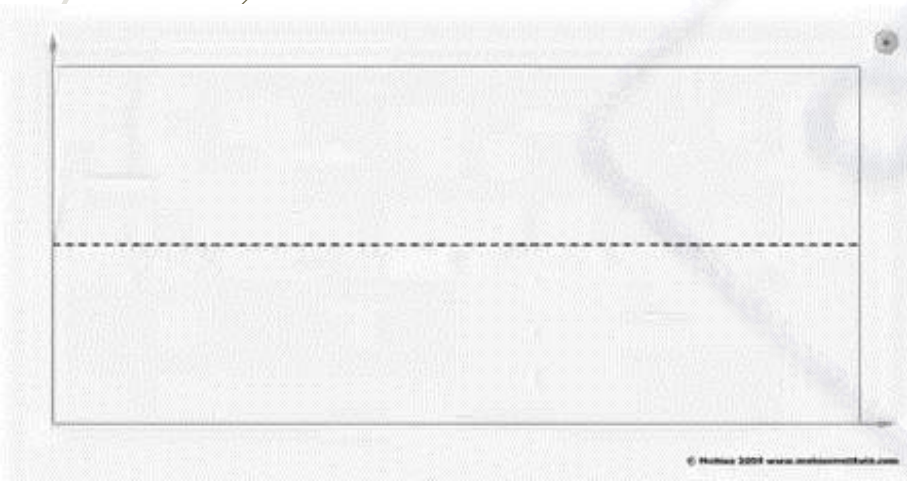

- For a purely sinusoidal signal: Peak-to-Peak =2 x Peak
- "Peak-to-Peak" is abbreviated "pk-pk"
- "Peak" is abbreviated to "pk" or "0-pk"

Karakteristik Vibrasi

Amplitudo (bersambung)

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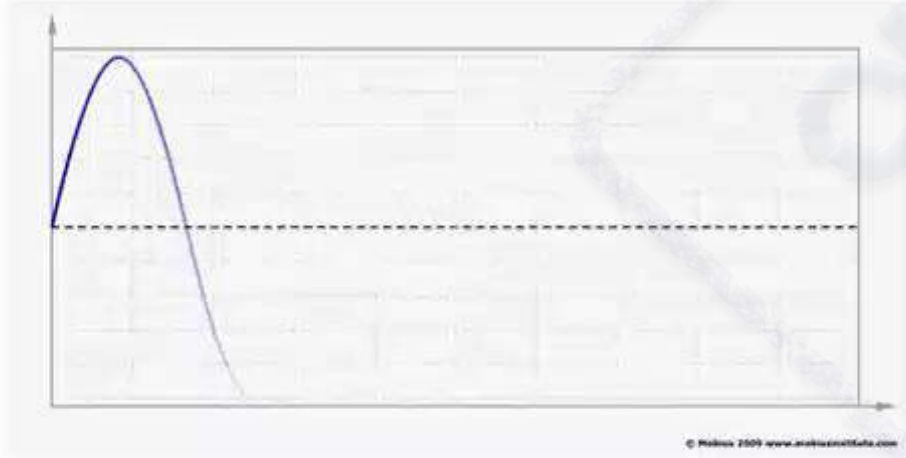


$$RMS = \frac{Peak}{\sqrt{2}} = 0.707xPeak$$

$$0.707 = \frac{1}{\sqrt{2}}$$

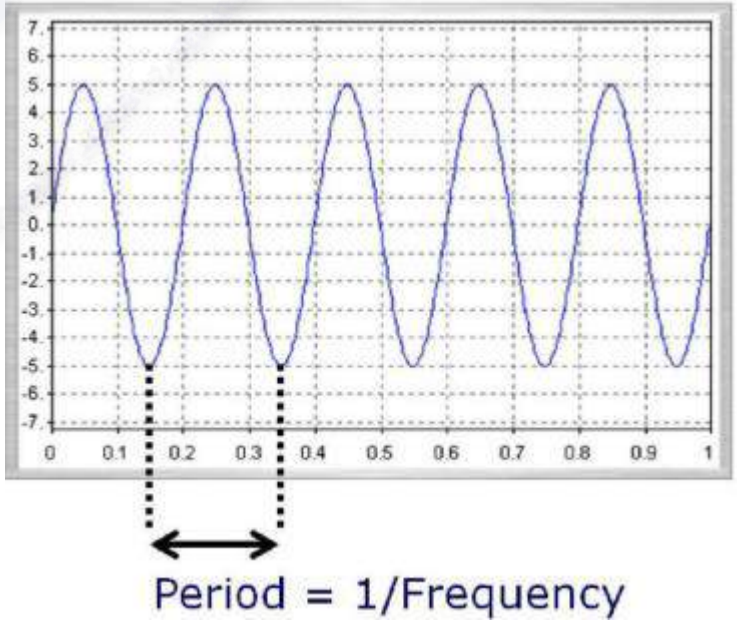
KARAKTERISTIK VIBRASI

Frekuensi

Jumlah siklus vibrasi yang terjadi selang waktu tertentu

- Kebalikan dari Perioda (T)
- Diukur dalam satuan Hz /CPM
- CPM berkorelasi langsung dengan RPM

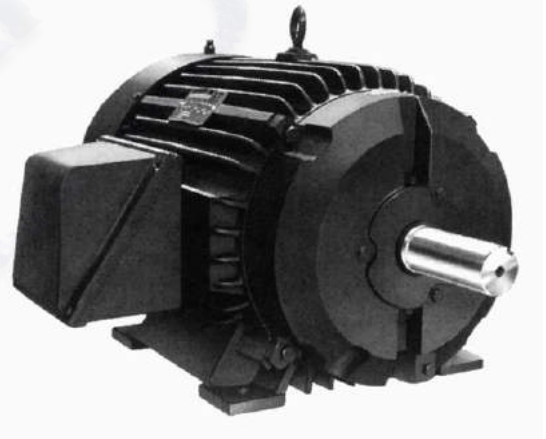
$$\text{Frequency} = \frac{1}{\text{Period}} = \frac{1}{T} = \frac{\text{Cycles}}{\text{Second}}$$



KARAKTERISTIK VIBRASI

Frekuensi (bersambung)

- Dapat dinyatakan dalam:
  1. CPM – Cycles Per Minute
     - 1CPM = 1RPM
  2. Hz – Cycles Per Second
     - CPM / 60
  3. Orders – kelipatan dari kecepatan putar

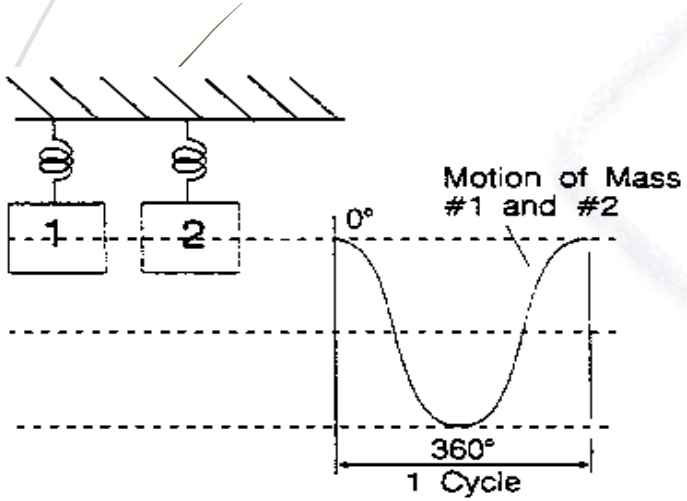


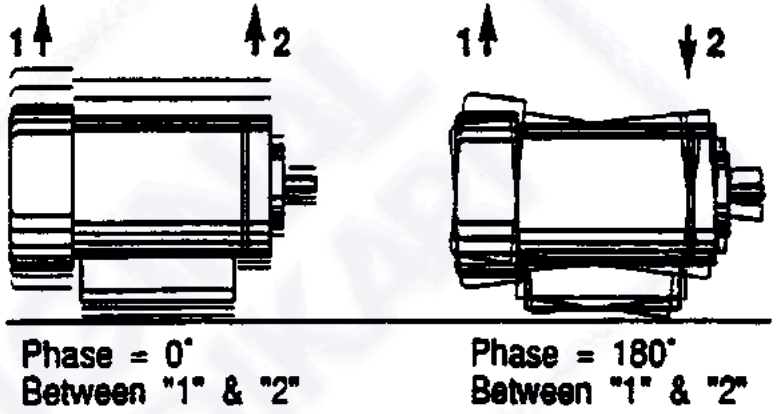
- Anggap suatu motor memiliki kecepatan putar 1485RPM, sehingga dapat dinyatakan sbb:
  - 1485 CPM (1rpm = 1cpm)
  - 24.75 Hz (1485/60) (menit ke detik)
  - 1 Orders (1 x putran shaft)

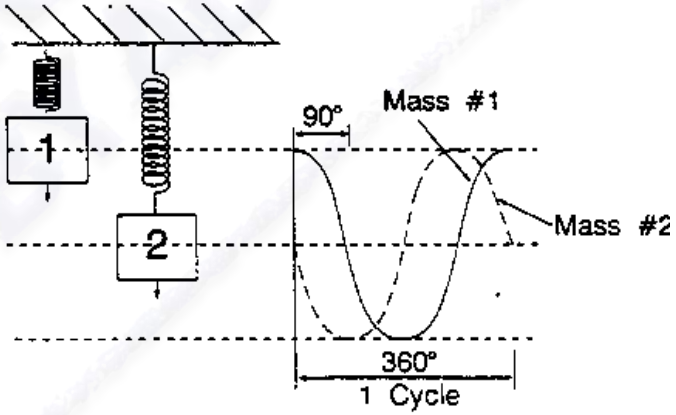
Karakteristik vibrasi

Fasa

- Ukuran yang menyatakan beda waktu antara dua kejadian (vibrasi) yang memiliki frekuensi yang sama.







Karakteristik vibrasi

Fasa (bersambung)

Fasa Absolut

- Fasa absolut adalah hubungan antara puncak sinyal vibrasi dengan referensi tetap.

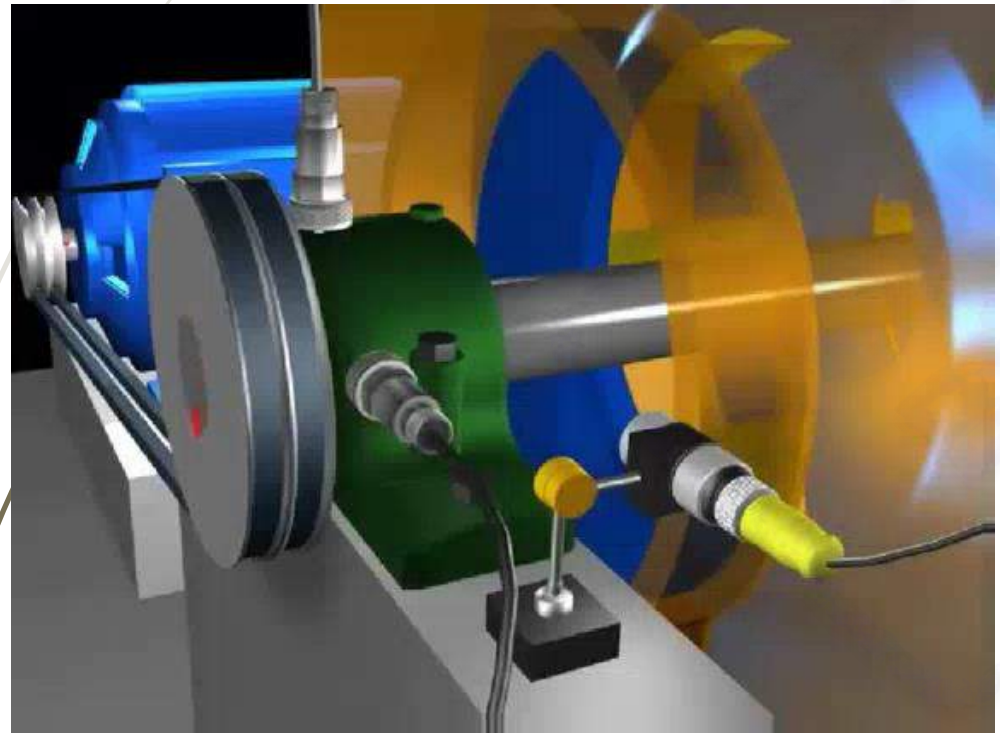
Fasa Relatif

- Fasa relative hubungan antara dua puncak sinyal vibrasi.

Karakteristik vibrasi

Fasa (bersambung)

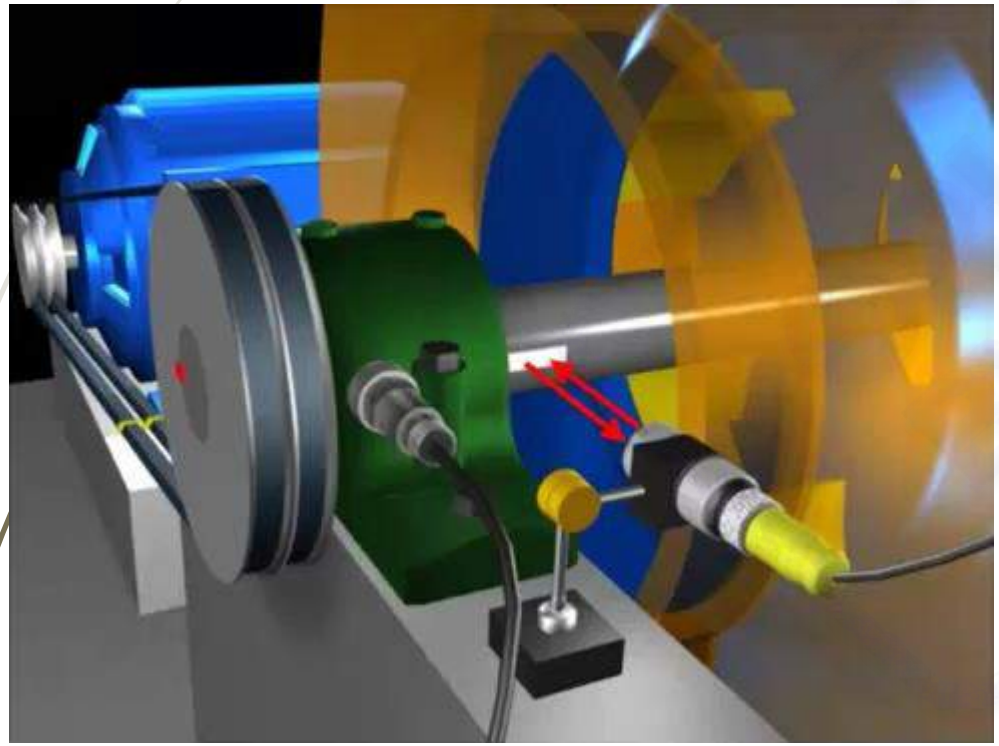
- ***Fasa Absolut***



Karakteristik vibrasi

Fasa (bersambung)

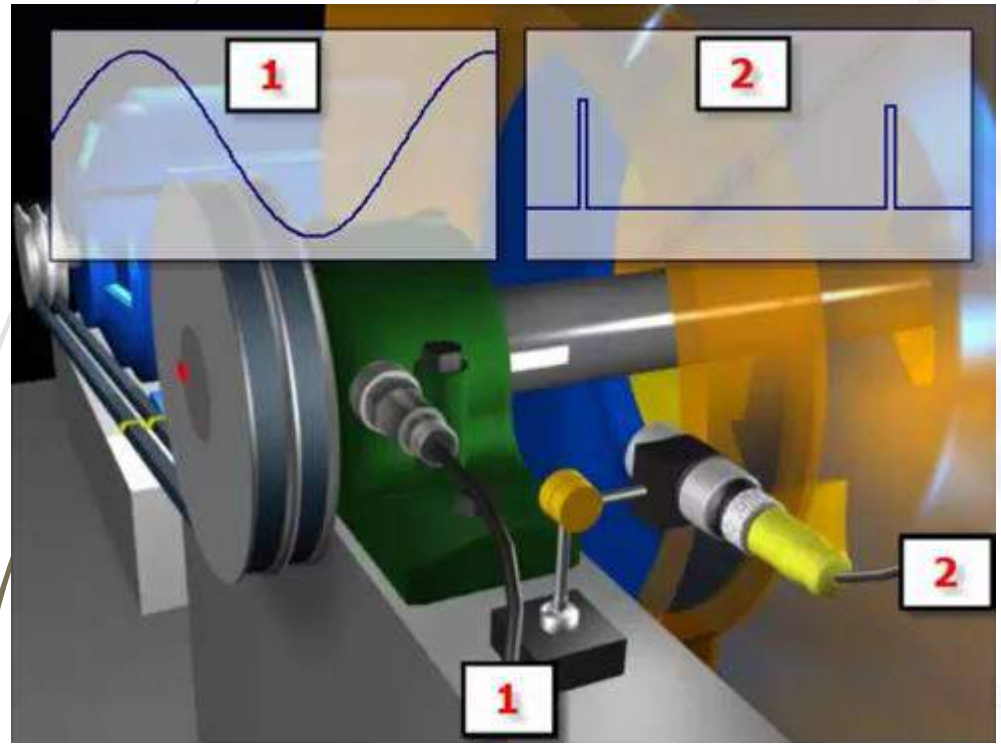
- ***Fasa Absolut***

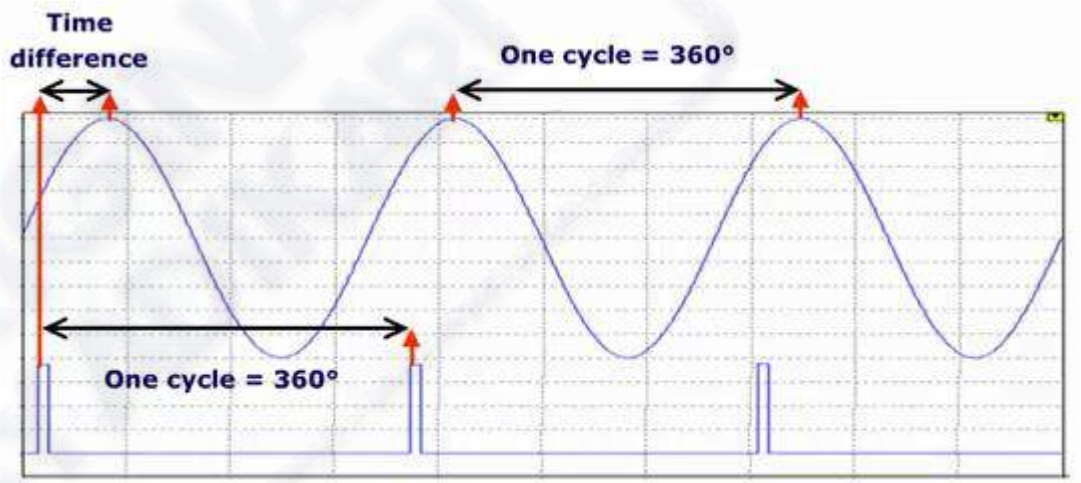


Karakteristik vibrasi

Fasa (bersambung)

- ***Fasa Absolut***

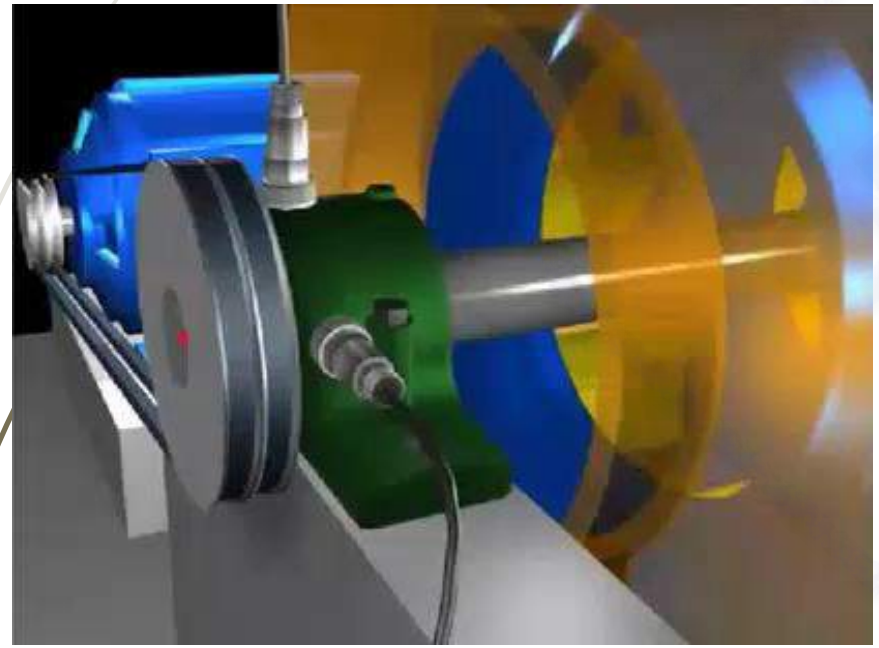


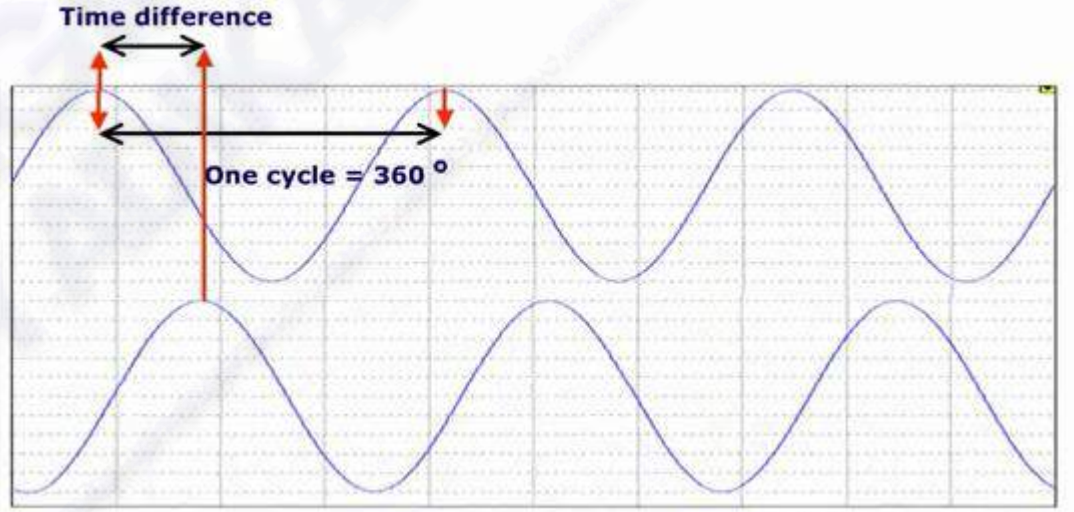


Karakteristik vibrasi

Fasa (bersambung)

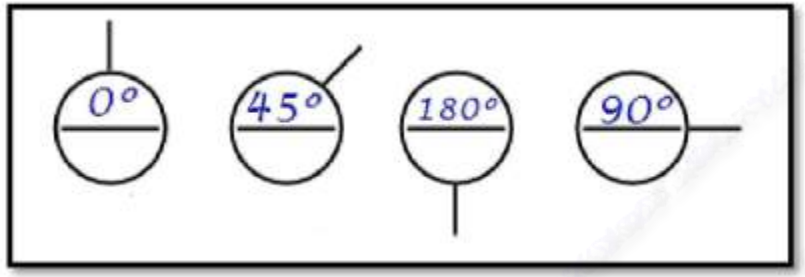
- ***Fasa Relatif***

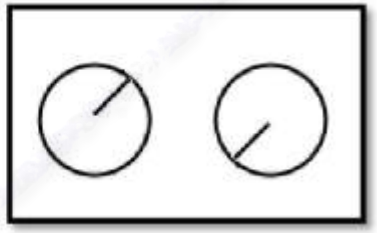




Karakteristik vibrasi

Fasa (bersambung)





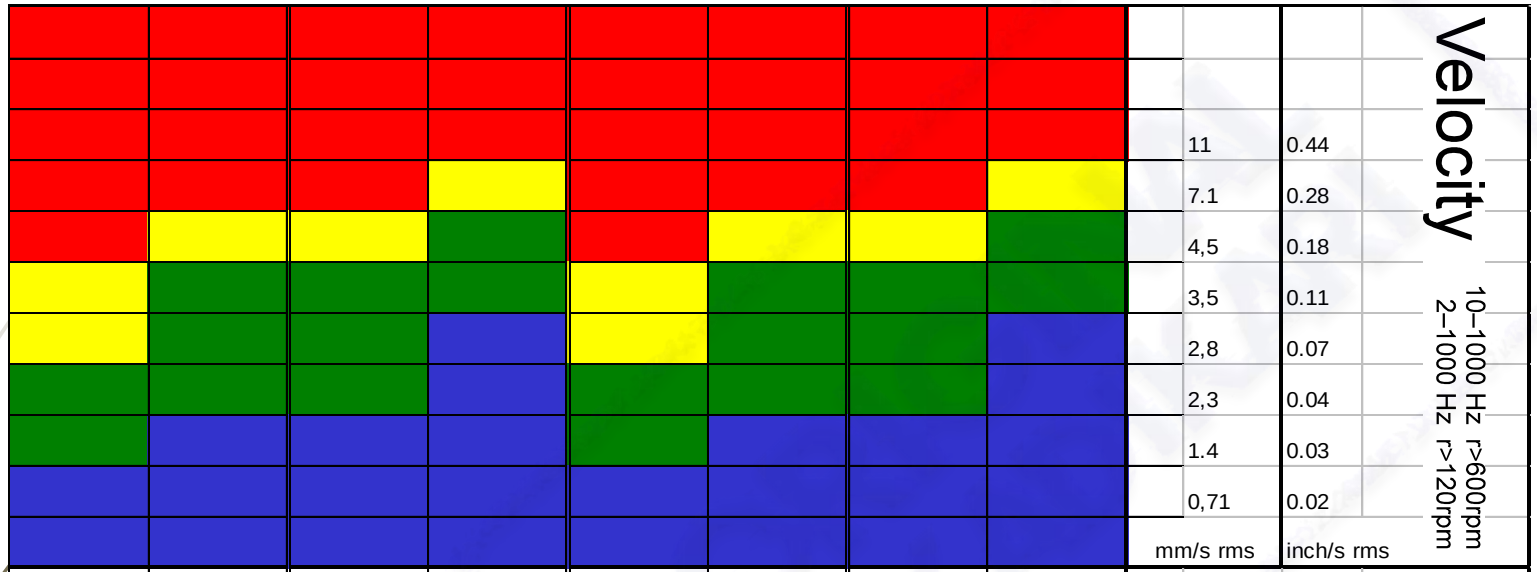
Vibration Fundamentals

How Much Vibration is Too Much ?

1. Use Absolute Vibration Levels
   - Given by machine makers
   - Published Vibration Severity Standards
     eg. ISO 10816

2. Use Relative Vibration Levels

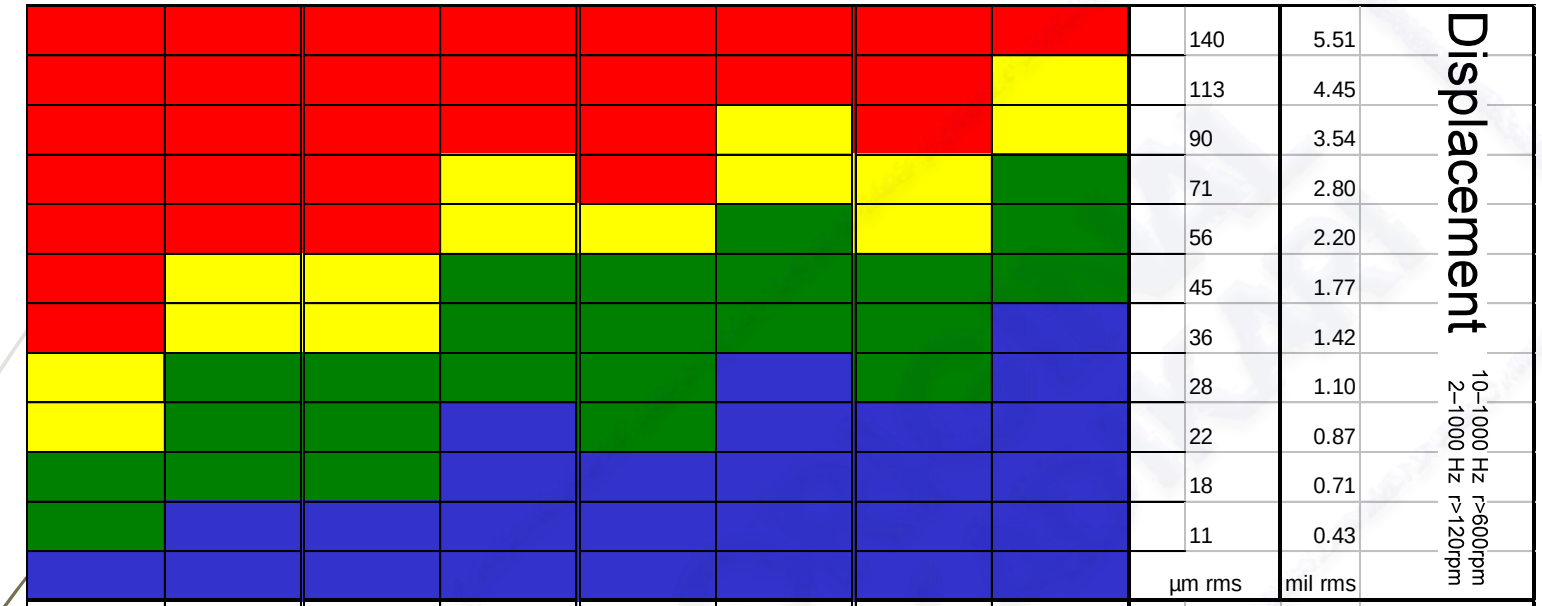
ISO 10816-3



										Velocity	
										10–1000 Hz r>600rpm	
										2–1000 Hz r>120rpm	
								11	0.44		
								7.1	0.28		
								4,5	0.18		
								3,5	0.11		
								2,8	0.07		
								2,3	0.04		
								1.4	0.03		
								0,71	0.02		
								mm/s rms	inch/s rms		
rigid	flexible	rigid	flexible	rigid	flexible	rigid	flexible				**Foundation**
pumps > 15 kW				medium sized machines		large machines					
radial, axial, mixed flow				15 kW < P ≤ 300 kW		300 kW < P < 50 MW					**Machine Type**
integrated driver		external driver		motors		motors					
				160 mm ≤ H < 315 mm		315 mm ≤ H					
Group 4		**Group 3**		**Group 2**		**Group 1**					**Group**

A	newly commissioned
B	unrestricted long-term operation
C	restricted long-term operation
D	vibration causes damage

ISO 10816-3



								140	5.51	Displacement 10–1000 Hz r>600rpm 2–1000 Hz r>120rpm
								113	4.45	
								90	3.54	
								71	2.80	
								56	2.20	
								45	1.77	
								36	1.42	
								28	1.10	
								22	0.87	
								18	0.71	
								11	0.43	
								µm rms	mil rms	
rigid	flexible	rigid	flexible	rigid	flexible	rigid	flexible			**Foundation**
pumps > 15 kW				medium sized machines		large machines				
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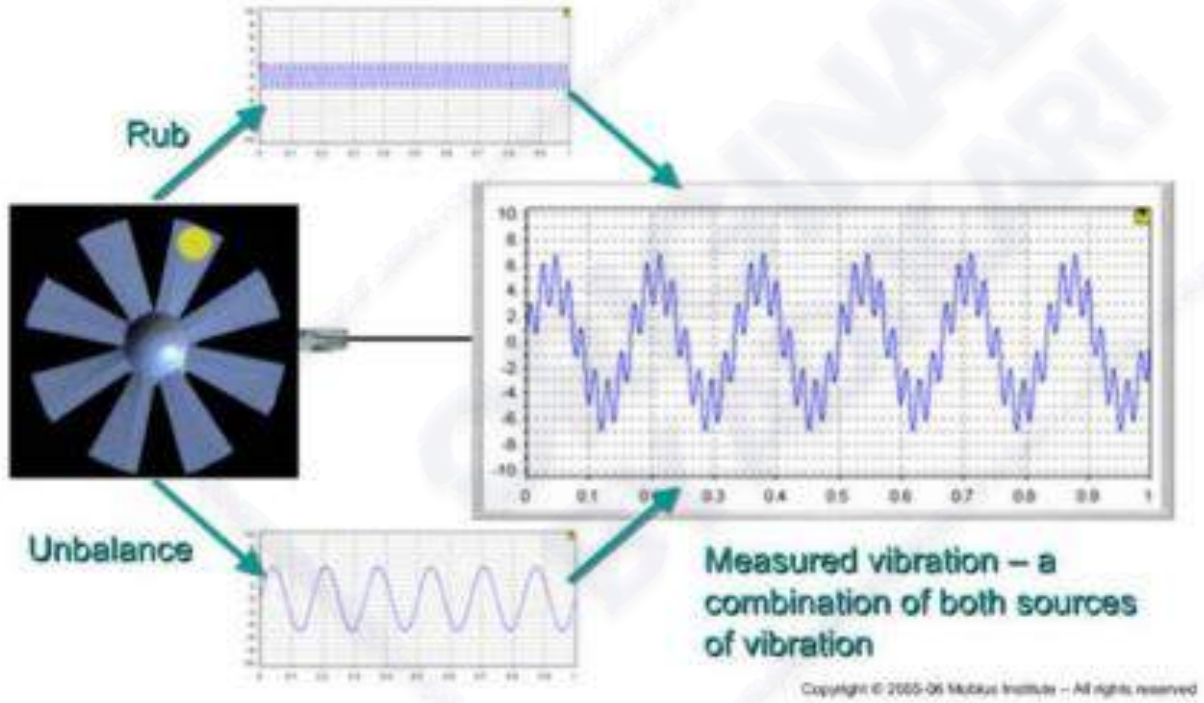
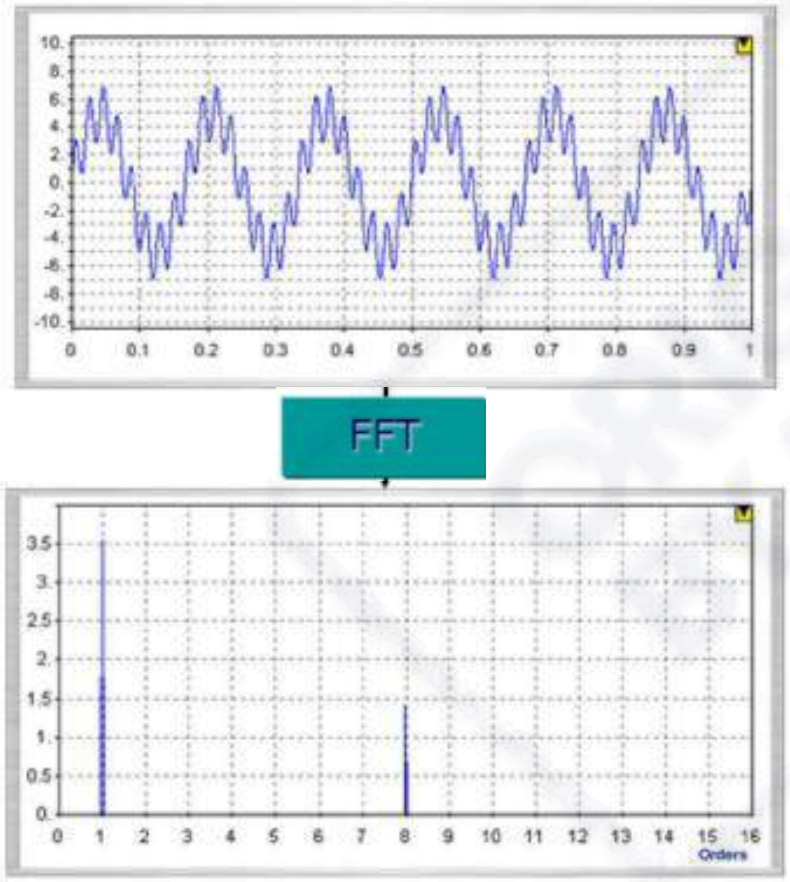
Vibration Fundamental



Vibration Fundamental



Timewaveform

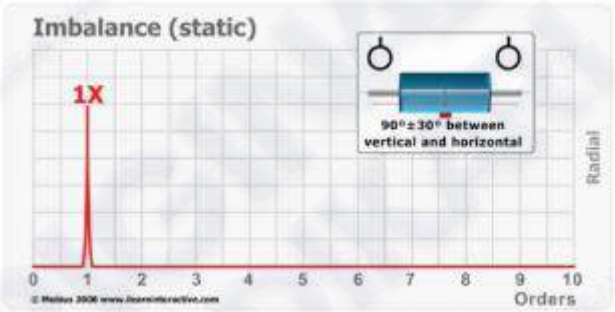
Spectrum

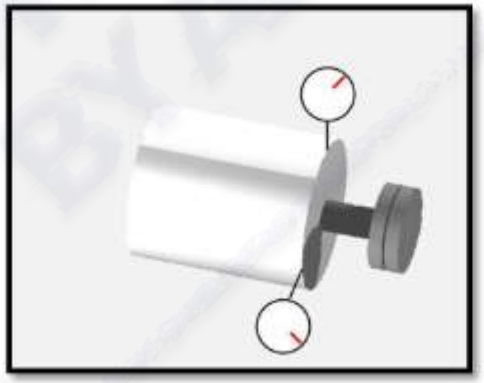
Fault condition vibrasi

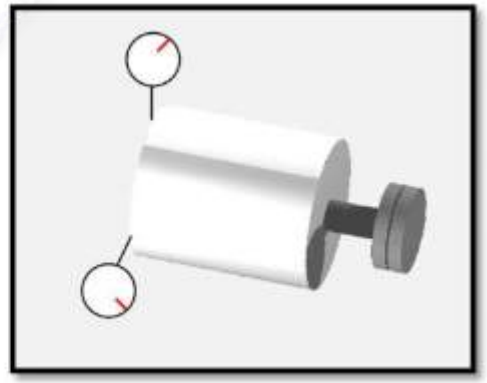
- Unbalance
- Misalignment
- Looseness
- Resonance

Fault condition

- Unbalance

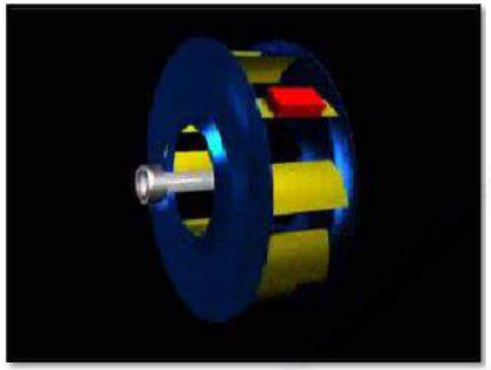


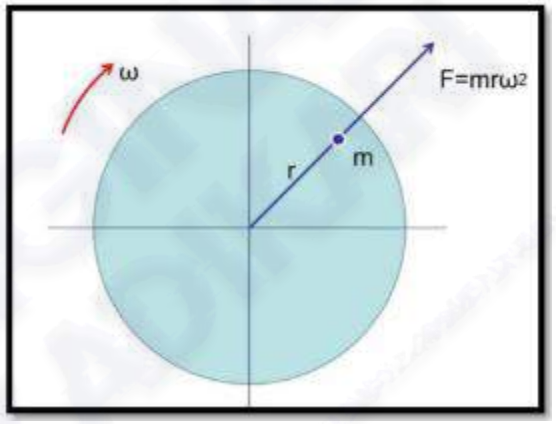




Fault condition

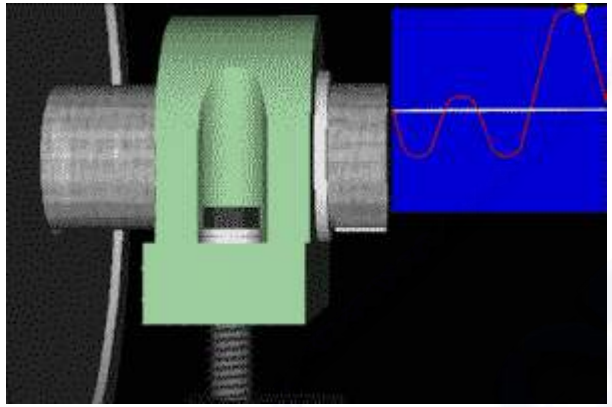
- Unbalance

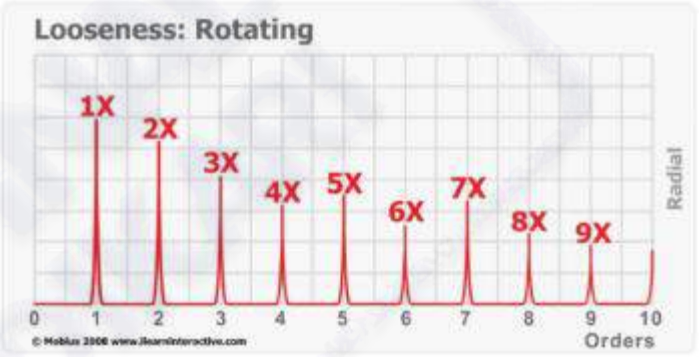


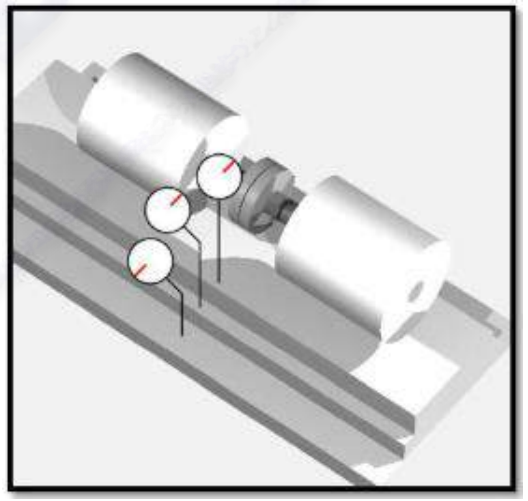


Fault condition

- Looseness

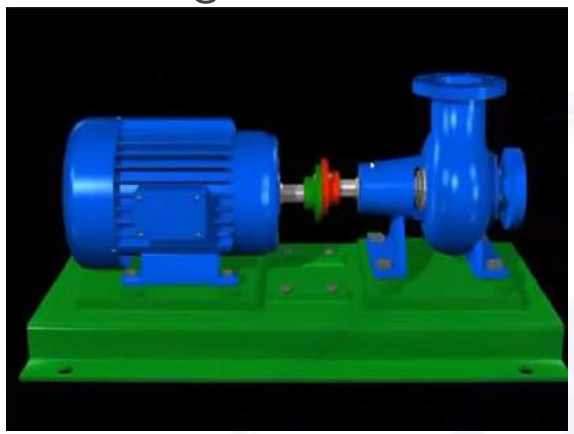


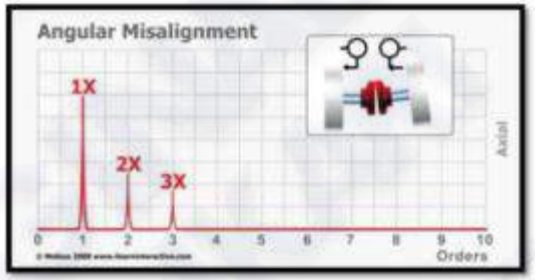


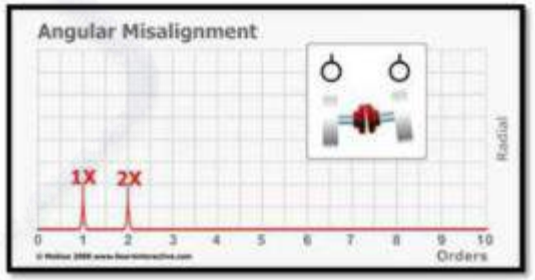


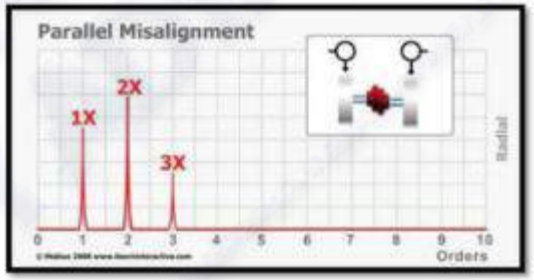
Fault condition

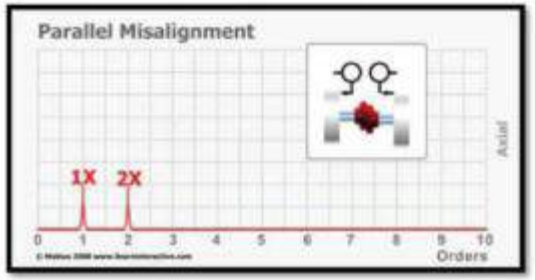
- Misalignment











Fault condition

- Misalignment

Softfoot

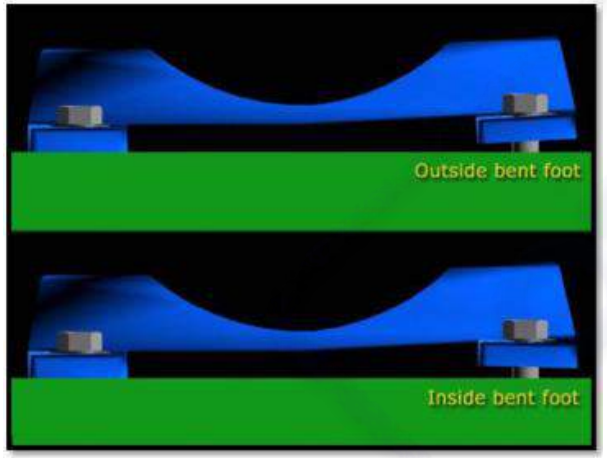
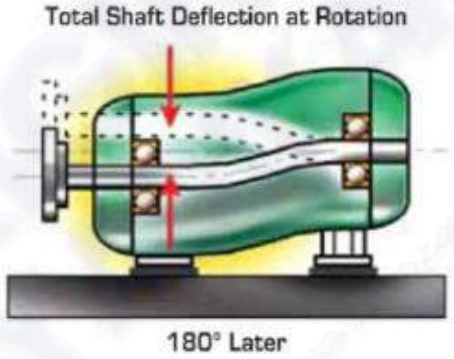


Figure 17-11 Gross soft foot check – obvious gaps under feet



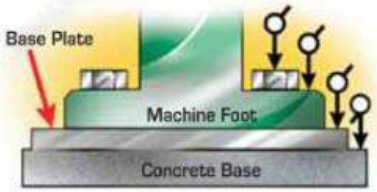


Figure 2. Phase relationship can show differences between vertical measurements on the bolt, machine foot, base plate or base.

Fault condition

- Misalignment

Thermal growth

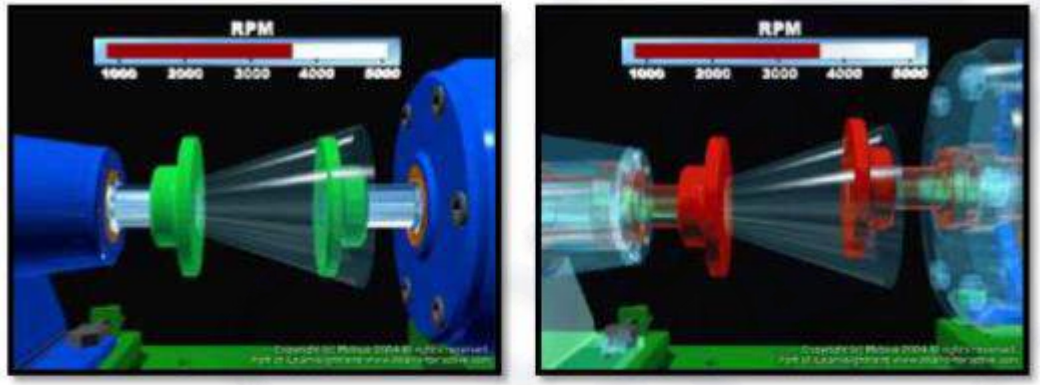


Figure 17-34Misalignment within tolerance when cold (left), but out of alignment when running (right)

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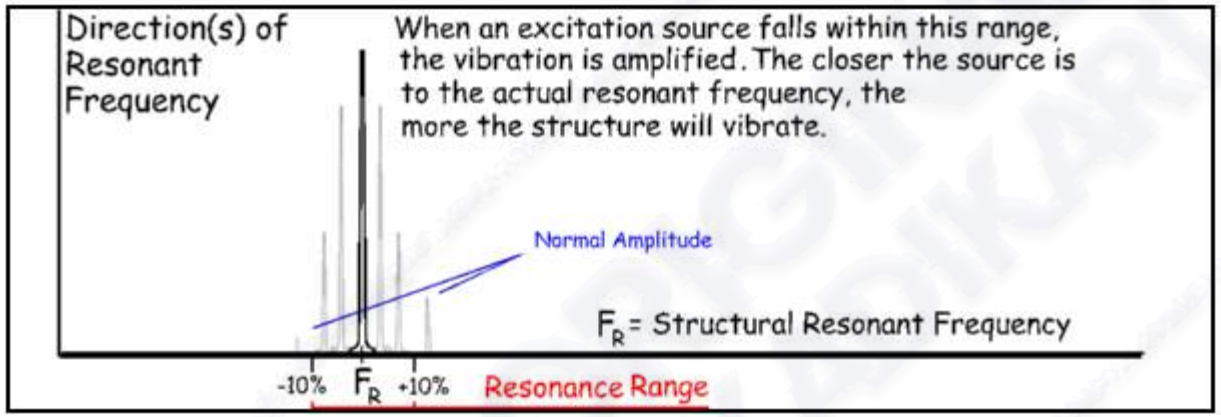
Fault condition

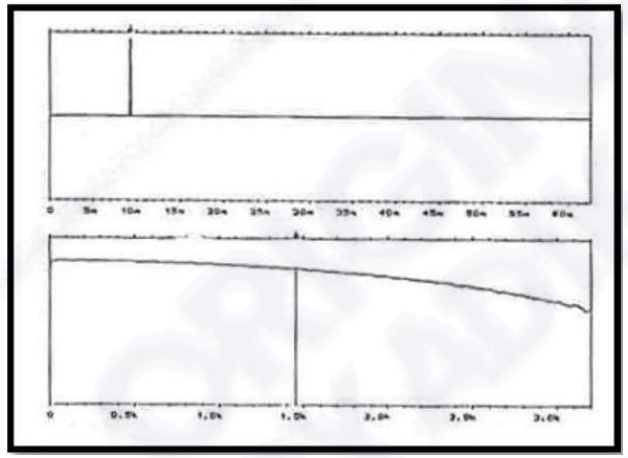
- Resonance



$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Bump test

- Pengujian dengan melakukan bump (pukulan) pada struktur.



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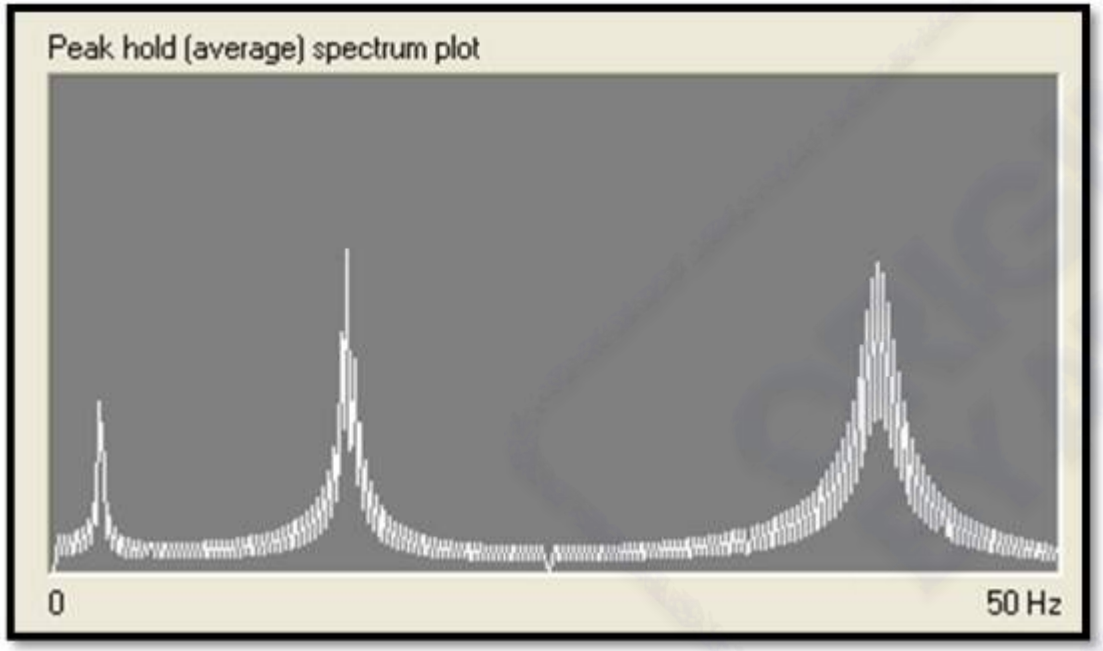
Bump test

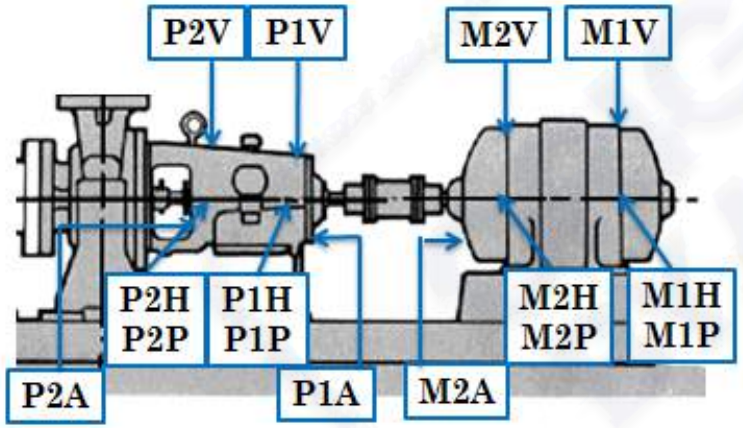
- Spektrum hasil bump test



Bump test

Contoh Kasus

- Pompa A



Contoh Kasus

- Pompa A

Finding

- High 1xrpm vibration on motor horizontal direction

Analisis

- Phase data shows indication softfoot condition

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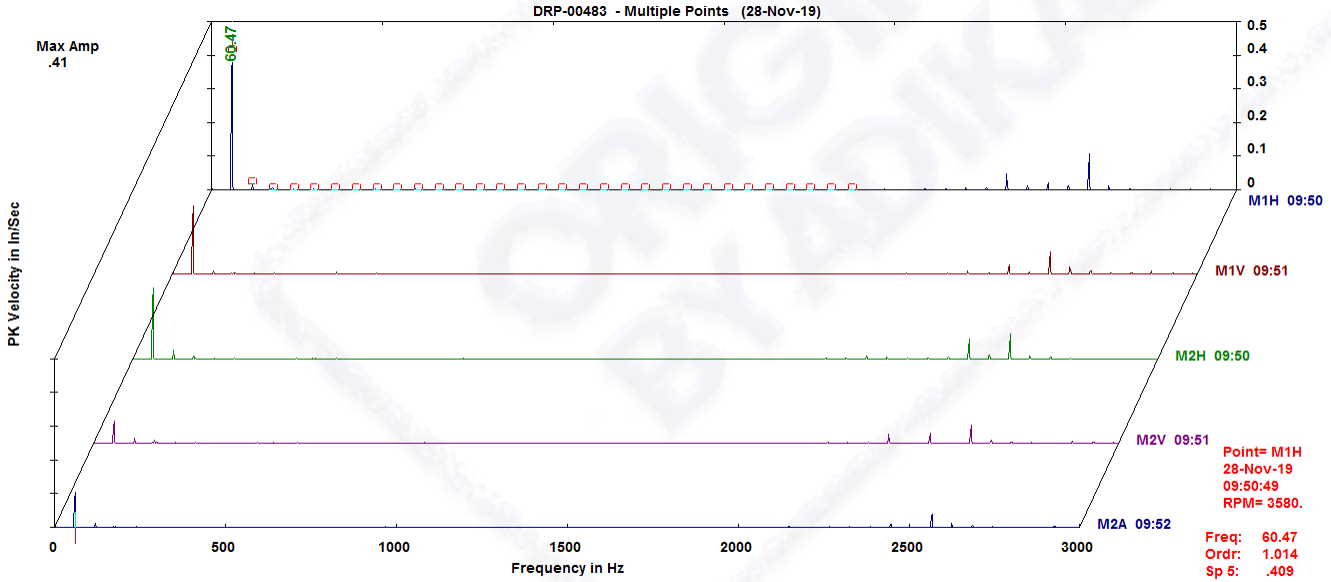
Contoh Kasus

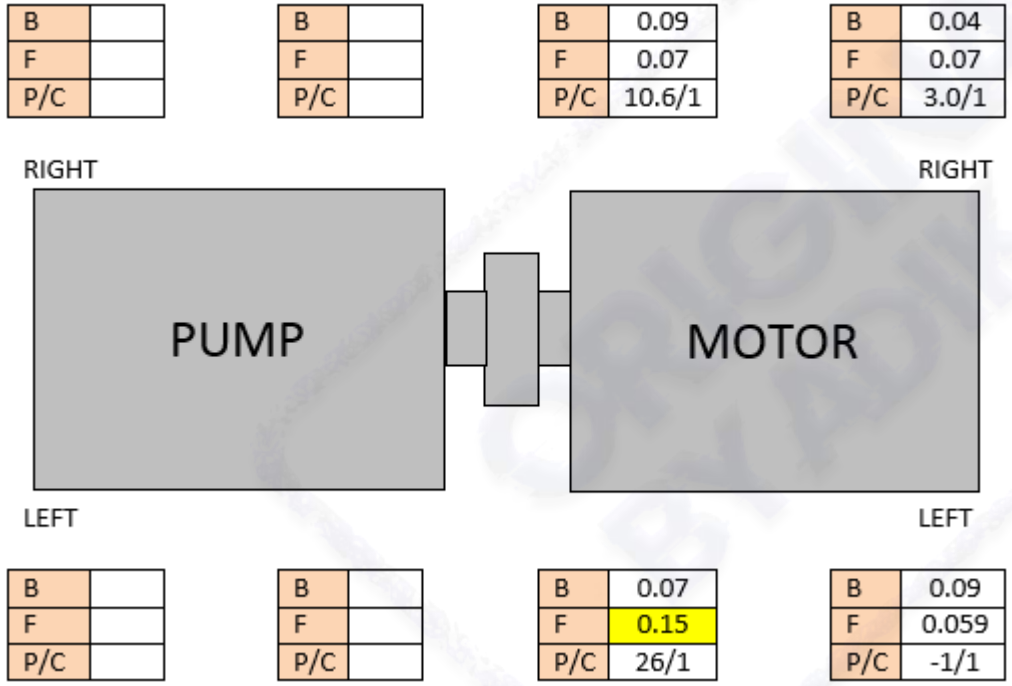
	Vibration Overall (In/sec & G's)															
	Electric Motor							Pump								
Acq. Date	M1H	M1P	M1V	M2H	M2P	M2V	M2A	P1H	P1P	P1V	P1A	P2H	P2P	P2V	P2A
14 Jul 17	0.23	1.55	0.15	0.16	1.19	0.09	0.13	0.05	0.87	0.10		0.05	0.59	0.07	0.07
31 Oct 17	0.09	0.27	0.11	0.12	1.03	0.06	0.08	0.06	0.85	0.09		0.05	0.49	0.08	0.07
05 Mar 18	0.14	0.19	0.08	0.12	1.12	0.07	0.07	0.05	1.03	0.08		0.05	1.03	0.08	0.09
12 Mar 19	0.88	0.31	0.58	0.50	0.67	0.26	0.42	0.09	0.84	0.10		0.07	1.14	0.09	0.08
28 Nov 19	0.60	0.79	0.25	0.33	1.05	0.11	0.16	0.05	0.62	0.09		0.05	0.48	0.08	0.07

Contoh Kasus

Spektrum



Contoh Kasus



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Contoh Kasus

Data setelah koreksi softfoot

	Vibration Overall (In/sec & G's)															
	Electric Motor							Pump								
Acq. Date	M1H	M1P	M1V	M2H	M2P	M2V	M2A	P1H	P1P	P1V	P1A	P2H	P2P	P2V	P2A
14 Jul 17	0.23	1.55	0.15	0.16	1.19	0.09	0.13	0.05	0.87	0.10		0.05	0.59	0.07	0.07
31 Oct 17	0.09	0.27	0.11	0.12	1.03	0.06	0.08	0.06	0.85	0.09		0.05	0.49	0.08	0.07
05 Mar 18	0.14	0.19	0.08	0.12	1.12	0.07	0.07	0.05	1.03	0.08		0.05	1.03	0.08	0.09
12 Mar 19	0.88	0.31	0.58	0.50	0.67	0.26	0.42	0.09	0.84	0.10		0.07	1.14	0.09	0.08
28 Nov 19	0.60	0.79	0.25	0.33	1.05	0.11	0.16	0.05	0.62	0.09		0.05	0.48	0.08	0.07
07 Jan 19	0.17	0.76	0.10	0.15	2.17	0.27	0.15	0.05	0.83	0.07		0.05	0.87	0.07	0.07
12 Mar 20	0.24	0.54	0.16	0.16	0.27	0.14	0.05	0.05	0.74	0.07		0.05	0.95	0.07	0.06

Kesimpulan

- Setiap vibrasi memiliki karakteristik tersendiri
- Beberapa fault condition yang umumnya terjadi dan memiliki symptom hampir sama di antaranya: unbalance, misalignment, looseness, dan resonansi.
- Untuk membedakan fault condition tersebut bisa dilakukan analisis fasa.
- Jika diperlukan, dilakukan analisis lebih lanjut menggunakan "advanced analysis" sebagai data pendukung yang memperkuat hasil analisis sebelumnya

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Sesi kedua

Operating deflection Shape (ODS)

- ODS membantu dalam memvisualisasikan getaran.
- Vibrasi bisa berasal dari unbalan, misalign, resonansi, atau lainnya.
- Mengetahui bagaimana suatu struktur bergetar pada frekuensi tertentu

Dari informasi ini kita bisa menentukan tindakan yang dilakukan untuk mengurangi tingkat getaran

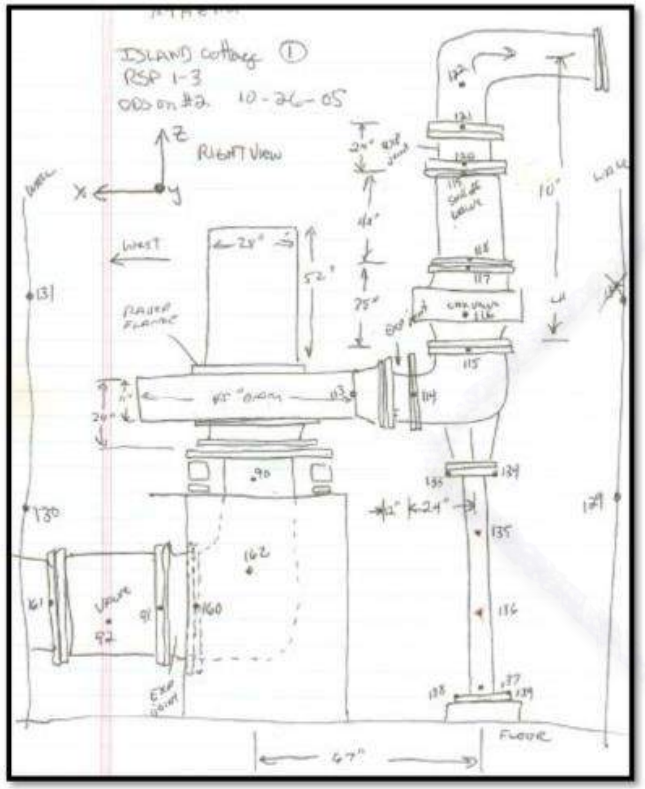
- Balansing atau align equipment
- Mengkakukan atau menambah massa untuk mengganti natural frequency
- Mengubah kondisi operasi mesin

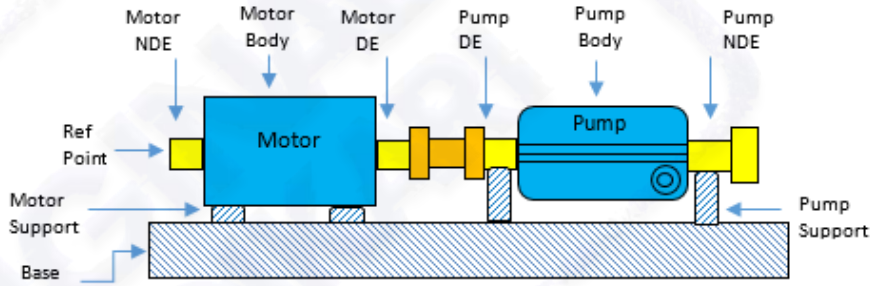
Operating deflection shape

- Plan the job
- Pengambilan data
- Animating the machine
- ME'Scope software

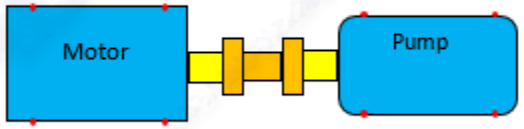
Operating deflection shape

- Plan the job

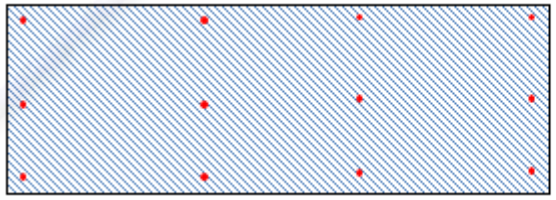




Side View



Top View



Top View

Operating deflection shape

- Pengambilan data

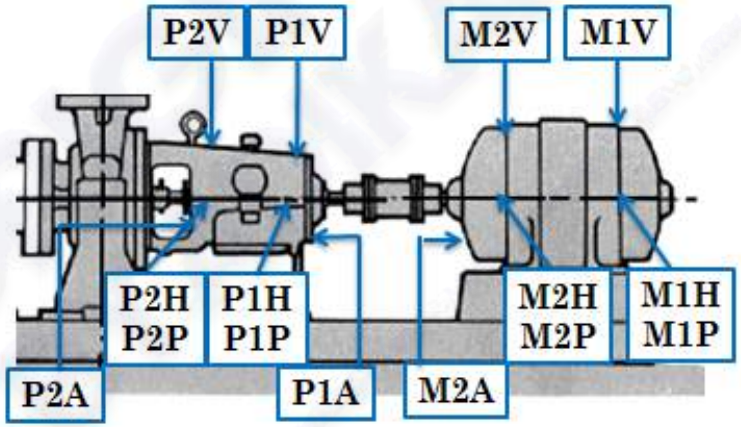
Contoh kasus

- Pompa B

Driver		Driven	
Manufacturer	U.S Motor	Manufacturer	Peerless Pump
Type	Induction	Model	
Rating	100 hp	Type	Centrifugal
Number of Poles	2	Inlet Type	Volute
Number of Phases	3	Pump Support	Centerhung
Rated Voltage	460 Volts	Pumped Liquid	Water
Rated Current	116 amps	Number of Stages	1
Rated RPM	3560	Number of Vanes	5
Line Frequency	60 Hz	Required NPSH	- ft.H_20
Inboard Radial Bearing	Antifriction	Inlet Volume Flow	
Manufacturer Identification	6214E	Inboard Radial bearing	Antifriction
Lubrication Type	Grease	Manufacturer identification	6207
Outboard Radial Bearing	Antifriction	Lubrication Type	Grease
Manufacturer Identification	6214E	Outboard Radial Bearing	Antifriction
Lubrication Type	Grease	Manufacturer identification	7310
Shaft Orientation	Horizontal	Lubrication Type	Grease

Contoh kasus

- Pompa B



Contoh kasus

- Pompa B

- Findings:
  - Premature bearing failure
  - High temperature on pump bearing
  - High 1xrpm pump vibration
  - Suspect: misalignment

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Contoh kasus

- Pompa B

	Vibration Overall (In/sec & G's)														
	Electric Motor							Pump							
Acq. Date	M1H	M1P	M1V	M2H	M2P	M2V	M2A	P1H	P1P	P1V	P1A	P2H	P2P	P2V	P2A
28 Aug 17	0.77	2.10	0.36	0.87	1.17	0.63	0.16	0.92	1.22	1.09		0.63	1.30	0.81	1.06
10 Nov 17	0.10	0.27	0.15	0.23	0.19	0.74	0.62	0.77	0.80	1.53		0.35	0.45	0.70	0.84
26 Mar 18	0.06	0.18	0.07	0.09	0.19	0.10	0.05	0.40	1.35	0.51		0.25	0.68	0.33	0.33
09 Jul 18	0.13	0.19	0.16	0.13	0.27	0.17	0.18	0.57	4.16	0.84		0.39	2.06	0.48	0.43
03 Jan 19	0.18	0.26	0.17	0.18	0.59	0.09	0.09	0.15	1.04	0.23		0.18	4.62	0.15	0.24
27 Mar 19	0.18	0.32	0.18	0.15	0.58	0.11	0.15	0.28	3.14	0.20		0.19	3.19	0.17	0.18
27 Sep 19	0.20	0.33	0.19	0.16	0.52	0.22	0.17	1.42	5.67	1.08		0.39	1.34	0.50	0.54
23 Dec 19	0.15	0.19	0.17	0.18	0.25	0.17	0.26	2.27	4.50			1.18	1.37	1.34	0.95
24 Apr 20	0.13	0.69	0.07	0.14	0.33	0.14	0.16	0.29	1.45	0.49		0.21	1.17	0.21	0.20
18 Jun 20	0.12	1.00	0.09	0.12	0.38	0.14	0.18	0.42	0.72	0.71		0.17	1.26	0.32	0.52

Contoh kasus

- Pompa B

Point Measurement	Amp Ch. A (ips)	Amp Ch. B (ips)	Phase (degree)	Coherence
M1H-M1V	0.112	0.036	-104.9	1
M1H-M2H	0.113	0.1	10.73	1
M1V-M2V	0.04	0.097	-63.4	1
M2H-M2V	0.1	0.09	154.7	1
M2H-P1H	0.1	0.44	-130.4	1
M2V-P1V	0.09	0.69	166.3	1
P1H-P1V	0.38	0.7	93.4	1
P1H-P2H	0.38	0.12	55.9	1
P1V-P2V	0.57	0.3	173.9	1
P2H-P2V	0.1	0.3	-125.0	0.99
M2A-P1A*	0.15	0.44	123.1	1

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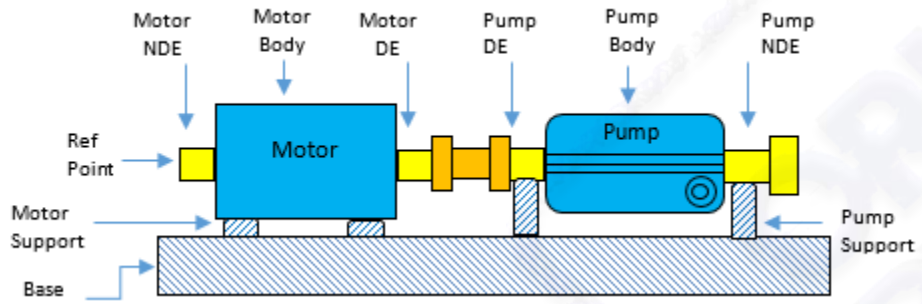
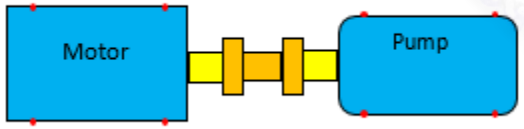
Contoh kasus

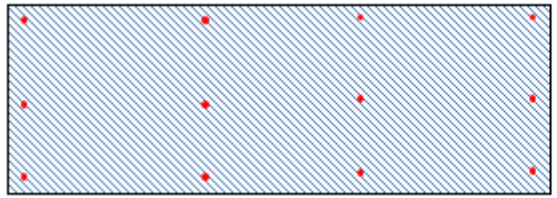
- Pompa B



Side View



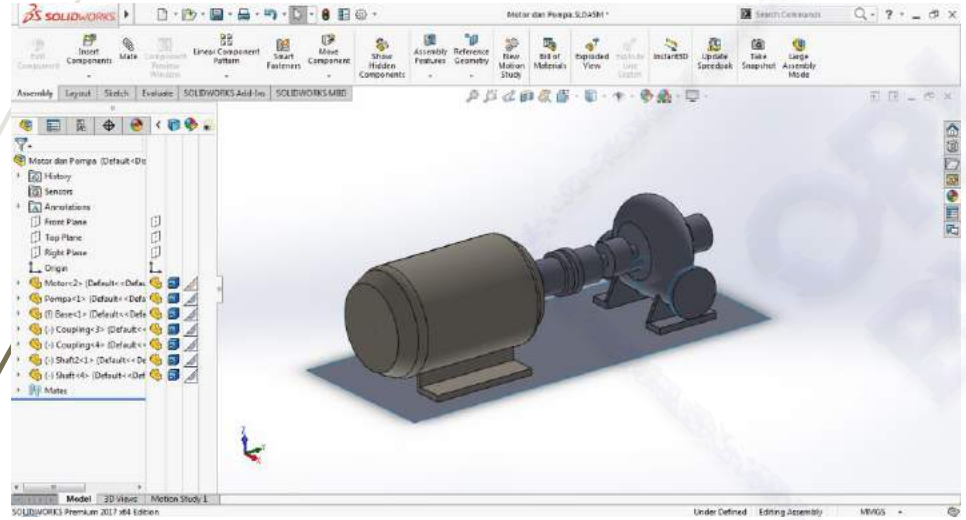
Top View

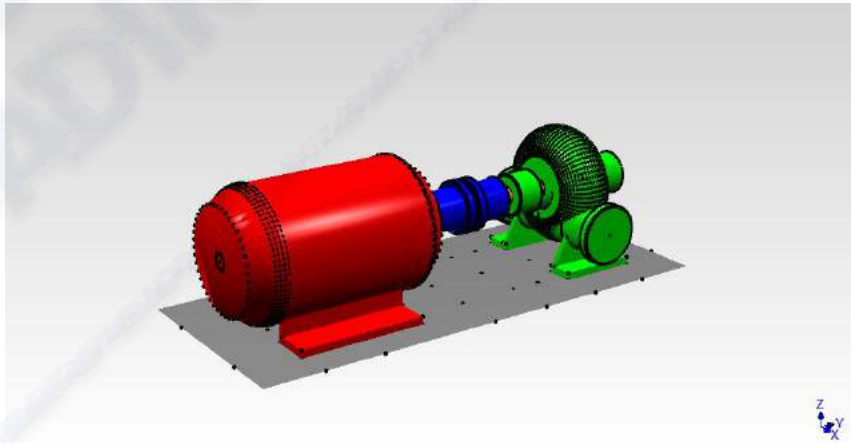


Top View

Contoh kasus

- Pembuatan 3D Model





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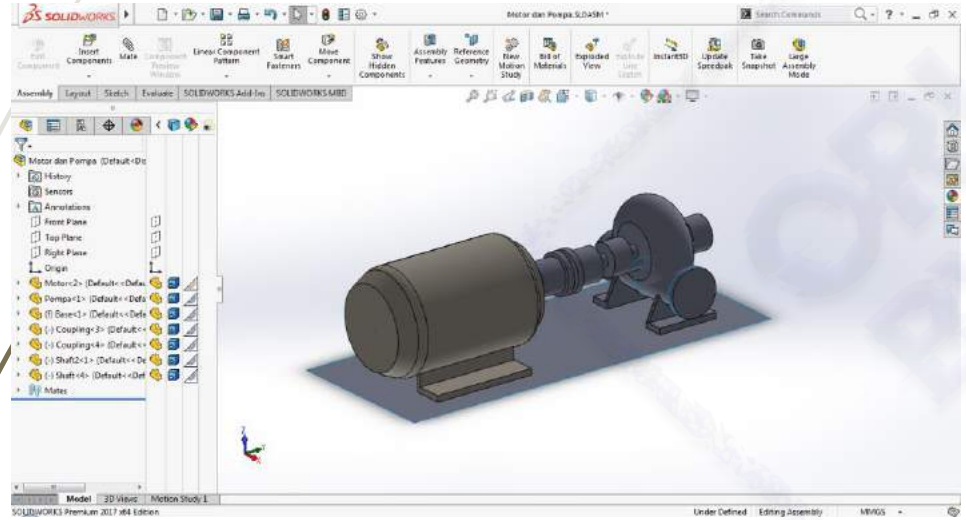
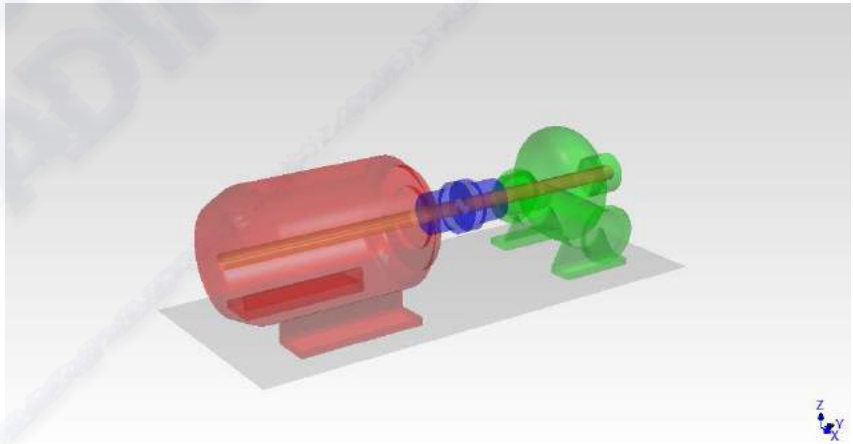
Contoh kasus

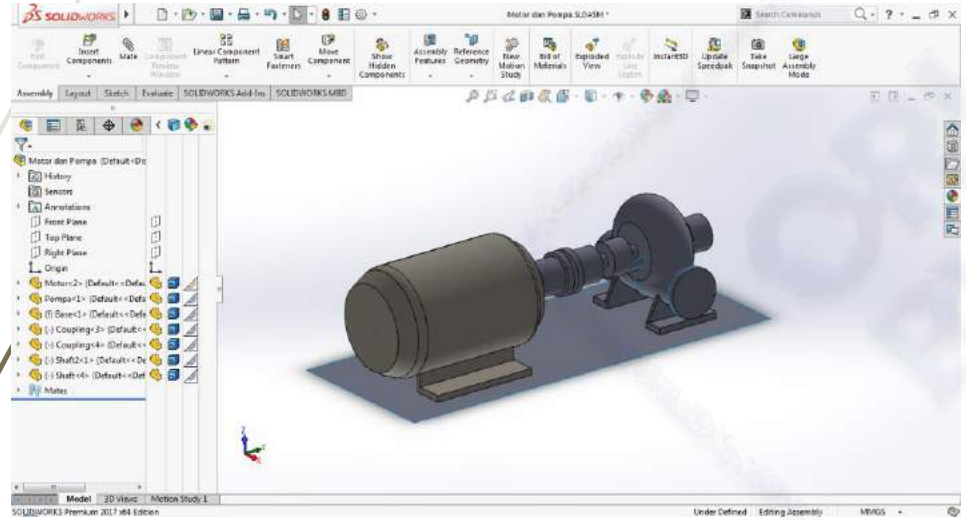
- Pembuatan 3D Model

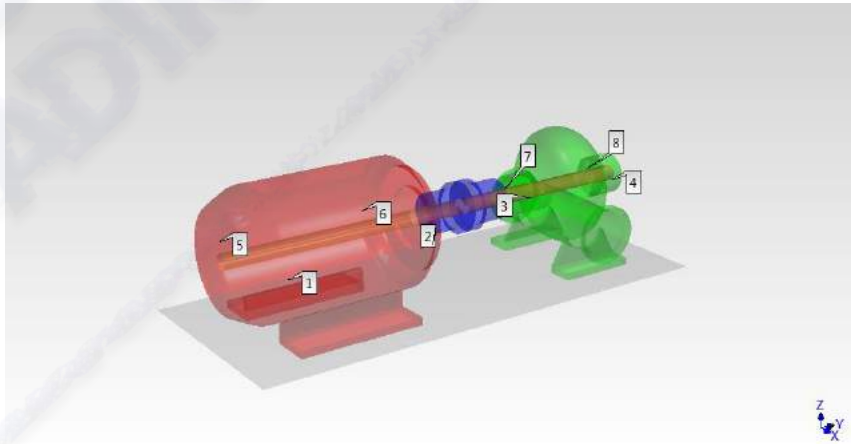




Contoh kasus

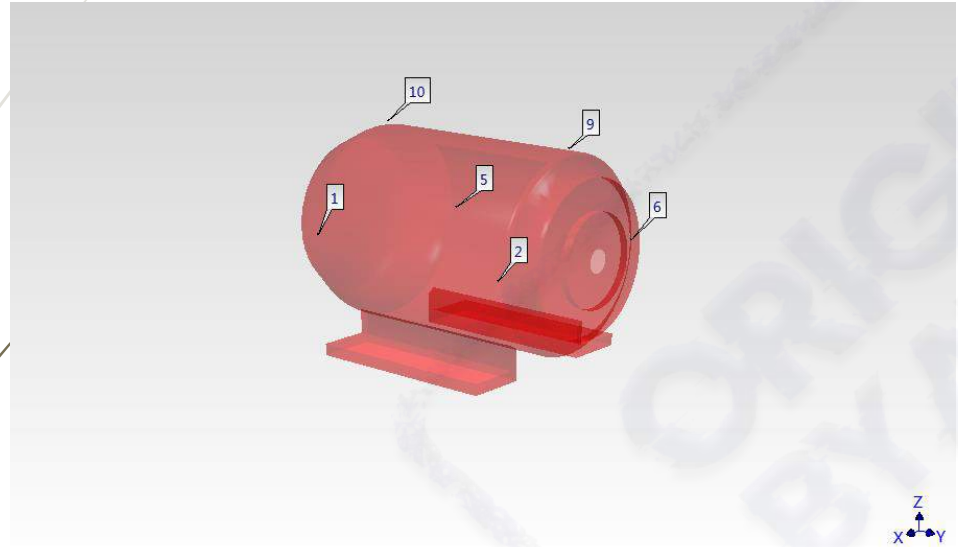
- Pembuatan 3D Model





Contoh kasus

- Menentukan titik

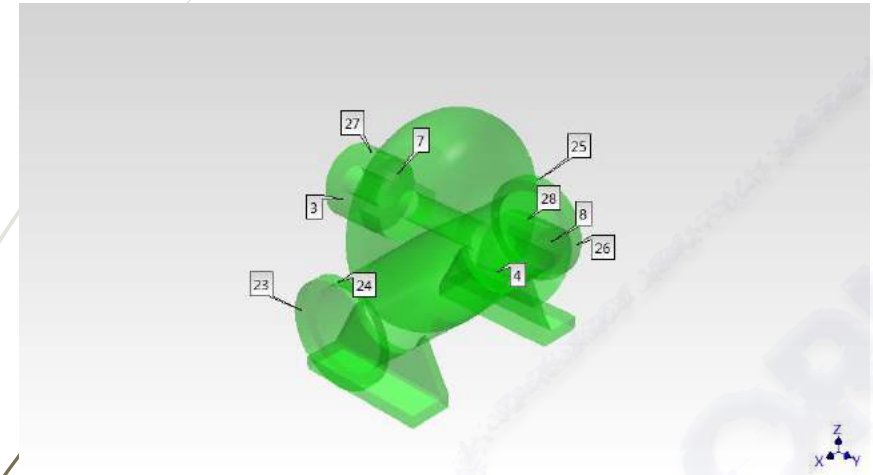


Sensor position based on above points

Motor Non Drive End	1, 5, 10
Motor Drive End	2, 6, 9

Contoh kasus

- Menentukan titik

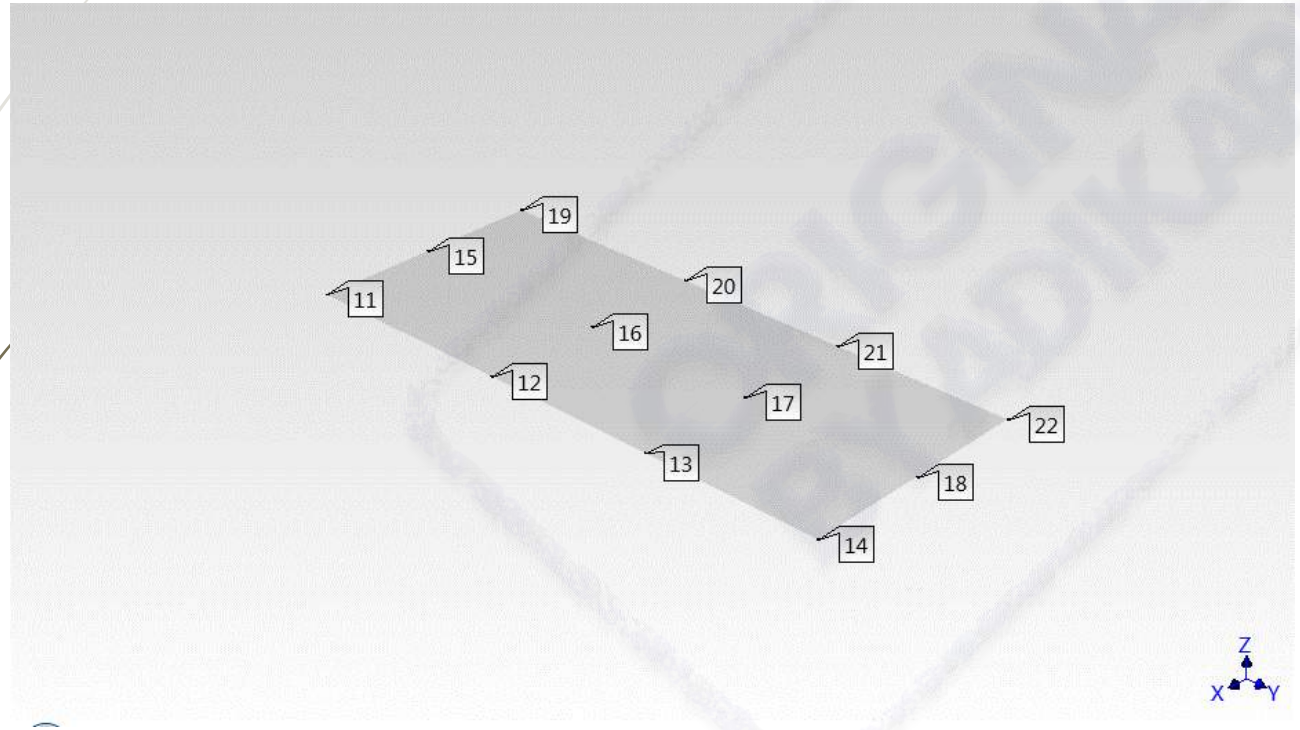


Sensor position based on above points

Pump Drive End	3, 7, 27
Pump Non Drive End	4, 8, 28
Pump Suction Flange	23, 24
Pump Discharge Flange	25, 26

Contoh kasus

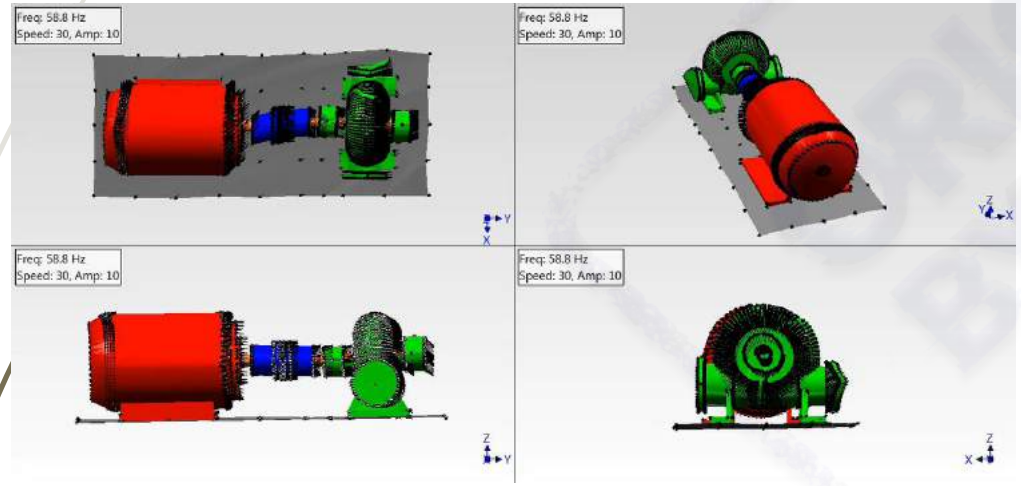
- Menentukan titik

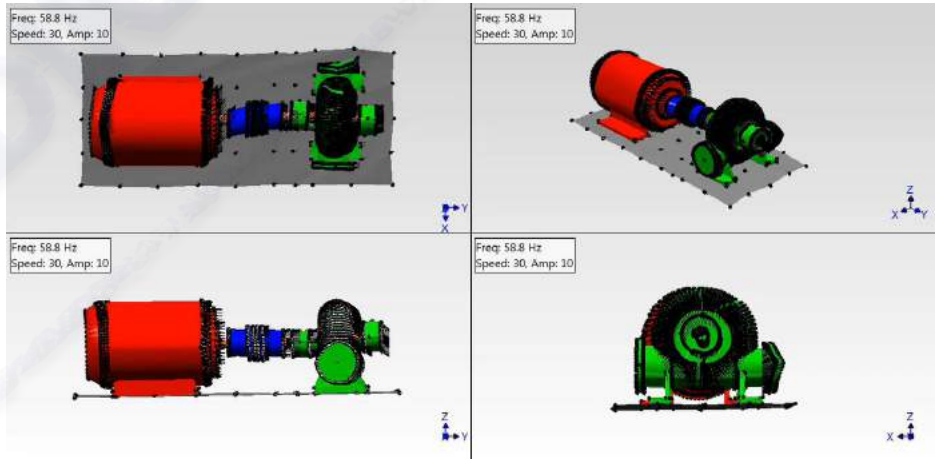


Contoh kasus

- Animasi

Visualisasi vibrasi yang terjadi pada motor dan pompa





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Contoh kasus

Data fasa

Point Measurement	Amplitude	Amplitude	Phase (degree)
M1H-M1V	1.08	0.307	187
M1H-M2H	1.08	1.17	9.27
M1V-M2V	0.307	0.473	144
M2H-M2V	0.307	0.265	61
M2H-P1H	1.17	0.356	173.73
M2V-P1V	0.265	0.59	107
P1H-P1V	0.356	0.59	42
P1H-P2H	0.356	0.905	153.6
P1V-P2V	0.59	1.32	143
P2H-P2V	0.905	1.32	31.4
M2A-P1A	1.42	1.49	1.2

Summary

- Motor dan pompa terkonfirmasi mengalami misalignment
- Kondisi misalignment ini terlihat dari gerakan motor dan pompa dari hasil Operating Deflection Shape
- Adanya termal growth yang menyebabkan kondisi misalignment

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THANK YOU


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