الحل النموذجي

لمادة هندسة وتخطيط الصيانة

الفرقة : الرابعة

قسم : الهندسة الصناعية

الدرجة العظمى للتحريرى: ٩٠ درجة

أستاذ المادة: دكتور/ إسلام هلالي عبد العزيز

العام الجامعى: ٢٠٠٩/٢٠١٠

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رابعة هندسة صناعية – لائحة جديدة

Fayoum Univ. Faculty of Eng	**Maintenance Planning**
Dept. of Industrial Eng.	**Time Allowed: 3hour**
Final Exam	**12/ 6/ 2010**

Assume any missing data

Please attempt all questions. No. of Questions:4 No. of pages: 4

Q1: (30 Marks)

1. Tick (√) or (X) in front of the following:
   1. A vibrometer measures vibration displacement. **(2 Marks)**
   2. Accelerometers can not measure high frequency vibrations. **(2 Marks)**
   3. Vibrometer has relatively a small mass. **(2 Marks)**
   4. An accelerometer has relatively a large mass. **(2 Marks)**
   5. Error in the measured vibration depends on vibration frequency. **(2 Marks)**

2. The line diagram of a pumping system (feed-water pump)is as shown in Fig. 1. Find the possible vibration frequencies for the following machinery faults:-
   1. Unbalance in motor and pump. **(5 Marks)**
   2. Misalignment of motor and gear box shafts **(5 Marks)**
   3. bearing 3 outer race if it is a ball bearing having: **(5 Marks)**
      Number of ball=10, ball diameter =5 mm
      Pitch circle diameter = 50mm, Angle, ß = 0
   4. Bearing 4 problem (journal bearing) **(5 Marks)**

Vibration Trouble Shooting Chart

Nature of fault	Frequency of Dominant Vibration (Hz=rpm/60)
Rotating members out of balance	1 * rpm
Misalignment & Bent shaft	(1 to 2) * rpm
Damaged rolling Elements bearing (ball, roller, etc.)	Impact rates for the individual bearing component. * Vibration at high frequencies (2 to 60 kHz)
Journal bearings loose in housing	(1/2 to 1/3) rpm
Oil film whirl or Whip in Journal bearings	Slightly less than half shaft speed (42 to 48%)
Mechanical looseness	2 * rpm

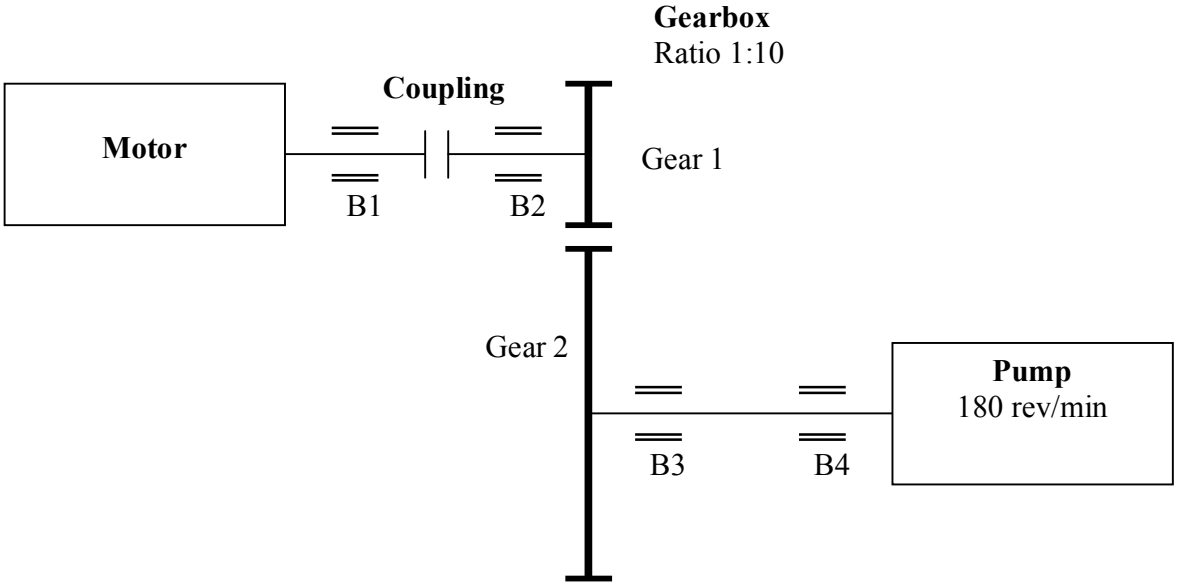


Figure 1

Q2: (20 Marks)

a) Discuss briefly reliability, availability and maintainability (RAM). Then give example. **(4 Marks)**

b) M/s Escorts Limited manufactures a wide range of products like, tractors, cranes, excavators, loaders, motorcycles, piston assemblies, automotive and railway shock absorbers, railway brakes, couplers telecommunication equipment. At one of its plant at Bahadurgarh (Pb) (Escorts Mahle Ltd) the company is engaged in producing TATA 92 - Shim Type Pistons . Using machines namely, KD2, M8, FD1, EA2, for seat machining, Grooving, diamond turning and pin hole boring of piston.

Machines	Failure rate (1/h)	Maintenance time t (h)	MTTR (h)
KD2	0.00611	5.250	2.71
M8	0.00611	1.916	1.29
FD1	0.00574	3.416	3.19
EA2	0.006294	5	1.62

Requirements:

1. The mean-time between failure for each machine (MTBF). **(4 Marks)**
2. Reliability (R) for each machine. **(4 Marks)**
3. Availability for each machine. **(4 Marks)**
4. Maintainability for each machine. **(4 Marks)**

Q3: (20 Marks)

The annual maintenance works report for a maintenance project in chemical process company is as follows:

No.	Description	Type	Year 2008	Year 2009
1	**Maintenance manpower (Man-hours)**	Engineers	16000	15000
		Tech. &Helpers	31000	31000
2	**Actual PM**	No. of W/O	5000	7000
		Man Hours	12000	14000
		Duration (Hrs)	4000	5000
		Back Log	650	600
3	**Actual CM**	No. of W/O	600	800
		Man Hours	5000	6000
		Duration (Hrs)	500	3000
		Back Log	50	70
4	**Total cost (1000 LE)**	Planned	3500	3500
		Actual	4200	4500
5	**Revenue (1000 LE)**	Planned	5000	5000
		Actual	6000	7000

Based on these data, determine the different performance evaluation indicators for this project.

Q4: (20 Marks)

Overall vibration levels for dryer equipment (large machine with rigid and heavy foundation) in sulphide factory according ISO standard 10816 are as follows:-

Point name	Vibration Measurements	Units
Point1	6.299	mm/s
Point2	12.373	mm/s
Point3	15.407	mm/s
Point4	7.15	mm/s
Point5	5.71	mm/s
Point6	11.481	mm/s
Point7	10.717	mm/s
Point8	3.268	mm/s
Point9	11.59	mm/s
Point10	8.369	mm/s
Point11	6.77	mm/s
Point12	5.504	mm/s

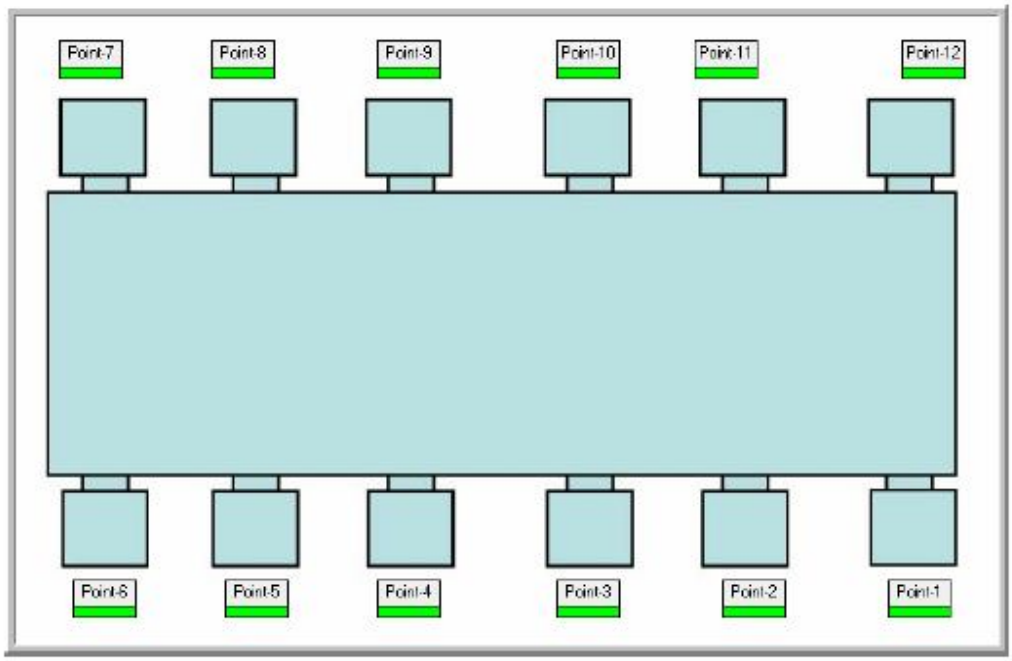
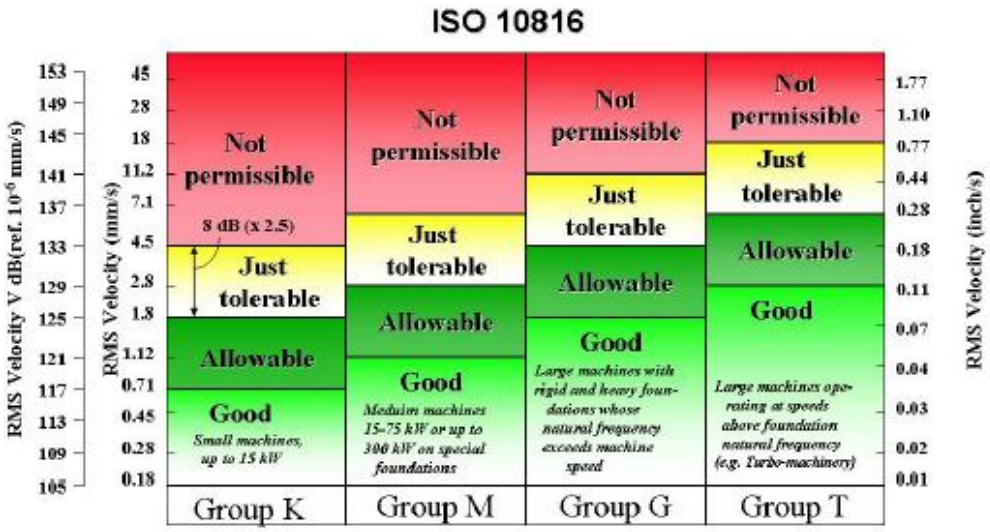


Fig. 2



Based on these data , discuses the fault detection & diagnosis for dryer machine made by vibration analysis.

Good Luck
Dr. Islam H.

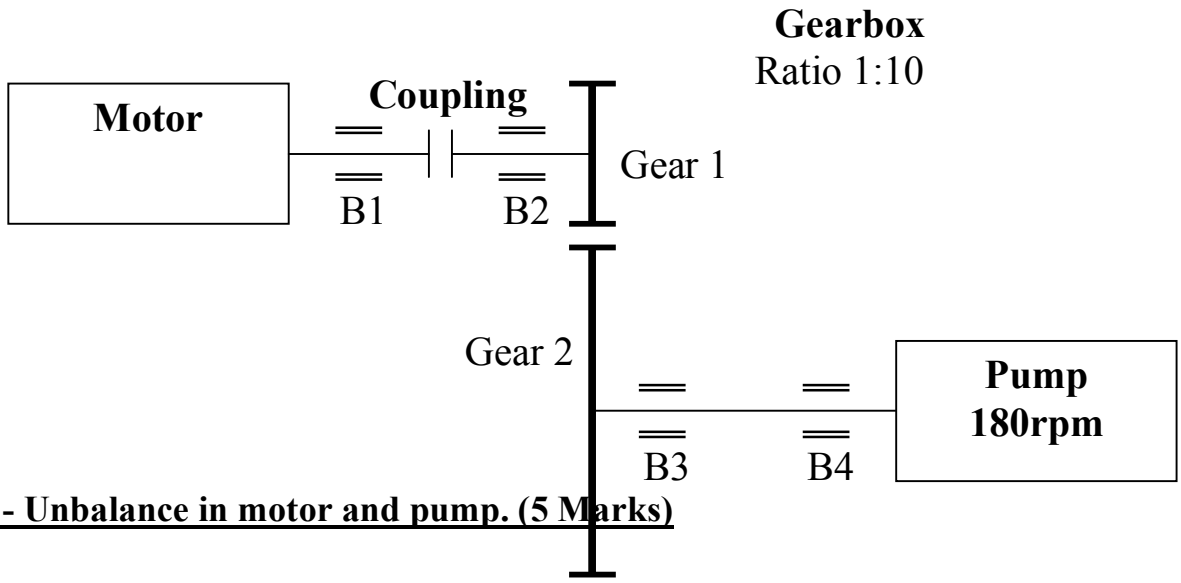
Model Answer

Q1: (30 Marks)

a)

1. A vibrometer measures vibration displacement. (√) **(2 Marks)**
2. Accelerometers can not measure high frequency vibrations. (X) **(2 Marks)**
3. Vibrometer has relatively a small mass.(X) **(2 Marks)**
4. An accelerometer has relatively a large mass. **(X)** **(2 Marks)**
5. Error in the measured vibration depends on vibration frequency. (√) **(2 Marks)**

b)



1- Unbalance in motor and pump. (5 Marks)

Pump 180 rpm, Gearbox Ratio 1:10

N1 = ? N2= 180 Z1/Z2 = 10/1

Speed ratio = N1 / N2 = Z1 / Z2

N1/180 = 10 / 1 N1= 180 rpm

From fault diagnosis table,

The frequency of vibration due to unbalance in motor

= 1 * rpm = 1800 rpm = 1800/60 = 30 Hz

The frequency of vibration due to unbalance in pump

= 1 * rpm = 180 rpm = 180/60 = 3 Hz

2- Misalignment of motor and gear shafts. (5Marks)

The frequency misalignment of motor:

= (1 to 2) * rpm = (1 to 2) * 1800 rpm

From (30 to 60) Hz

The frequency misalignment of gear shifts:

= (1 to 2) * rpm = (1 to 2) * 180 rpm

From (3 to 6) Hz.

3- Bearing 3 outer race: (5 Marks)

if it is a ball bearing having

n = number of balls 10,

Bd = ball diameter 5 mm,

Pd = Pitch circle diameter 50 mm,

β= Angle =0.

The frequency of vibration due to outer race defect:

= (n/2) (rpm/60) (1 – (Bd/Pd) cos β

= (10/2) (180/60) (1 – (5/50) cos 0

= 5 * 3 * 0.9 = 13.5 Hz

4- Bearing 4 problems (journal bearing). (5 Marks)

The frequency of vibration due to journal bearing loose in housing:

= (1/2 to 1/3) rpm

rpm: rev/min of pump shaft = 180

The frequency of vibration due to journal bearing loose in housing:

= (1/2 to 1/3) 180/60 = (1.5 to 1) Hz

Oil film whirl or whip in Journal bearings: Slightly less than half shaft speed (42 to 48%)

(0.42 to 0.48) 180/60 = (1.26 to 1.44) Hz

Q2 (20 Marks)

a) Reliability is a measure of *the probability for failure-free operation* during a given interval, i.e., it is a measure of success for a failure free operation. It is often expressed as **(2 Marks)**

$R(t) = \exp(-t/MTBF) = \exp(-\lambda t)$

Maintainability deals with duration of maintenance outages or *how long* it takes to complete (ease and speed) maintenance actions compared to a datum.

$M(t) = 1 - \exp(-t/MTTR)$ **(1 Marks)**

Availability deals with the duration of available time for operations and is a measure of how often the system is available and well.

A = (Total time – Total downtime) / Total time **(1 Marks)**

b) **(16 Marks)**

Machines	Failure Rate (1/h)	Maintenance Time t (h)	MTTR (h)	MTBF %	R %	A %	Maint. %
KD2	0.00611	5.250	2.71	163.63	88.98	98.36	56.4
M8	0.00611	1.916	1.29	163.63	95.7	99.21	52.1
FD1	0.00574	3.416	3.19	174.19	96	98.2	52.3
EA2	0.006294	5	1.62	158.82	95.6	98.9	53.7

Q3: (20Marks)

Performance evaluation for maintenance projects:

KPI	Type	2008	2009	PE
1- CM / PM	No. of W/O	12 %	11.43 %	
	Man-hours	41.7%	42.8%	
	Duration	12.5%	60%	
	Overall (10-20%)	6.255 %	29.3%	
2- Utilization	(50-60%)	36.2%	43.5%	
3- Quality Rate	(80-90%)	89.3%	89.7%	
4- Reliability	(80-90 %)	70.6%	70%	
5- OCE	(30- 40%)	22.8%	27%	
6- Performance Rate (L.E / man-hour)	Planned	294	250	
	Actual	353	350	

- CM/PM Overall =

  (No of WO ratio + man-hours ratio + Duration ratio)/3

- Utilization =

  Total Work orders man-hours / Total Available man-hours

- PM Quality Rate = PM efficiency

  (No of PM) / (No of PM + No of CM)

- PM Reliability =

  (PM man-hours) / (PM man-hours + CM man-hours)

- Overall Craft Effectiveness =

  Utilization X Quality Rate X Reliability

- Performance rate =

  Revenue / total man-hours.

Q4: (20 Marks)

Point name	Vibration Measurements Mm/s	Analysis	Action
Point1	6.299	Just tolerance	Call of service
Point2	12.373	Not permissible (Dangerous vibration values - damage could occur)	Shut down and corrective action
Point3	15.407	Not permissible (Dangerous vibration values - damage could occur)	Shut down and corrective action

Point4	**7.15**	**Just tolerance**	**Call of service**
Point5	**5.71**	**Just tolerance**	**Call of service**
Point6	**11.481**	**Not permissible (Dangerous vibration values - damage could occur)**	**Shut down and corrective action**
Point7	**10.717**	**Just tolerance**	**Call of service**
Point8	**3.268**	**Allowable**	**Steady state**
Point9	**11.59**	**Not permissible (Dangerous vibration values - damage could occur)**	**Shut down and corrective action**
Point10	**8.369**	**Just tolerance**	**Call of service**
Point11	**6.77**	**Just tolerance**	**Call of service**
Point12	**5.504**	**Just tolerance**	**Call of service**

Recommendation:

1. Shutdown for the dryer machine>
2. Check list inspection for the dryer machine>
3. RCFA for the dryer machine
4. Corrective Action.