Multidisciplinary Capstone Design: VIA Dynamic Load Simulation On A Journal Bearing Test Rig

In 2010, Dresser-Rand, a global supplier of rotating equipment, donated ESH-1 reciprocating compressor to the Rochester Institute of Technology and has continually sponsored multidisciplinary senior design (MSD) projects. Dr. Jason Kolodziej, Assistant Professor of Mechanical Engineering at Rochester Institute of Technology, commissioned the construction of a dynamic journal bearing similarity test rig. The objective of this rig is to reduce the time required to perform seed of fault research of journal bearings. The project was split into a two phase build utilizing two consecutive multidisciplinary senior design teams. While the similarity test rig will assist Dr. Kolodziej and future graduate students with research at RIT, it also served as a "real world" design and development project for 10 soon-to-be engineers.

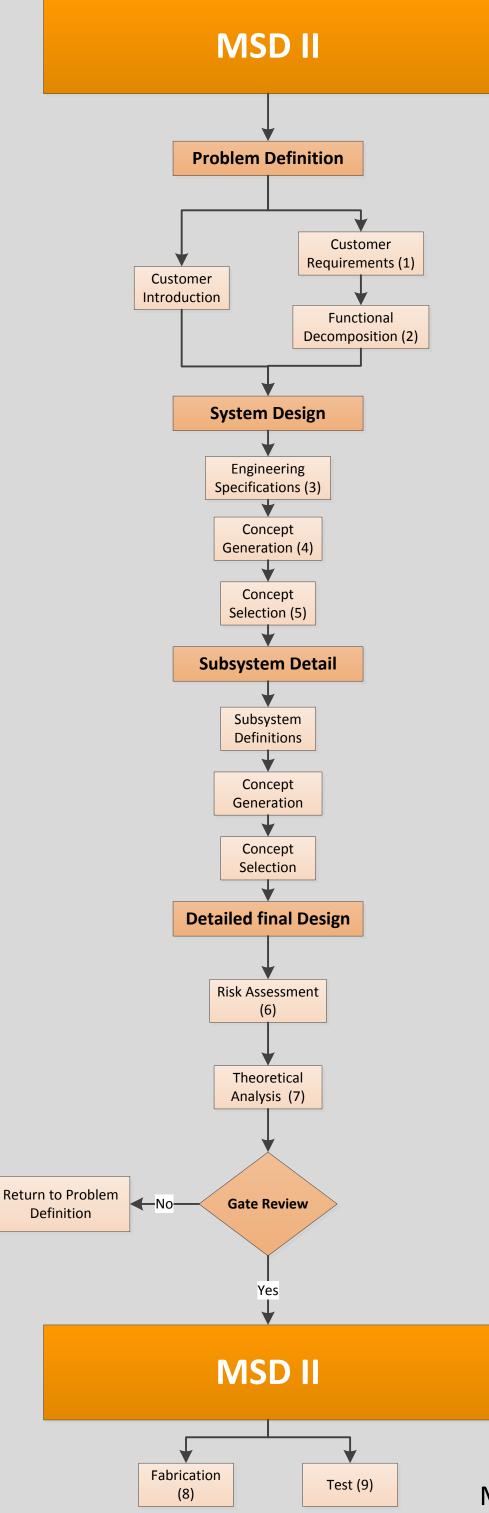
Course Structure:

- Required for all engineering seniors
- Team-Based, Capstone Design Experience
- Two Semester Breakdown 30 Weeks
- MSD I focus Design phase
- MSD II Implementation, build & Test

Concept Selection (5)

Pugh charts assist in team based concept selection, by measuring how well each option meets requirements

Criteria #	Selection Criteria	Cam Concept 1	Cam Concept 2	Electro Hydraulic	Piezo and Spring	Pneumatic 1	Pneumatic 2	Electric Linear 1	Electric Linear 2	Piezo Electric 1	Piezo Electric 2	Piezo Electric 3
1	Applied Load Achievable T=0 [X]	-	-		S	-	-	S	S	S	-	S
2	Applied Load Achievable T=0 [Y]	S	S	1	S	S	S	S	S	S	-	S
3	Applied Load Achievable at T=Life [X]	-	-	DATUM	S	-	-	S	S	S	-	S
4	Applied Load Achievable at T=Life [Y]	-	-	DATUM	S	S	S	S	S	S	-	S
5	Response Time	+	+	1	+	S	S	+	+	S	+	+
6	Adaptability to Current System	+	-	1	-	+	+	S	S	+	+	-
7	Cost	+	+	~\$2000	-	S	S	S	S	-	-	-
8	Estimated Life of System	-	-		S	+	+	S	S	+	+	+
8	Acoustic Noice Level	S	S		S	-	-	+	+	+	+	+
10	Deplecebility of Maine Components	+	+	1		\$	\$	\$	S	_		



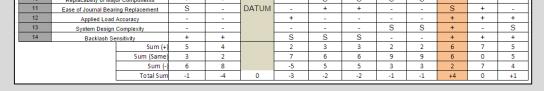
Customer Needs (1)

The key requirements the customer expects from the finished product

	P1545	3 Custo	omer Requirements				
Revision Letter: •							
Туре	Cust. Rqmt. #	Importance	Description				
Cost	CR 1.1	9	Fits within budget				
	CR 2.1	9	Replicates load profile of ESH-1 Compressor				
	CR 2.2	9	Rapid Bearing replacment				
	CR 2.3	9	Measures Load				
	CR 2.4	9	Measures Oil Return Temperature				
	CR 2.5	9	Measures Bearing Temperature				
Functionality Properties	CR 2.6	9	Measures Oil Pan Temperature				
riopenies	CR 2.7	9	Measures Vibration				
	CR 2.8	3	Measure Gap Between Journal & Sleeve				
	CR 2.9	3	Modify Oil Flow Rate In/Out Measurment				
	CR 2.10	3	Able to isolate bearing vibration from oil system vibration				
	CR 2.11	1	Measures Bearing Wear				
	CR 3.1	9	Guarded Rotating Assembly				
Safety	CR 3.2	9	Add E-Stop				
	CR 3.3	3	Low noise				
Lieshility	CR 4.1	9	Records test data				
Usability	CR 4.2	9	Compatible with existing DAQ equipment				

Functional Decomposition (2)

Small ,easily definable steps, taken to achieve



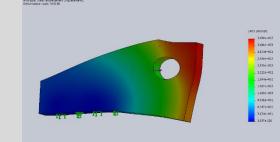
Risk Assessment (6)

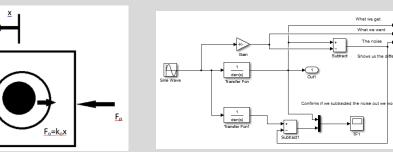
Measure the likelihood and severity of the risks associated with the chosen design

Risk #	Risk Item	Effects	Cause	Reason	Likelihood	Severity	Importance	Action to minimize	Statistic
1	False Brinnelling	Screw components wear prematurely	а	Forgetting to maintain cycle count	1	9	9	Schedule cycling based on use schedule	Analytica
			b	Low initial lubrication	1	9	9	Inspect upon receival	Analytica
2	2 Over Heat actuator Actuator will shut down during testing		а	Ran too long	3	3	9	Do not exceed 18 minutes run time	Analytica
			b	torque used exceeds allowable	1	3	3	Do not exceed 2000lb force	Analytica
3	Backlash Noticable	Incorrect load profile	а	EMA is not preloaded	3	3	9	Design can function with preload	Analytica
4	4 Exceed Budget Not able to purchase optimal components		а	change in pricing between estimates and purchasing	1	9	9	Keep in contact with suppliers	Arbitrary
			ь	Displacement required is larger than expected	1	1	1	Accurate Prediction of worse case scenario	Analytica
5	Adaptability Issues	Extra foturing required	а	Fixturing required is larger than space available	1	3	3	Optimize Fixturing Design	Analytica
6	Spring Failure	No longer can perform load actuation	а	Spring fixture failure	1	9	9	Optimize Fixturing Design	Arbitrary
			b	Spring has defect	1	9	9	Inspect spring on reception	Arbitrary
			с	Spring surpases life limit	1	9	9	scheduled replacement based on analysis	Analytica
7	Bearing replacement exceeds 1 hr	disatisfying customer requirement	а	Complex futuring	3	9	27	Optimal foture design	Analytica
8	Inability to replace actuator	Unable to run test	а	Part is out of stock	1	9	9	Verify extra actuator in stock	Arbitran
9	Bearing house rotation	incorrect displacement data, in-correct load profile	а	Actuators not centered on bearing housing	1	3	3	Check precision of critical mounts	Arbitrary
			ь	Component obstructing bearing housing movement	1	3	3	Make sure area is clear of tools and fixtures have proper clearences	Arbitrary
10	Thermocouple Failure	Temperature readings are inaccurate or incorrect	а	Connection error with internal wiring	3	1	3	Ensure wires are properly connected/clamped to the screws inside the thermocouple. Also, ensure that the wires are not touching	Arbitrary
			ь	Thermocouple is damaged due to poor handling	1	3	3	Use caution when installing and handling the thermocouples	Arbitrary
			с	Poor contact with bearing	3	1	3	Use thermo paste to ensure contact	
11	New connection fittings cause oil leaks	Oil flow disrupted, oil leak causing mess and safety hazard.	a	One or more connections are not fully threaded	1	3	3	Ensure all fittings are properly installed prior to running the test rig	Arbitrary
			b	Crack or flaw in fitting	1	3	3	Properly examine the fitting prior to installation	Arbitrary
12	Rig Incomplete	Incomplete Project	а	Lead Time Exceeds Expected	1	3	3	Allow for plenty of extra time before 'Needed'	Arbitrary
13	Testing Time Exceeds EMA capability	Testing would not be completed in full	а	Exceeds Heat capability for Actuator	1	1	1	Correlate Load weight with Max allowable time	Analytica
14	Oil Flow Meter does not work	Incapable of monitoring flow into bearing housing	a	Oil flow meter is broken	1	1	1	Test plan 3 to find out root cause of meter not outputting value	Arbitrary
			ь	Flow is not reaching meter	1	3	3	Test plan 3 to find out root cause of meter not outputting value	Arbitrary
15	Actuator Mounts Fail	Bolts Shear	а	Loading is larger than expected, addition torquing is applied	1	9	9	Double check calculations and keep a close eye on assembly to detect problems	Analytica
		Geometries Deflect Permanently	ь	Loading is larger than expected, componets are too heavely bolted	1	9	9	Double check calculations and keep a close eye on assembly to detect problems	Analytica
		Welds fail	c	Porosity, additional applied forces, extra material from weld creates areas of high stress	1	9	9	Run analysis on weld strength required	Analytica
		More Material is Required	d	Too little steel was ordered, propblems occur in machinging	3	3	9	Double check material requirments before placing	Arbitrary

Theoretical Analysis (7)

Can the concept be proved? Theoretically? By software?





Fabrication (8)

Students working hand and hand with RIT machine shop faculty to build design to specifications



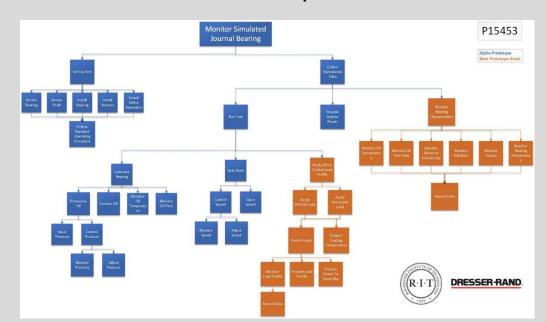


<u>Test (9)</u>

Test plans consisting of detailed steps which will, if passed, ultimately lead to system verification.

			Measure	Marginal Value	Ideal Value	Date Completed	Comments/Status	Test Plan	Conclu Condit
Motor and Contoller	System	Speed	RPM	300-600	360		Motor and controller run effectively. Motor has some slight problems getting started turning when weight is applied to the rig. At higher loads, motor runs slightly slower then unloaded.	SN 1, 2	0
Encoder	DAQ	Speed	RPM	300-600	360			SN 1, 2	0
Load Cell Accuracy	DQA	Force	Lbs	100-2000	1800		Unable to accurately correlate the force being applied using static loading plates and lever arm to force seen at the testing block housing. Further calbration of the load cell will be needed to accurately be able to read our force seen.	SN 3	۵
Lubrication System	Sub-System	Leaks	Visual	N/A	N/A	4/29/2014	No leaks were noted by visual inspection	SN 4, 5, 6,7	0
Lubrication System	Sub-System	Flow Rate	GPM	0.1-2.0	1	4/29/2014	Flow rate measured and recorded was lower then anticipated	SN 4, 5, 6 ,7	0
Lubrication System	Sub-System	Pressure	PSI	0-150	60	4/29/2014	Pressure was within ± 5 Psi of the set relief pressure	SN 4, 5, 6 ,7	0
Lubrication System	Sub-System	Temperature	٩F	0-200	70	4/29/2014		SN 4, 5, 6 ,7	0
Shaft	System	Runout	inch	0.0005*	0.0001*	4/3/2014	Runout noted was well within tolerance	SN 8	0
	Does not meet expect	Load Cell Acuracy DQA Lubrication System Sub-System Lubrication System Sub-System Lubrication System Sub-System Shaft System KEY Does not meet execution.	Load Cell Accuracy DQA Force Lubrication System Sed-System Feedback Lubrication System Sed-System Feedback Dubrication System Sed-System Freesback Dubrication System Sed-System Feedback System Burrout KEY	Lond Cell Acuracy DQA Force Us Lubrication System Sub-System Leats Visual Lubrication System Sub-System Fries Rate (2PM) Using System Sub-System Respective 7 Shaft System Sub-System Sub-System Respective 7 Sha	Land Fall Acureur, DQA Fore Las 20-2000 Lubrication System Sub-System Leaks Visual N(A Lubrication System Sub-System From Kars GMA 0.12.0 Lubrication System Sub-System Temperature 7 0.0005 Shaft System Sub-System Temperature 7 0.0005 KEV Does not meet execution	Lond Foll Accuracy DOA Fore: Lis 300-2000 1000 Lubrication System Sub-System Leaks Visual 1/1.0 N/A. Lubrication System Sub-System Four Asso GML 6/12.0 1 Universition System Sub-System Four Asso GML 6/12.0 1 Universition System Sub-System Four Asso GML 6/2.00 0.0021 Shaft System Text System Text System 7 2:00.0000 0.0021 KEV Dets not meet sequection KEV Text System 1 1	Encoder DAQ Speed PMI 300-400 300 5//2014 Load Cell Accuracy DQA Force Ibb 100-2000 1000 5//2014 Load Cell Accuracy DQA Force Ibb 100-2000 1000 5//2014 Lubricstein System Sub-System Teack Visual 1//4 N/A 4//201204 Lubricstein System Sub-System Teack FMI 0.120 1 4//2014 Lubricstein System Sub-System Teack FMI 0.120 1 4//2014 Lubricstein System Sub-System Teack FMI 0.120 1 4//2014 Lubricstein System Sub-System Teack FMI 0.120 70 4//2014 Shatt System Buntout inch 0.0000 0.0001 4//2014 Lubrication System System Teach FMI 0.120 6///2014 Lubrication System System Teach FMI 0.0001	Encoder DAQ Speed RM 300-400 Mod Sky/2014 Information of management and ma	Encoder DAQ. Speed RM 300-500 340 51/2014 Encoder data is within toterance of what values were seen using the stobuscoge. This means total cell accuracy DOA Force Lbs 200-2000 100 51/2014 Encoder data is within toterance of what values were seen using the stobuscoge. This means Unable to accurate young total targing young data data is within a total speed. Stobuscoge Stobuscog

customer requirements



Engineering Requirements (3)

A set of requirements that coincide with customer requirements but have technical values of measure.

	P15453 Engineering Requirements													
Rqmt. #	Importance	Source Cust. Rqmt #	Function	Engr. Requirement (metric)	Unit of Measure	ideal Value (range)	Accuracy							
ER 1	9	CR 1.1	Meet Financial Constraints	Yes/No	\$	\$5,000.00								
ER 2	9	CR 2.1	Dynamic Load Actuating	Apply cyclical load profile	Lbf / Hz	1900 / 6								
ER 3	9	CR 2.2	Rapid Bearing replacment	Does not exceed an hour	Min	45 min								
ER 4	9	CR 2.3	Measure Load	Measure load at a bit rate of 10 hz	Lbf	0 - 2000	10%							
ER 5	9	CR 2.4	Measure Oil Return Temperature	Measures Oil Return temperature at a bit rate of 10 hz	۰F	0 - 150	10%							
ER 6	9	CR 2.5	Measure Bearing Temperature	Measures Bearing temperature at a bit rate of 10 hz	۰F	0 - 150	10%							
ER 7	9	CR 2.6	Measure Oil Pan Temperature	Measures Oil pan temperature at a bit rate of 10 hz	۰F	0 - 150	10%							
ER 8	9	CR 2.7	Measure Bearing Vibration	Accelerometer measures vibration	kHz	0-10	10%							
ER 9	3	CR 2.8	Measure Journal-Sleeve Clearance	Measures gap distance at a bit rate of 10 khz	μin	0 - 1970	10%							
ER 10	3	CR 2.9	Modify Oil Flow Rate In/Out Measurment	Measures Oil Flow Rate for entire range of bearing load cycle at a bit rate of 10 hz	in3/s	0 - 5	10%							
ER 11	3	CR 2.10	Isolate Oil Pump Vibration	80% less vibration than current system produces without isolation	Hz	0	10%							
ER 12	1	CR 2.11	Measure Bearing Wear	Measures bearing wear at a bit rate of 10 hz	µin	0 - 1970	10%							
ER 13	9	CR 3.1	Guarded Rotating Assembly	Rotated assembly is to safety specifications	Binary	yes								
ER 14	9	CR 3.2	Add E-Stop	E-stop is present and functioning	Binary	yes								
ER 15	3	CR 3.3	Low noise	Meets manufacturing decible requirements or lower than current state	Decible	90	10%							
ER 16	9	CR 4.1	Records test data	Follows instrumentation properly & records data within current system	bit / s	12	10%							
ER 17	9	CR 4.2	Compatible with existing DAQ equipment	No extra programs are required to monitor data	Binary	Yes								

Concept Generation (4)

Morphological charts provide a platform to brainstorm concept ideas based on system or function.



TEAM INFO



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DRESSER RAND

