FERMILAB
Technical Devision
Superconductive Radio-Frequency Department
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Performing DFMEA for Tuner Mechanism of the 325 MHz SSR1 Resonator

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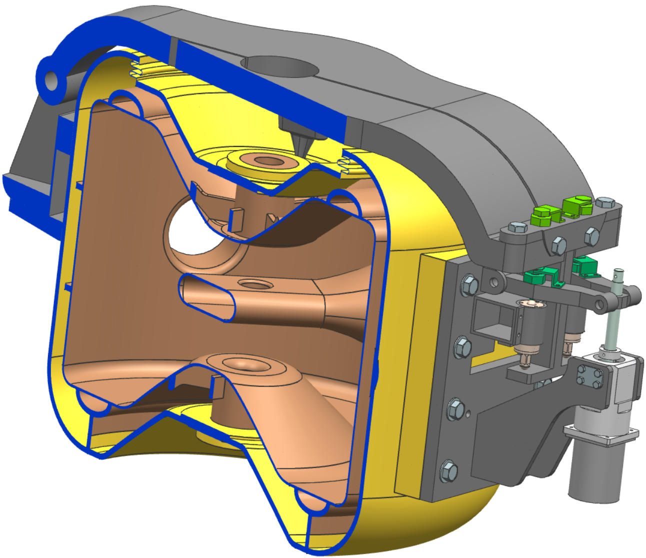
My work at Fermilab

- Take familiarity with Tuner mechanism of SSR1 project.
- Getting informed about Design Failure Mode and Effects Analysis (DFMEA).
- Performing DFMEA on the Tuner conceptual design.
- Analyze main issues of current design and search for possible improvements.

Tuner Mechanism - Conceptual Design



DFMEA

Design for Failure Mode and Effects Analysis.

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Advantages

- Discover and rate all failure mode of a design.
- Track design revisions and development.
- Systematic approach to develop of design.
- Organize design information.

DFMEA - Procedure

Step 1

- Collect information and specifications about design.
- Divide the system in parts and sub-parts.
- Individuate system main functions and working conditions.

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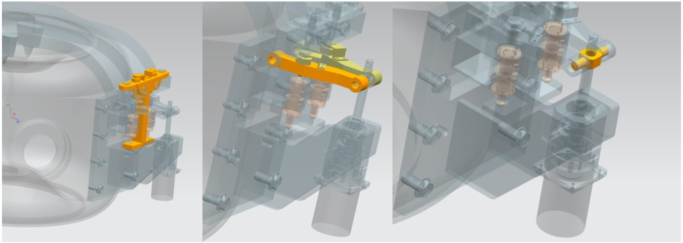

DFMEA - Procedure

Step 2

- Individuate and list all interfaces between components.

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	id	1a	1b	1c	1d	1e	2a	2b	3a	3b	3c	3d	3e	3f	4a	...
id	Item	weldedSu	flexibleJoint	arm	probes	probesPla	1st_2nd	diffScrew	piezoHou	upperPi	lowerPie	active crystal	strainGau	piezoCo	leverBo	...
1a	weldedSupport	1a	1a / 1b													
1b	flexibleJoint	1a / 1b	1b	1b / 1c												
1c	arm		1b / 1c	1c	1c / 1d		1c / 2a									
1d	probes			1c / 1d	1d	1d / 1e										
1e	probesPlate				1d / 1e	1e										
2a	1st_2ndleverJoint			1c / 2a			2a	2a / 2b						2a / 3f		
2b	diffScrews_1rsLever						2a / 2b	2b								...
3a	piezoHousing								3a	3a / 3b	3a / 3c	3a / 3d				
3b	upperPiezoPlate								3a / 3b	3b		3b / 3d		3b / 3f		
3c	lowerPiezoPlate								3a / 3c		3c	3c / 3d	3c / 3e			
3d	active crystal								3a / 3d	3b / 3d	3c / 3d	3d				
3e	strainGaugeBullet										3c / 3e		3e	3e / 3f		
3f	piezoContacts						2a / 3f			3b / 3f			3e / 3f	3f		...
4a	leverBody														4a	...
...	...							...						...	...	...

DFMEA - Chart

Step 3

- List functions, failure modes, effects, causes and process control for each item.
- Rate respective Severity, Occurrence, Detectability.

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(1-3) List of Items		(4) Fuction	(5) Failure Mode	(6) Failure Effects	(7) # S	(8) Potential Causes	(9) # O	(10) Process Controls	(11) # D	(12) # RPN
Assembly	Item									
Assembly 1 Name: motor	ID: motor1a	Function 1 of item motor1a	Failure of item motor1a	Failure effect to other items or parts	-	Causes of current failure	-	Detection methods used	-	-
	ID: motor1b	Function 1 of item motor1b	Failure of item motor1b							
	ID: motor1c	Function 1 of item motor1c	Failure of item motor1c							
		Function 2 of item motor1c								

DFMEA - Results

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Stiffness and efficiency specifications

Respecting design specification about stiffness and efficiency.

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Punctual contacts of rolling bearing have a non-linear elasticity and is difficult to model their stiffness.
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First arm stiffness

Stiffness of first Lever is the weaker part of the design and bring the system below specification.

Objective

System efficiency and stiffness

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Estimate system efficiency and optimize components stiffness.

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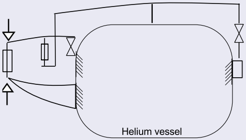
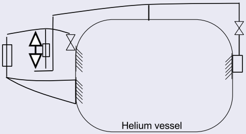
Three configurations considered

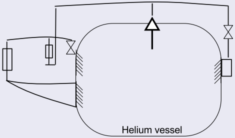
Coarse tuning



Fine tuning



Passive stiffness



System efficiency and stiffness - Model

Lumped parameters model

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- Punctual contacts
- Blending beams
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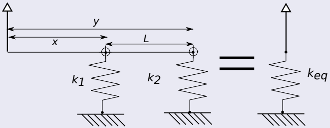
Calculate elastic lever equivalent stiffness.



$$k_{eq} = \frac{1}{\frac{x^2}{k_2 L^2} + \frac{y^2}{k_1 L^2}}$$

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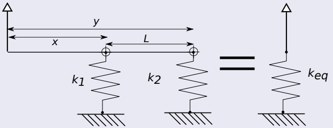

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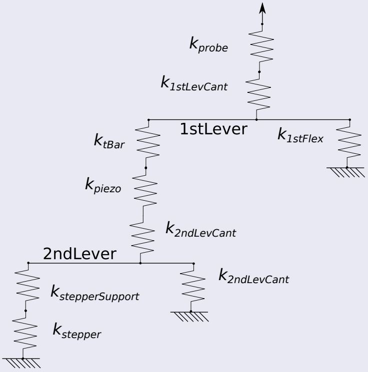
Example

Passive stiffness model



System efficiency and stiffness - Results

Item	stiffness from calculations [kN/mm]	passive stiffness coefficients	optimized stiffness [kN/mm]
cav	25.00	25.00	25.00
probeCont	132.00	1.00	1,000.00
1stLeverCan	7.00	0.00	7.00
1stLeverSup	60.00	1.00	60.00
1stFlex	1,000.00	4.00	250.00
TbarBody	800.00	4.00	250.00
TbarArms	158.00	4.00	250.00
piezoContUp	80.00	4.00	250.00
piezoContLo	104.00	4.00	250.00
piezo	200.00	4.00	250.00
2ndFlex	1,286.00	9.00	111.11
2ndLeverSup	88.00	4.00	250.00
2ndLeverCan	10.00	10.00	10.00
stepperSupport	28.00	36.00	100.00
stepper	100.00	36.00	27.78
			1,000.00
k pz2cav	2.87	[kN/mm]	3.14
k coarse	0.31	[kN/mm]	0.33
Rigid displacement	1.50	[mm]	1.50
Total displacement	3.40	[mm]	3.14
Efficiency	0.44	-	0.48
k fine	2.75	[kN/mm]	3.05
k passive	26.76	[kN/mm]	37.11

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Using Flexible Joint

- Linear elastic element for small displacement.
- Lower resistant momentum than roller bearing for small displacement.
- Easy manufacturing and assembly.

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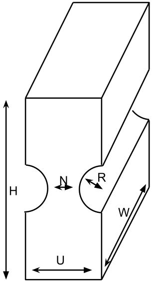

Flexible Joint - Analysis

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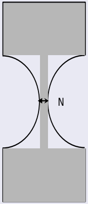
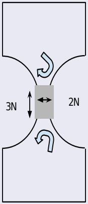
First order estimation



traction model



blending model

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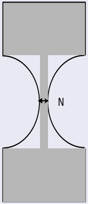
First order estimation



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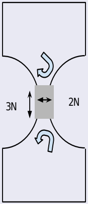
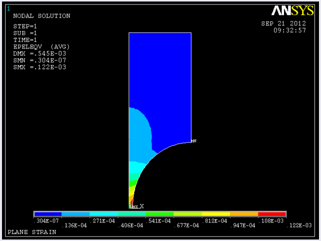
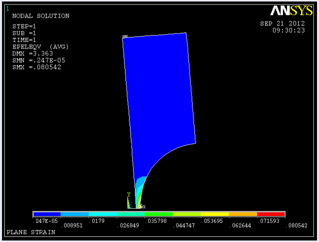


blending model

FEM Analysis





First Lever Optimization

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Objective Optimize geometry of first lever maximizing stiffness.

Respecting the constrains of size and weight.

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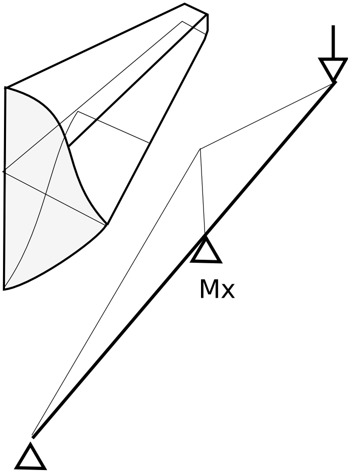
Work in progress

- Section Shape: Solid high rectangle or Double T shape .
- Beam Shape: Tapering along two dimensions.
- Manufacturing considerations.
- Using analytical model for finer optimization of parameters.

First Lever Optimization - Concept



Updating DFMEA

- Update DFMEA with the last design revisions.
- Check the system and search for new failure mode .
  Example *Higher weight of first lever could cause an unwanted displacement along y-axis due to gravitational force*
- Recalculate grades for each failure mode.
- Settle the design for manufacturing and test or select the others design issues to improve.

Thank you for your attention.