Development of a Pipe Crawler Inspection Tool for Fossil Energy Power Plants

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TECHNICAL NEED

Power Plant Inspections:

- Challenging and time consuming
- Typically manual and external
- Difficult/impossible to access areas

Robotic Inspection (Advantages):

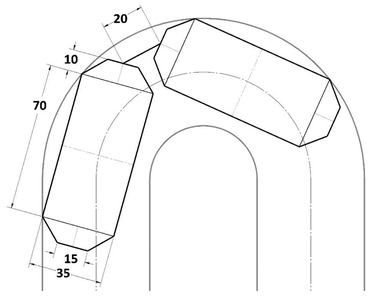
- Reaching hard to access places
- Conditions sometimes unsafe for human
- Better understand the health of critical components in infrastructure
- Reduces plant down time, increasing efficiency and cost savings

Manual external inspection of pipes

Superheater coils

Challenges:

- Scenario: Superheater coils of coal power plant
- Several 180 degree bends restricting turning
- Small diameter (~2 inch) pipes
- Overcoming weight of tether and friction due to turns
- Identifying appropriate sensors

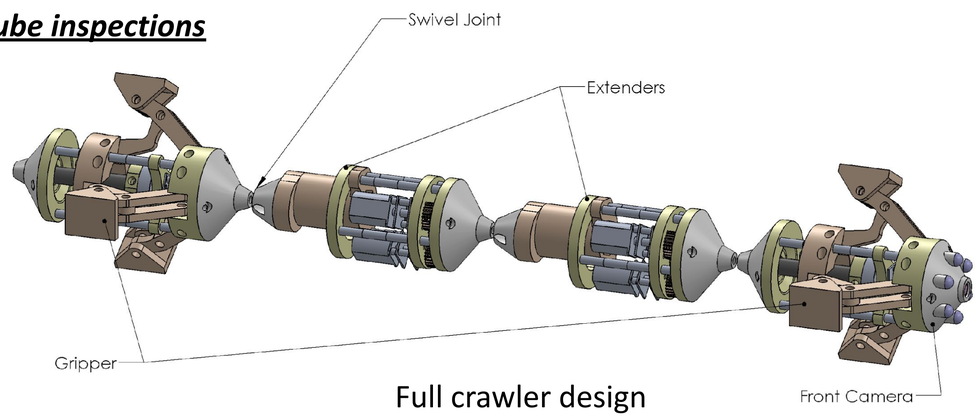


Internal pipe and crawler dimensions

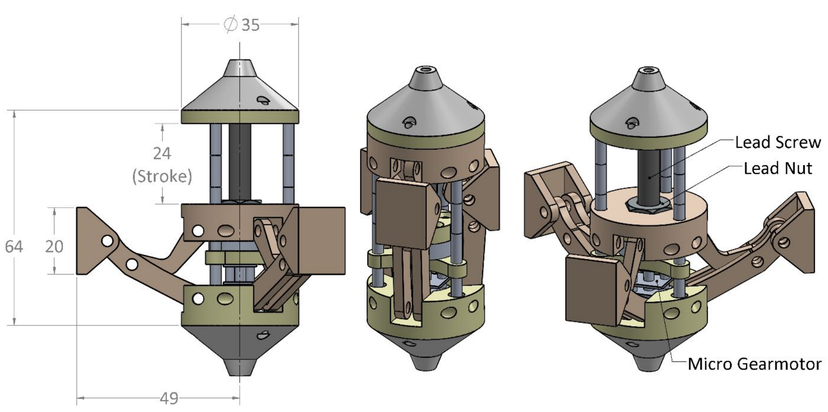
APPROACH

Inspection Crawler for Boiler Tube inspections

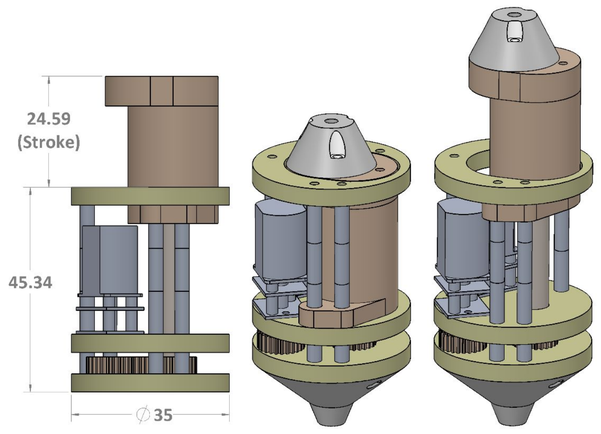
- Mechanism for actuation
- Motor selection
- Power over long pipe lengths
- Kinematic analysis
- Joint connections



Full crawler design



Gripper module design

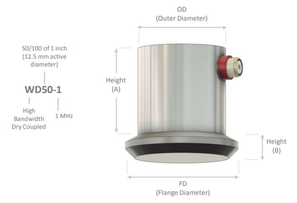


Extender module design

Sensor Investigation for the Crawler

- Ultrasonic Sensors for thickness measurements
- Investigate viable options
  - Dry couplant UT (Ultran Group) [1]
  - EMAT (Innerspec Technologies) [2]

Frequency	Active Diameter 3.2 mm	6.3 mm	9.5 mm	12.5 mm	19.0 mm	25.0 mm
500 kHz				WD50-0.5	WD75-0.5	WD100-0.5
1 MHz	WD12-1	WD25-1	WD37-1	WD50-1	WD75-1	WD100-1
2 MHz	WD12-2	WD25-2	WD37-2	WD50-2	WD75-2	WD100-2
5 MHz	WD12-5	WD25-5	WD37-5	WD50-5	WD75-5	WD100-5
10 MHz	WD12-10	WD25-10	WD37-10	WD50-10		
Height (A)	10	11	13	16	17	17
Height (B)	3	6	7	8	8	8
OD	6	6	13	17	25	32
FD	10	10	22	25	32	38



UT sensor specifications [1]

5.1.1.5. One Channel Small Diameter Butterfly Sensor (12mm Dia.)

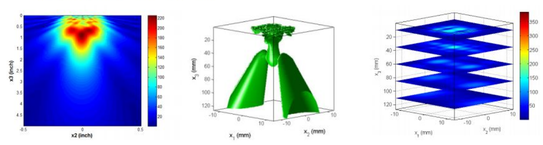
Part Number		274A0347
Sensor Type		SH Lorentz Permanent Magnet
Temperature Ranges		-30°C - 80°C
Connector		4 Pin Lemo 0B
Coil Geometry		Butterfly
Tuning Module[1]		See Below
Coil Width	Inch	0.38
	mm	9.5
Coil Length	Inch	0.38
	mm	9.5
Sensor	Inch	0.47 D x 1.57 H
	mm	12 D x 40 H
Anchor Points		Thread

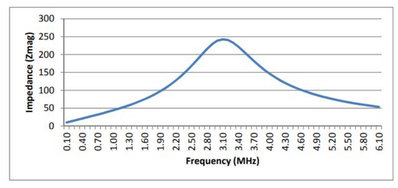
Tuning Module Data Sheet

Tuning Setting Module Name	Material	Tuning Frequency (kHz)	Recommended Frequency Range (kHz)	
			Min	Max
205T0003	Steel	3000	2000	4000
205T0005	Aluminum	3000	2000	4000

Tuning modules are not necessary when connecting directly to Innerspec PowerBox H without signal conditioning.

Frequency Spectra & 3dB Beam Profiles



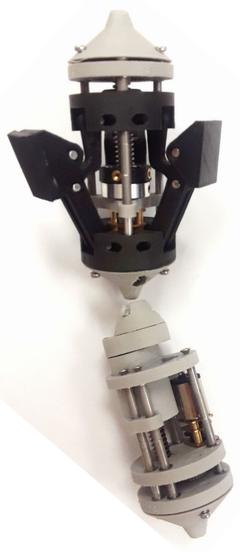


EMAT sensor specifications [2]

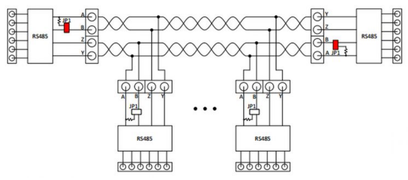
DEVELOPMENT

Crawler Design Progress

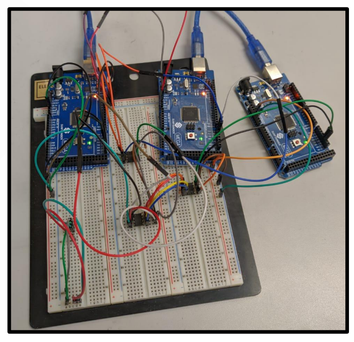
- Lead screw and nut linear actuator driven by 12V DC motor.
- Each extender has displacement of 2.5 cm – total translation per cycle is 5 cm.
- Limit switches are used to define the range of extension.
- Gears (1:1) are used to mount the motor vertically. A second motor can be added, if needed.
- RS-845 full duplex serial network for modular microcontroller communication



Physical Prototype



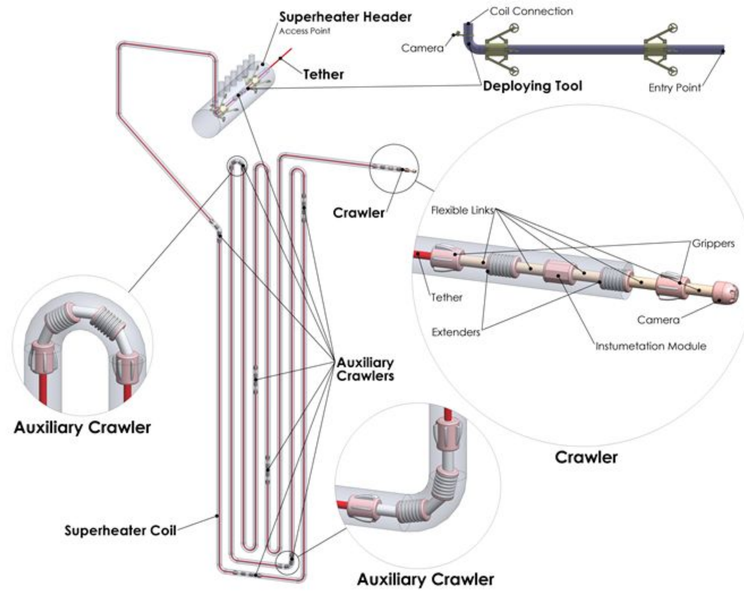
RS-485 network diagram [3]



Microcontroller network

BENEFITS AND FUTURE WORK

- After completing prototype development for the first crawler, bench scale testing will be conducted.
- A sensor module including UT or EMAT will be developed that will include a mechanism for surface preparation.
- Modifications will be made to utilize multiple crawlers to distribute the tether load.



Multiple crawler concept rendering

REFERENCES

[1] http://ultrangroup.com/products/transducers/conventional/dry-coupled-w-series/
[2] https://www.innerspec.com/assets/files/Sensors-Accessories-T-SA-C18.pdf.
[3] https://reference.digilentinc.com/reference/pmod/pmodrs485/reference-manual

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