FLUXTROL®

Physical Simulation of Soft Magnetic Composite Impeder Performance for use in Induction Tube Welding Systems

UIE

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EVOLUTION AND NEW TRENDS IN ELECTROTHERMAL PROCESSES

www.fluxtrol.com

Background

- Inductive welding is a popular method for making tubes used in a variety of industries
- Induction Tube Welding Process involves:
  - Rolls of steel strip are run through forming mills to create the tube shape with a closing seam
  - An inductor is used to heat the inside edges of this seam
  - The softened tube edges are squeezed together by the closing rolls to form a solid state weld

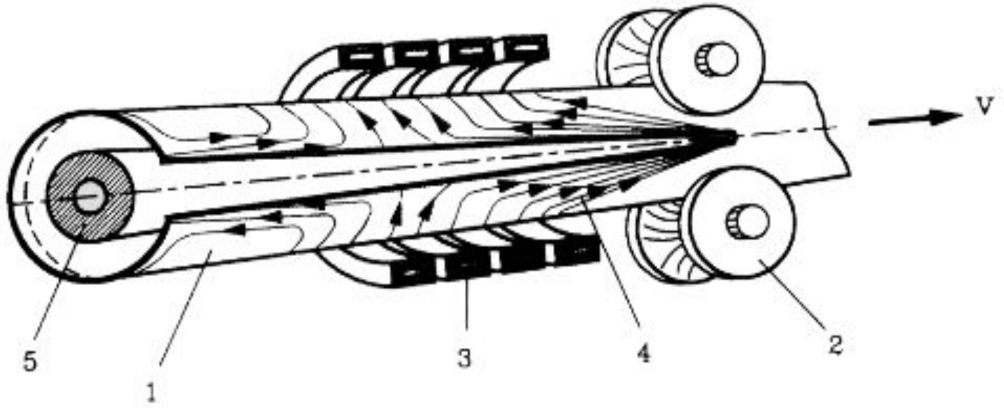


Image taken from UIE book "Induction Heating – Industrial Applications"

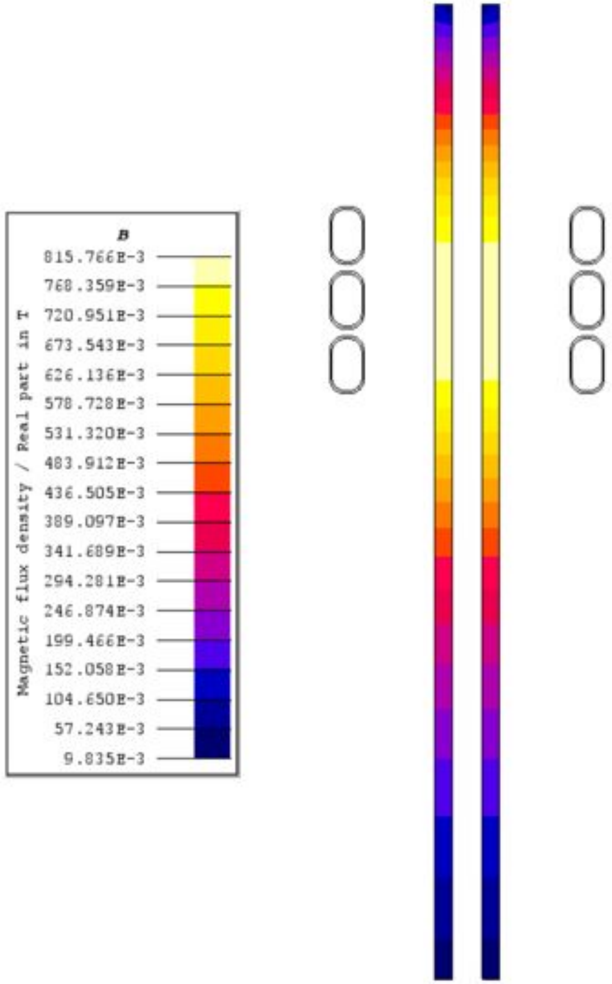
Impeder Background

- Impeders are typically manufactured using a combination of constructive elements and ferrite rods or tubes(ferrites)
- The ferrites have low saturation flux density which is strongly temperature sensitive and becomes more of an issue at lower frequencies
- This new situation creates an opportunity to improve the welding system performance using soft magnetic composite materials (SMCs)
- Fluxtrol impeders have been successfully tested in industrial tube mills and have shown significant performance improvements, matching well with simulation results presented previously at HES-19 in Padova

https://www.efd-induction.com/en/induction-heating-equipment/weldac-tube-welder

Experimental Validation

- One of the biggest concerns about using SMCs in these processes is survivability of the impeder due to the higher cost and higher magnetic losses
- While it would be preferable to run all tests on a full production line, a much more cost effective and controllable test stand was constructed to simulate these conditions
- Using the electrical parameters for the inductor, a simulation can be run to estimate the loading of the SMC core



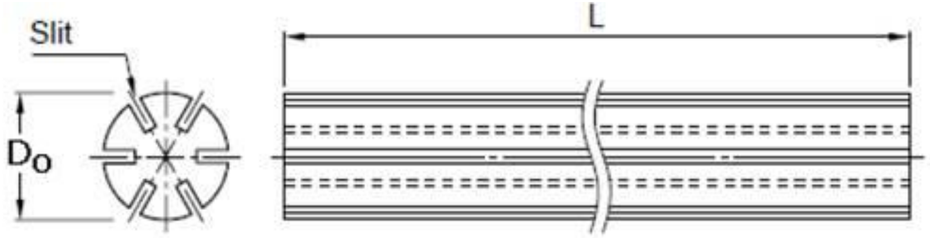
Experimental Setup

- The test stand can be seen in the image to the right, which mimics the magnetic flux density the impeder would experience in a real welding installation
- Voltage and current from the coil are measured using a voltage probe and Rogowski belt, and these values are used to model the magnetic loading of the impeder
- Losses for the impeder are calculated using the recorded change in water temperature and flowrate and are compared to simulated losses
- After running each SMC impeder at increasing power settings, an upper operational range for each material can be constructed

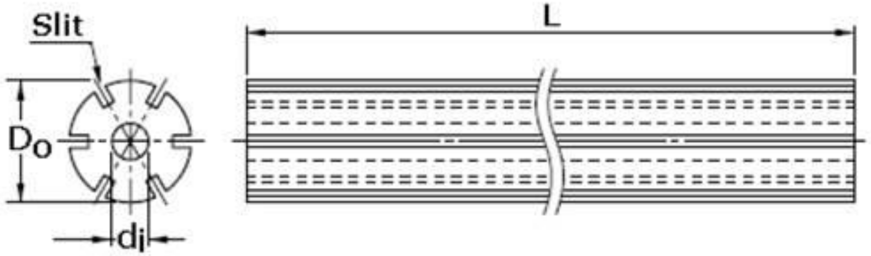
Impeder Geometries

- Standard Impeder geometries were chosen to make use of readily available impeder casings

- The shapes of the ferrites to be replaced in these casings include:
  - Flow through impeder
    - Core OD 10mm
    - Length 200mm
    - 6 Flutes



  - Return Flow impeders
    - Multiple ODs and IDs
      - Core OD 12mm, ID 6mm
      - Core OD 14mm, ID 7mm
      - Core OD 19mm, ID 9mm
    - Length 200mm
    - 8 Flutes



Experimental Trials

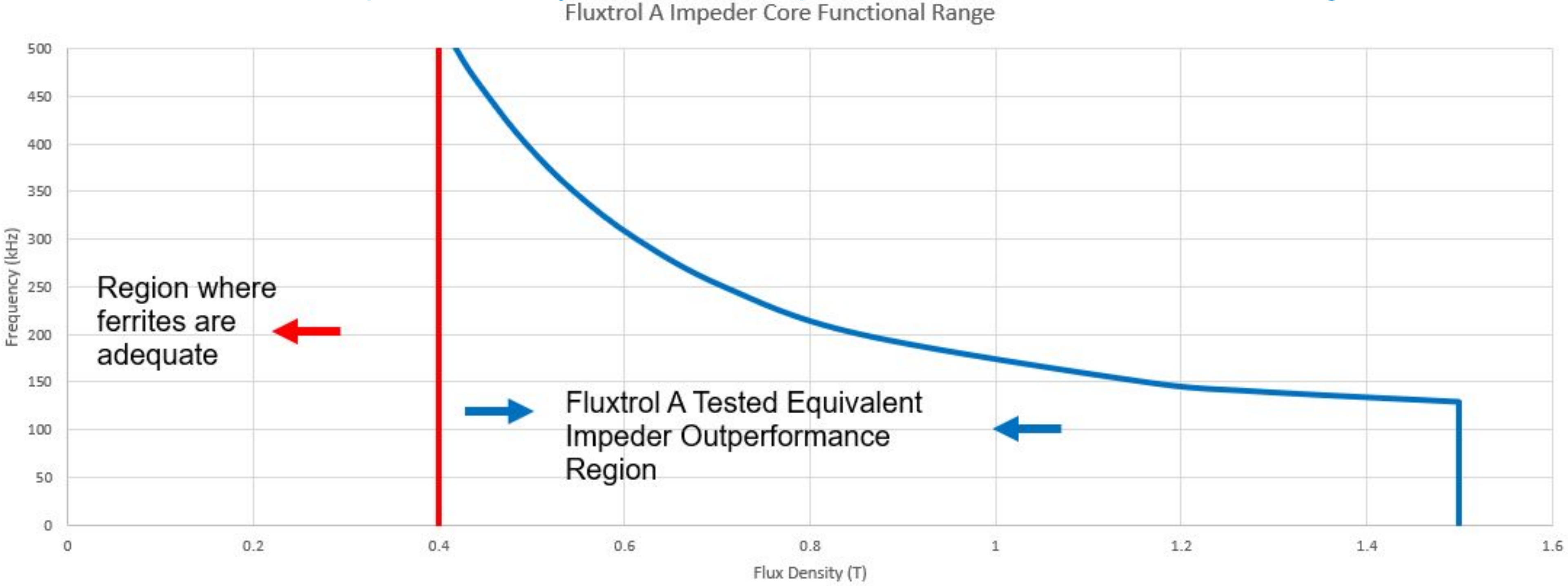
- The following trials were run for 1 hour using 14mm Impeders made from various materials, cooling water with an inlet temperature of 15°C and 40 PSI pressure

Trial	f (kHz)	Max Flux Density (T)	Flowrate (GPM)	ΔT (°C)	Measured Losses (kW)	Estimated Losses (kW)	Ratio
A	300	0.61	2.1	9.1	3.8	3.2	1.19
559H	306	0.55	2.4	2.9	1.4	1.5	0.93
559 Org	300	0.64	2.3	3.8	1.7	2.3	0.74

- Losses were calculated using the difference in inlet and outlet water temperature and the flowrate, and was estimated using magnetic flux densities from Flux 2D and new Fluxtrol loss data
- Overall delta T in the cooling water was acceptable in all cases as expected based upon the water flow rate
- Measured Losses are around predicted losses with error potentially coming from a stack up of error in the various measurements

Fluxtrol A Impeder Operational Range

- Shown here is a graph detailing the performance characteristics of Ferrite and Fluxtrol A impeder cores when placed within standard impeder casings and supplied with sufficient cooling water pressure (40PSI)
- Regions to the left of each line are the functional ranges for each core, and regions to the right, non-functional ranges due to either magnetic saturation or overheating
- The Fluxtrol Impeder Outperformance Region relates to opportunities for improved welding system performance
  - Red Line is Operational Limit for a ferrite with a saturation flux density of 0.4T
  - Blue Line is Experimentally Validated Equivalent Conditions on Test Rig



Ferrotron 559 Impeder Operational Range

- Shown here is a graph detailing the performance characteristics of Ferrite and Ferrotron 559 impeder cores when placed within standard impeder casings and supplied with sufficient cooling water pressure (40PSI)
- Regions to the left of each line are the functional ranges for each core, and regions to the right, non-functional ranges due to either magnetic saturation or overheating
- The Fluxtrol Impeder Outperformance Region relates to opportunities for improved welding system performance
  - Red Line is Operational Limit for a ferrite with a saturation flux density of 0.4T
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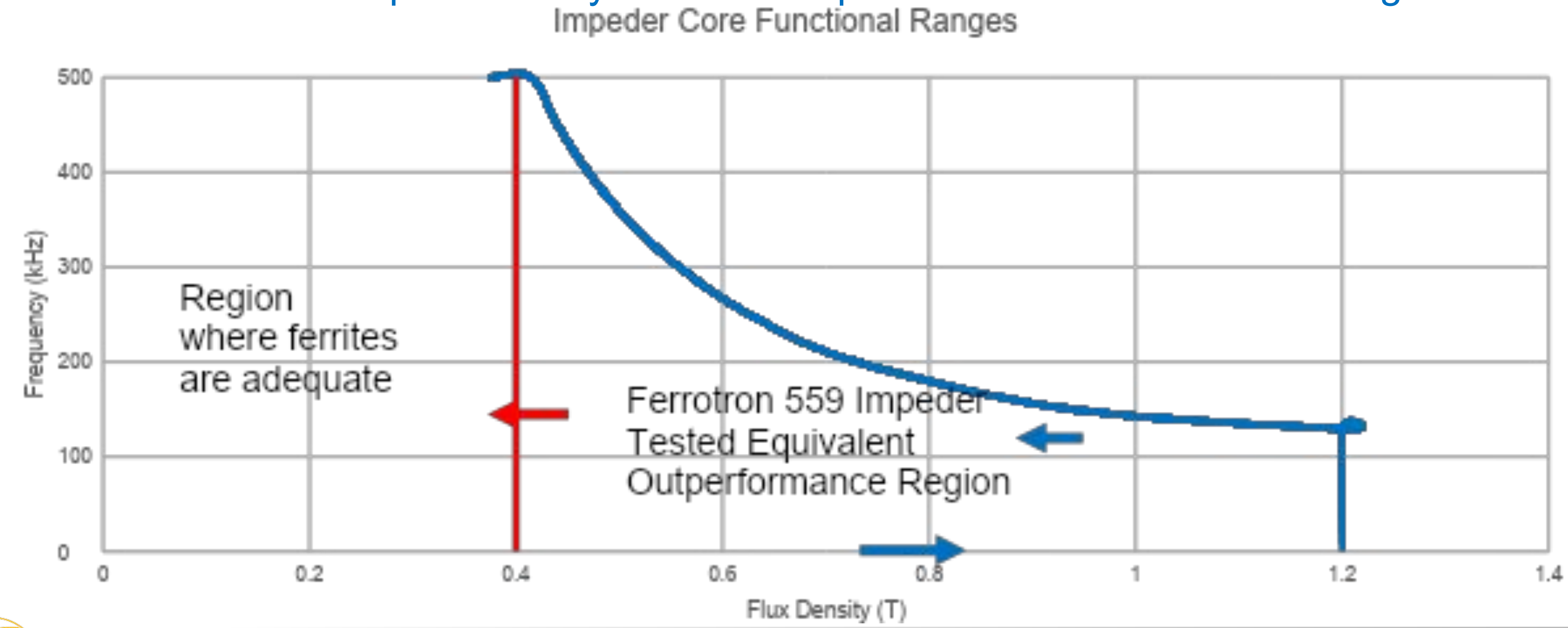
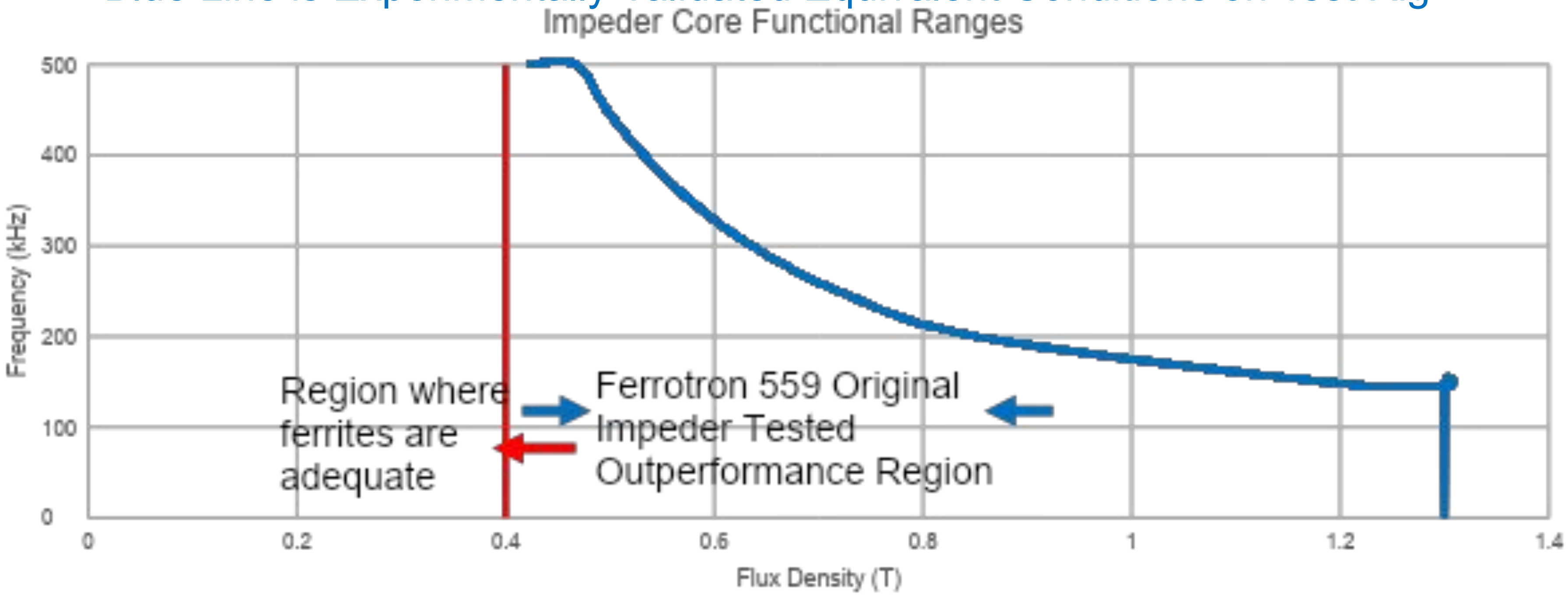


Ferrotron 559 Original Impeder Operational Range

- Shown here is a graph detailing the performance characteristics of Ferrite and Ferrotron 559 Original impeder cores when placed within standard impeder casings and supplied with sufficient cooling water pressure (40PSI)
- Regions to the left of each line are the functional ranges for each core, and regions to the right, non-functional ranges due to either magnetic saturation or overheating
- The Fluxtrol Impeder Outperformance Region relates to opportunities for improved welding system performance
  - Red Line is Operational Limit for a ferrite with a saturation flux density of 0.4T
  - Blue Line is Experimentally Validated Equivalent Conditions on Test Rig



Conclusions

- An experimental test stand has been developed in the Fluxtrol laboratory for physical simulation of industrial tube welding conditions
- Tests with 3 grades of SMC showed that the materials could survive at 300 kHz at flux densities exceeding the saturation flux density of ferrites commonly used for tube welding impeder cores
    - Potential for increased productivity and efficiency
- Using published loss data, the equivalent loading was calculated at various frequencies showing the experimentally validated operational window for the SMC materials
- For tube welding cases where the ferrite is saturated, there is room for improvement when switching to an SMC impeder provided there is proper cooling and system controls

Further Trials

- In order to fully develop the operational ranges for all these materials, an extensive list of trials is planned using the test rig in the Fluxtrol Lab
- Other materials were deemed potentially useful for use in induction tube welding systems including Fluxtrol 50 and Fluxtrol 75

Material	Impeder Size
Fluxtrol A	10mm,12mm,14mm,19mm
Fluxtrol 50	10mm,12mm,14mm,19mm
Fluxtrol 75	10mm,12mm,14mm,19mm
Ferrotron 559H	10mm,12mm,14mm,19mm
Ferrotron 559 Original	10mm,12mm,14mm,19mm

- The goal is to find the maximum survivable setting for each material and size in order to best define the operational range for each material, and optimize the geometries to maximize impeder and tube mill performance
- Additionally, work is being done in parallel to run trials on industrial tube mills

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Questions?