



Industrial Consultancy & Sponsored Research (IC&SR)

A Mechanical Metamaterial Transducer Add-On (MeTradd) Filter for Enhancement of Linear and Nonlinear Ultrasonic Damage Detection IITM Technology Available for Licensing

Problem Statement

- The mechanical integrity of wires, rods, pipelines, & other cylindrical structures is a **crucial factor in guaranteeing safety & reliability** when they are utilized for storing high-pressure substances or transmitting them.
- The conventional methods often **fall short of accurately detecting micro & fatigue cracks** or **identifying damage** in the early stages of the component's structural lifespan.
- The structural life of the component estimated closely by monitoring the **higher harmonics** from the material discontinuity. Further the nonlinearity from instrumentation, transducer, & couplant creates **false positives** apart from material-based or **micro-crack-related nonlinearity**, which leads to **inaccurate nonlinear measurements**, including other drawbacks. Present invention addresses above issues in efficient manner.

Technology Category/Market

Technology: Mechanical Metamaterial Transducer Add-On (MeTradd) Filter;

Industry: Oil & Gas Pipelines, Automotive, Aerospace Industries, Structural Instruments;

Applications: NDE & Structural Health Monitoring ultrasonic systems, Energy & Power, etc.

Market: The global metamaterial technologies market grow USD **14.5** billion by **2032** & at a **CAGR** of **37%** during forecast period **2024-32**.

Technology

- Present invention describes a **mechanical metamaterial (MM) add-on filter** for the **transducer** for the **enhancement** of linear & non-linear ultrasonic **damage** detection on **cylindrical** rod structures.
- Said mechanical metamaterial add-on filter **placed along the cylindrical rod** with an array of **axisymmetric metamaterial baffles**

arranged **periodically** on the surface of the rod for **harmonic filtering** of signals,

- The axisymmetric metamaterial baffles are either **constant** axisymmetric baffles or **tapered** axisymmetric baffles enclosed in a **shell**. (Refer Figs. 1a, 1b, 1c)

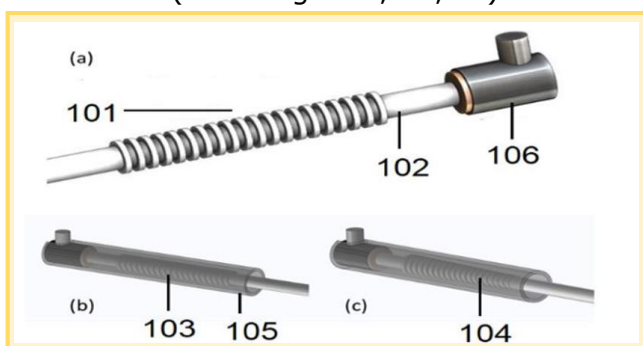


Fig.1 illustrates (a) Metamaterial Transducer Add-On (MeTradd) filter placed along a cylindrical rod; & MeTradd with (b) constant baffles & (c) tapered baffles represented in an encapsulated shell;



Fig.2 shows the use of proposed MeTradd filter with tapered baffles illustrating that the selective generation of enhanced $L(0,3)$ mode in the rod leads to the effective generation of bulk longitudinal waves in a target sample at a higher temperature.

Intellectual Property

IITM IDF Ref. 2300;
Patent Application No. 202341040127

TRL (Technology Readiness Level)

TRL-4, Proof of Concept ready, tested and validated in Laboratory

Research Lab

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Technology (Contd.)

- Further claimed a **system** for generating & directing ultrasonic waves for inspections of specimens using the add-on filter, said system comprises:

- a custom-made **holder** setup to attach transducer & add-on assembly to the workpiece for proper ultrasonic wave propagation;
- a **device** to generate the electric pulses for the transducer;
- an **ultrasound pulser receiver device** used for receiving the ultrasonic waves;
- an **oscilloscope** used to display the signals, &
- a **computer** to process the signal.

(Refer **Fig 4**: Prototype of the claim system)

- Facilitates a technique that aims to **isolate certain guided wave modes** in cylindrical waveguides that play a key role in the **fluid flow & temperature measurement** process.

- The waveguide metamaterial **suppresses** all the **unwanted nonlinearity** by creating an ultrasonic bandgap near the **fundamental frequency range**.

- Facilitates a **long-range inspection** as well as **inspect** micro & fatigue cracks.

Key Features / Value Proposition

❖ Technical Perspective:

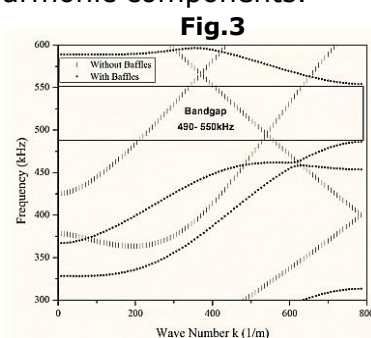
❖ Suppression & Enhancement of Harmonic:

Said **mechanical MM add-on filter** proposes many vital features, like capable of:

- suppression of all** harmonic components,
- selective suppression** of harmonic components (e.g., selective suppression of certain mode $L(0,2)$ along with enhancement of another mode $L(0,3)$), &
- enhancement of all** harmonic components.

❖ Bandgaps:

The bandgap of **60kHz** is generated for the basic case of metamaterial from **490 kHz to 550 kHz** which is multiple times higher than the bandgap in the existing product. (Refer Fig.3 (right))



❖ Improves Defect Detection capability:

Detect **defects** such as **discontinuity in the cylindrical waveguide** from the nonlinear responses.

❖ Industrial Perspective:

❖ Application Areas:

Specifically targets **cylindrical waveguides**, & their linear & non-linear ultrasonic inspections & addresses applications e.g. inspecting **wires, rods, cylindrical structures, & pipelines** in **efficient & cost-effective** manner.

Images



FIG.4: Illustrates an experimental setup showing the MM rod clamped between the transducers with the help of spring-loaded mechanism;

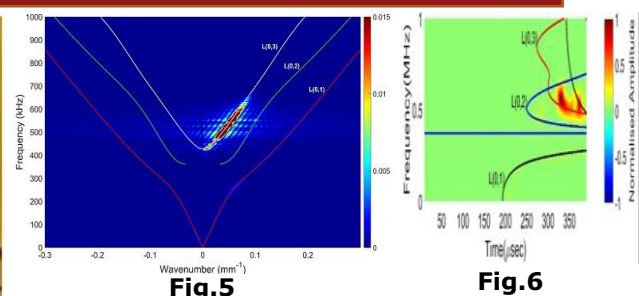


Fig.5 (Left) illustrates Frequency-wavenumber dispersion plot with Tapered baffles;

Fig.6 (Right) illustrates Time spectrogram plot obtained from simulation with Tapered baffles;

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