Advanced Ultrasonic Peening Process Training
Focus on HFMI for Titanium, High-Strength Aluminium Alloys, Inconel & Advanced Materials

COURSE SUMMARY

This course provides advanced training on High-Frequency Mechanical Impact (HFMI) / Ultrasonic Peening for high-performance materials including titanium alloys, high-strength aluminium alloys, and nickel-based superalloys such as Inconel. Emphasis is placed on parameter optimization, treatment tailoring, and achieving targeted mechanical and fatigue-performance outcomes.

TARGET AUDIENCE

This course is specifically designed for aerospace professionals working with high-performance metallic structures and components, including:
- Aerospace structural and materials engineers
- Fatigue, durability, and damage-tolerance engineers
- Manufacturing and welding engineers in aerospace programs
- MRO engineers and specialists in aircraft life extension
- R&D engineers working with advanced metallic materials and joining technologies
- Technical authorities and specialists responsible for certification and structural integrity

REQUIRED QUALIFICATIONS / BACKGROUND

Participants are expected to have:
- An engineering degree or equivalent professional experience in aerospace, mechanical, materials, or structural engineering
- Fundamental understanding of fatigue, fracture mechanics, and metallic material behavior
- Familiarity with welded or mechanically joined aerospace structures

Prior experience with ultrasonic peening or HFMI is not required. However, the course is intended for engineers and specialists operating in high-performance or safety-critical environments.

COURSE DURATION & FORMAT

Duration: 3 days

Format:
- Instructor-led training (in-person or virtual)
- Advanced technical lectures combined with case studies
- Practical demonstrations and hands-on parameter optimization (where applicable)
- Group exercises and assessment

Typical daily duration: approximately 6–7 hours per day.

DAY 1 — Fundamentals of HFMI & Material-Specific Behavior

1. Introduction to HFMI / Ultrasonic Peening
- Principles of ultrasonic impact treatment
- Residual stress generation
- Weld toe geometry improvement
- Fatigue life enhancement mechanisms

2. Material Science Foundations
- Dislocation movement and plastic deformation
- Hardness and material response
- Microstructure sensitivity to HFMI
- Comparison with conventional steel behavior

3. HFMI for Titanium Alloys
- Titanium mechanical behavior and weldability
- Residual stress challenges
- Parameter guidelines for titanium HFMI
- Avoiding overheating and micro-damage

4. HFMI for High-Strength Aluminium Alloys
- Behavior of 2xxx, 6xxx, 7xxx aluminium alloys
- Age-hardening effects on HFMI performance
- Managing high ductility and lower hardness
- Optimal peening windows for aluminium structures

5. HFMI for Nickel-Based Superalloys (Inconel)
- High-temperature strength and deformation behavior
- Required peening energy levels
- Achievable residual stress depths
- Typical applications in demanding environments

DAY 2 — Process Parameters, Treatment Optimization & Quality Control

1. Ultrasonic Peening Equipment & Control
- Ultrasonic generators and tuning
- Tooling variations
- Frequency, amplitude, force, and contact duration
- Multi-pass peening approaches

2. Optimization of HFMI Treatment Parameters
- Achieving desired compressive stress levels
- Selecting appropriate parameter combinations
- Material-dependent adjustments

- Stabilizing process outputs for repeatability

3. Desired Treatment Result Metrics
- Residual stress magnitude and penetration depth
- Surface refinement and weld toe radius improvement
- Fatigue enhancement indicators
- Identifying and preventing over-peening

4. Quality Assurance & Verification Techniques
- XRD residual stress measurement
- Surface profilometry and 3D scanning
- Hardness testing
- Documentation, traceability, and qualification

5. Practical Demonstration / Hands-On Session
- Real-time parameter tuning
- Sample treatment on titanium, aluminium, and Inconel
- Post-treatment inspection and validation

DAY 3 — Advanced Applications, Modelling & Case Studies

1. Fatigue & Performance Prediction for Advanced Materials
- S–N curve modifications
- Crack initiation vs propagation delay
- Fracture mechanics considerations
- Predictive modelling of HFMI performance

2. Application-Specific Optimization
- Aerospace lightweight structures
- Automotive and motorsport aluminium joints
- Marine and offshore Inconel components
- Additive manufacturing (AM) surface improvement

3. Troubleshooting & Failure Modes
- Detecting under- and over-treatment
- Correcting parameter drift
- Addressing complex geometries

4. Industrial Case Studies
- Titanium aerospace brackets
- Inconel turbine housings
- Aluminium 7xxx welded components
- Mixed-material solutions

5. Group Exercise & Certification Assessment
- Designing a parameter set for a chosen material
- Interpreting residual stress and geometry data
- Producing an optimization plan

LEARNING OUTCOMES

Participants will learn to:
- Apply HFMI to high-performance materials
- Optimize treatment parameters for target results
- Validate and document high-quality HFMI treatments
- Predict fatigue benefits for advanced materials
- Troubleshoot treatment issues and process deviations