BEYOND VERTICAL & LINEAR VIBRATION

The Next Generation of Geogrid Welding Technology

White Paper · June 2026

CDXLI · Chengdu, China

This white paper examines the fundamental limitations of current geogrid welding technologies — vertical ultrasonic and linear vibration friction welding — and presents torsional ultrasonic vibration as the next-generation solution for PET and fiber-reinforced geogrid manufacturing.

TABLE OF CONTENTS

PART I — The Hidden Cost of Vertical Ultrasonic Welding

For decades, vertical ultrasonic welding has been the workhorse of geogrid manufacturing. The principle is simple: an ultrasonic horn presses vertically onto the strip intersection, delivering 15-20kHz mechanical vibration to fuse the plastic matrix. It is fast, clean, and requires no consumables.

But for a growing segment of the market — namely PET geogrid and fiber-reinforced (FRP) geogrid — this technology has a fundamental problem.

The Problem: Fiber Damage at the Node

In vertical ultrasonic welding, the horn impacts the material surface perpendicularly. The high-frequency vertical hammering creates a shear action at the fiber-matrix interface. For PP and steel-plastic geogrids, this is manageable because the matrix is ductile and the fibers are embedded in a relatively thick coating.

However, for PET and fiberglass geogrids, the vertical shear force fractures the brittle fibers at the weld node. The result:

- Node strength drops to 40-60% of the parent material (vs. 90%+ achievable with PP)
- The weld zone becomes a stress concentration point — the grid fails at the node, not the rib
- Production speed must be reduced to compensate, hurting throughput

This is not a tuning issue. It is a physics issue: vertical ultrasonic welding inherently shears fibers at the weld interface. The industry has known about this for years but lacked a practical alternative — until now.

PART II — Industry's Attempts at Linear Vibration Friction Welding

In response to the fiber damage problem, a number of manufacturers began exploring linear vibration friction welding. Instead of vertical impact, the tool vibrates horizontally, rubbing the two strip surfaces together to generate frictional heat. The horizontal motion preserves fiber integrity because the shear direction is parallel to the fiber plane, not perpendicular.

However, this technology itself has split into two implementation paths — **motor-driven** and **electromagnetic-driven** — and each has critical weaknesses in the context of geogrid production.

2.1 Motor-Driven Linear Vibration

A servo or variable-frequency motor drives an eccentric wheel or crank-connecting rod mechanism, converting rotary motion into linear reciprocating motion.

- Frequency range: 100-200Hz
- Amplitude: fixed by eccentricity, mechanically limited adjustment
- High load capacity — can drive heavy tooling and large parts

Fatal flaw for geogrid manufacturing: The massive inertia of the rotating components makes it impossible to start and stop quickly. In a step-and-weld cycle (move → stop → weld → move), the delay caused by the machine's slow start/stop adds up to significant lost production time. Furthermore, the sheer size and weight of the mechanism makes it impractical to deploy multiple independent units across a 1m+ working width.

2.2 Electromagnetic Linear Vibration

An electromagnetic coil driven by alternating current generates an oscillating magnetic field, which directly drives the armature (mover) in linear reciprocating motion.

- Frequency range: 100-300Hz
- Amplitude: electronically adjustable, fast response
- Compact construction — fewer moving parts

Fatal flaw for geogrid manufacturing: Thermal runaway. Continuous high-power operation (as required in multi-shift geogrid production) generates intense heat in the electromagnetic coils. Without aggressive cooling, the coils overheat and fail. But adding cooling systems increases complexity and cost. Additionally, the inherent trade-off between force and stroke means that welding wide strips (80mm+) requires impractically high instantaneous currents.

2.3 Critical Comparison: Motor vs. Electromagnetic Linear Vibration

Dimension	Motor-Driven	Electromagnetic-Driven
Frequency	100-200Hz	100-300Hz
Amplitude	Fixed (mechanical)	Adjustable (electronic)
Control precision	Low (mechanical wear)	High (electronic)
Load capacity	High	Limited by coil size
Size & weight	Very large, heavy	Relatively compact
Heat dissipation	Moderate	High — risk of thermal runaway
Start/stop response	Slow (high inertia)	Fast
Multi-head integration	Nearly impossible	Challenging
Primary failure mode	Bearing/linkage wear	Coil burnout / insulation aging

Table 1: Motor-driven vs. electromagnetic-driven linear vibration friction welding.

The conclusion is clear: **Neither motor-driven nor electromagnetic-driven linear vibration welding is a clean answer for geogrid production.** Both introduce engineering compromises that make them difficult to justify for high-speed, multi-point, continuous production lines.

PART III — Torsional Ultrasonic Vibration: The Ultimate Solution

Having identified the limitations of both conventional vertical ultrasound and the emerging linear vibration alternatives, a superior third path emerges: **20kHz torsional ultrasonic vibration.**

This is not an incremental improvement. It is a fundamentally different way of applying mechanical vibration to the weld interface.

3.1 How Torsional Ultrasonic Welding Works

A specially designed torsional horn converts the longitudinal vibration from the ultrasonic transducer into a torsional (twisting) oscillation at the horn tip. The horn tip oscillates in the horizontal plane — a high-frequency microscopic "twisting" motion — while maintaining constant downward pressure on the workpiece.

- Frequency: 20kHz (mature, proven industrial frequency)
- Vibration direction: Horizontal (circumferential twist)
- Amplitude: Micron-level, precisely controlled
- Response time: Milliseconds (inherited from ultrasonic)

3.2 Why It Is the Perfect Answer

Principle-level fiber protection: The vibration direction is parallel to the fiber axis. When the plastic matrix melts under frictional heat, the glass or PET fibers are simply re-embedded in the molten polymer — not sheared or fractured. This is the fundamental scientific advantage of torsional ultrasonic.

Retains ultrasound's speed advantage: At 20kHz, each weld cycle completes in 0.1-0.5 seconds. This matches perfectly with the step-and-weld rhythm of geogrid production lines.

Multi-head cluster capability: Because each torsional horn can be designed as a compact, independent unit, deploying 5-10 heads across a single crossbeam is entirely feasible. A single multi-channel DSP generator controls them all simultaneously.

Rugged and production-ready: No precision guide rails, no force sensors. Simple spring-loaded or compliant mechanisms provide consistent weld pressure and adapt to material thickness variation. This is what geosynthetic manufacturing demands.

3.3 Three-Stage Comparison: Vertical Ultrasound vs. Linear Vibration vs. Torsional Ultrasound

Dimension	Vertical Ultrasound	Linear Vibration (Motor/EM)	Torsional Ultrasound
Vibration direction	Vertical impact	Horizontal reciprocating	Horizontal circumferential twist
Fiber damage (PET/FRP)	Severe — shear fracture	Minimal — fibers preserved	None — fibers re-embedded
Response time	Millisecond instant	100-500ms slow	Millisecond instant
Multi-head cluster	Difficult (coupling issues)	Nearly impossible	Feasible (compact heads)
Sensitivity to material tolerance	High (coupling unstable)	High (needs rigid fixtures)	Low (compliance mechanism)
System complexity	Low	High (mechanical or thermal)	Low
Maintenance cost	Low	High	Low
Energy efficiency	Very high	Moderate	Very high
Production readiness	**Mature**	**Limited**	**In development**

Table 2: Three-generation comparison — vertical ultrasound, linear vibration, and torsional ultrasound.

PART IV — Your Upgrade Path Starts Today

Torsional ultrasonic welding represents the next frontier for geogrid manufacturing. The acoustic stack development and industrial validation require collaborative effort across the supply chain. But that does not mean you must wait.

Start with the Generator — the Foundation of the Future System

Even if your production line still uses conventional vertical ultrasonic welding heads, upgrading to CDXLI's **DSP-controlled ultrasonic generator** delivers immediate benefits:

- Constant power / constant energy modes suppress power overshoot, reducing fiber damage risk
- Millisecond frequency tracking and adaptive control compensate for material elasticity variations
- Multi-channel capability (up to 10 heads) prepares your line for future torsional head deployment

And crucially: **when the torsional ultrasonic acoustic stack completes its industrial development, your generator does not need to be replaced.** Simply remove the vertical horn assembly and install the torsional vibration assembly. Your production line upgrades smoothly, without a capital equipment overhaul.

We are looking for forward-thinking geogrid manufacturers who want to optimize their current production lines with our DSP generators today — and help define the welding standard of tomorrow, together.

Ready to evaluate your production line?

Our application engineers can perform a free welding assessment on your material samples. Contact us:

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