Layered Structures - Innovative Tube/Pipe Manufacturing Process

K. McNeil, C. Ritchie

Techreo: kmcneil@techreo.com, critchie@techreo.com

ABSTRACT

High Performance Tubular Structures (HPTS) is an emerging technology being developed by Techreo in the Cincinnati, Ohio area. HPTS will provide breakthrough performance advantages in a wide range of metal tubular structures, including pipes transporting liquid, gas, or solids, as well as structural tubes. The objective of the program is to provide breakthrough metal pipe and tube performance capabilities while solving key problems that persist with existing pipes/tubes.

Keywords: tube, pipe, lightweight, structures, energy

1 LIMITATIONS OF CURRENT MANUFACTURING

Metal pipes and tubes have been used for over 150 years. The manufacturing methods are mature and refined. While existing tubular products provide proven solutions in a wide range of applications, significant constraints and missed opportunities remain in the following key areas:

1.1 Corrosion Protection

Metal pipes and tubes often convey water, steam, or other materials that are corrosive. They may also be transported, stored, or used in corrosive environments. Corrosion protection is thus often needed on the internal surface and/or the external surface. Many corrosion mitigation approaches exist, from paint and galvanized steel to the use of high performance materials such as titanium or nickel alloys. The best solutions work well but their high cost limits their use. Lower cost options often fail over time. Better options are needed.

1.2 Lightweight and Strength-to-Weight

Metal pipes and tubes are nearly all homogenous structures and the material is usually steel or stainless steel. These materials are very strong but are also very heavy. Options to reduce weight or improve strength-to-weight are generally limited to alternative materials (e.g. aluminum, titanium, carbon fiber reinforced polymer) which have tradeoffs in cost, strength, temperature rating, etc. Again, better options are needed.

1.3 Insulation

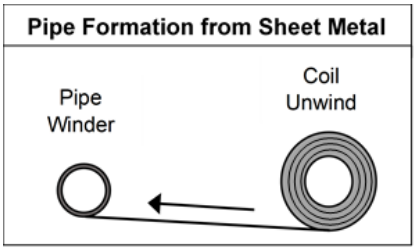
Many piping applications require insulation to control the temperature of the liquid or gas being conveyed or to prevent condensation on the pipe's external surface. The insulation is usually applied around the pipe after installation. The insulation typically helps but often requires ongoing maintenance and/or replacement – far from an ideal solution.

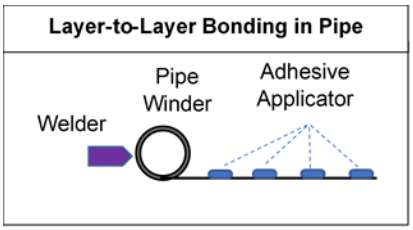
1.4 Energy Consumption

Current manufacturing methods rely on heating metal plates or billets to a malleable ("glowing orange") state and then forming it into a final, cylindrical shape. Once in-service, traditional pipes and tubes with their homogeneous metal walls readily transfer energy, requiring insulation (as described above) or active heating via heat tracing. When the extensive length of installed pipes and tubes are considered in total, the manufacturing and installed energy losses – and potential for reduction using HPTS – are expected to be significant.

2 PROCESS OVERVIEW

HPTS capability improvements are based on a breakthrough manufacturing process that forms each layer of the pipe separately and sequentially by convolutely winding thin sheet metal onto a mandrel. This direct layer-on-layer formation method enables multi-material structures and is conceptually similar to Additive Manufacturing but can be done at much higher build rates (1,000X or more), thus providing a much improved cost structure.





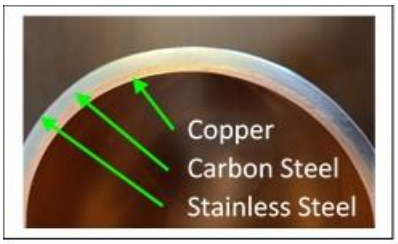
Structural integrity can be created between adjacent layers of the pipe by structural adhesive and/or welding. These methods may be controlled to provide a significant range of any desired layer-to-layer spacing of sheet metal within the pipe wall. This provides the opportunity to create a wide range of asymmetrical pipe wall structures.

3 HPTS SOLVES / ALLEVIATES THE ABOVE LIMITATIONS

Key pipe and tube product opportunities derived from the new process include:

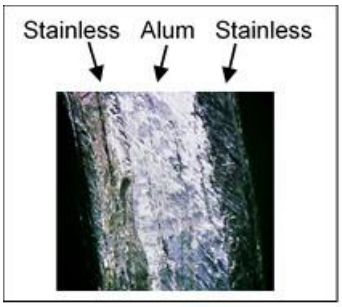
3.1 Customized Corrosion Protection

Any cold rolled metal available in coils may be used to form a pipe. Metals may be rapidly switched during the winding process, thereby enabling the use of multiple metals to form a single pipe wall. For example, the initial wall layers forming the pipe's inside surface may be copper, the middle of the pipe wall may be carbon steel, and the final outer diameter layers may be stainless steel. Many cost effective combinations are feasible.



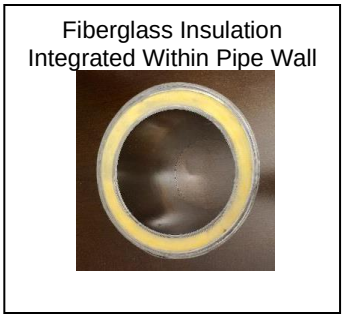
3.2 Lightweight & High Strength-to-Weight

The pipe/tube may be formed to create very lightweight or improved strength-to-weight structures by substituting a lighter material in the pipe wall middle region. Alternatively, the gap comprising adhesive between adjacent metal layers within the pipe wall may be controlled to provide a desired pipe/tube wall density. The incoming metal may also be formed in the z-direction to create voids and further lower density wall structures.



3.3 Built-in Insulation

The wall structure layer spacing described above can also be controlled to provide a significant level of built-in insulation for a pipe or tube (multiple layers of adhesive and air provide the same effect as triple pane windows). The ability to integrate commercial insulating materials into the pipe walls during fabrication is an additional option that provides significant incremental insulation capability. Insulating materials such as aerogel, fiberglass, and closed cell foam may be successfully integrated within pipe walls. All options may be totally integrated within the pipe wall, thereby eliminating costly maintenance.



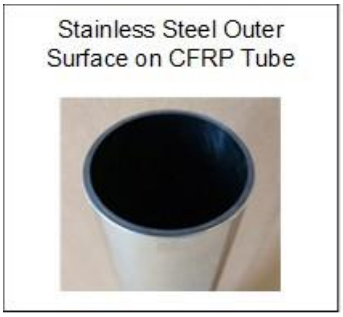
3.4 Energy Efficiency

Replacing current manufacturing methods which rely on significant heating costs ("glowing orange") with a room temperature process will yield significant energy reduction benefits. Other than the energy for servo motors and a very low wattage laser (when necessary), there is comparatively little energy used in the manufacture of HPTS pipes and tubes. The built-in insulation described above dramatically reduces in-service energy losses. These energy advantages are apparent, but the energy consumption of current production methods need to be quantified in order to accurately assess the true opportunities.

The pipe and tube product opportunities described above may be leveraged as stand-alone capabilities or integrated together to create a wide range of structures and features. The flexibility of the new manufacturing process enables customized solutions for most applications.

4 STRUCTURES

Beyond pipes for fluids, HPTS technology also provides performance advantages for high strength-to-weight or low deflection tubular structures. High strength steel may be used in a reduced density laminate structure for improved strength-to-weight. These structures may also be bonded to and integrated with carbon fiber tubes on the outer diameter and/or inner diameter surfaces. The resulting structure leverages the advantages of carbon fiber strength-to-weight while mitigating potential cracks and fractures in the carbon fiber (CFRP) tube due to localized stresses.



5 DEVELOPMENT STATUS

Many key HPTS capabilities have been demonstrated in pilot trials and preliminary lab tests. Research and prototyping efforts are continuing and should provide a more comprehensive understanding of the technology. Current focus areas include geometrical accuracy, strength/deflection, structural density options, bending, couplings, conductivity and insulation, welding vs adhesive bonding, and vibration/noise damping. External labs are being used to validate results.

6 APPLICATION TO INDUSTRY

HPTS technology offers significant advantages for a wide range of industrial and military applications. Metal pipes and tubes are used extensively in vehicles, robotics, buildings, and operation, maintenance, and support systems for a wide range of assets. The new HPTS pipes and tubes will have improved corrosion protection and longer life, be lighter and more fuel efficient, provide higher strength-to-weight, better insulation, more energy efficient, and will be more cost effective.

7 WELCOME

We welcome engagement from interested parties to move this emerging technology forward.

Kevin McNeil
President, Techreo
kmcneil@techreo.com

Charlie Ritchie
Vice President, Commercial Development
critchie@techreo.com