Fibre Reinforced Composite Cross Arms for Transmission Lines

by FRP Transmission Innovations Inc.

Introduction:

Traditionally, transmission line structures have utilized treated lumber, steel, or concrete as a construction material.

Recently it became clear that large quantity of good quality timber for transmission line H-frames was difficult to procure. Particularly after major wind and/or ice storms when suddenly large shipments of timbers are needed for restoration. In addition, high demand creates price inflation for these products.

Quality of timber has declined in recent years as only second growth wood is available, making large size structural pieces harder to come by. Many newly installed wood cross arms fail within a short time and according to some utilities the newly installed timber cross arms are less reliable then some old wood cross arms that have been in the field for a long time.

Utilities started to use galvanized steel as a wood cross arm alternative. It worked well for certain application. Unfortunately, steel is electrically conductive, as is its wood replacement, therefore using it in live line installation is very dangerous. Steel procurement time is currently running around 6 month and the cost of steel increased significantly in recent years due to high demand. Steel cross arms are also very heavy compare to wood. Most of the time Hollow Structural shapes (boxed sections) are specified and their internal corrosion is difficult to monitor.

Over the last decade, new engineered materials have been emerging as an alternative to the old, widely used conventional materials. Two-component polyurethanes are now widely known to exhibit superior strength and toughness and may allow manufacturers to cost effectively produce lighter, stronger and more damage tolerant profiles. [2] These high tech engineered materials show great promise in providing solutions to the old goals of Transmission Structures: giving reliable, cost effective and durable support for conductors, under challenging environmental conditions.

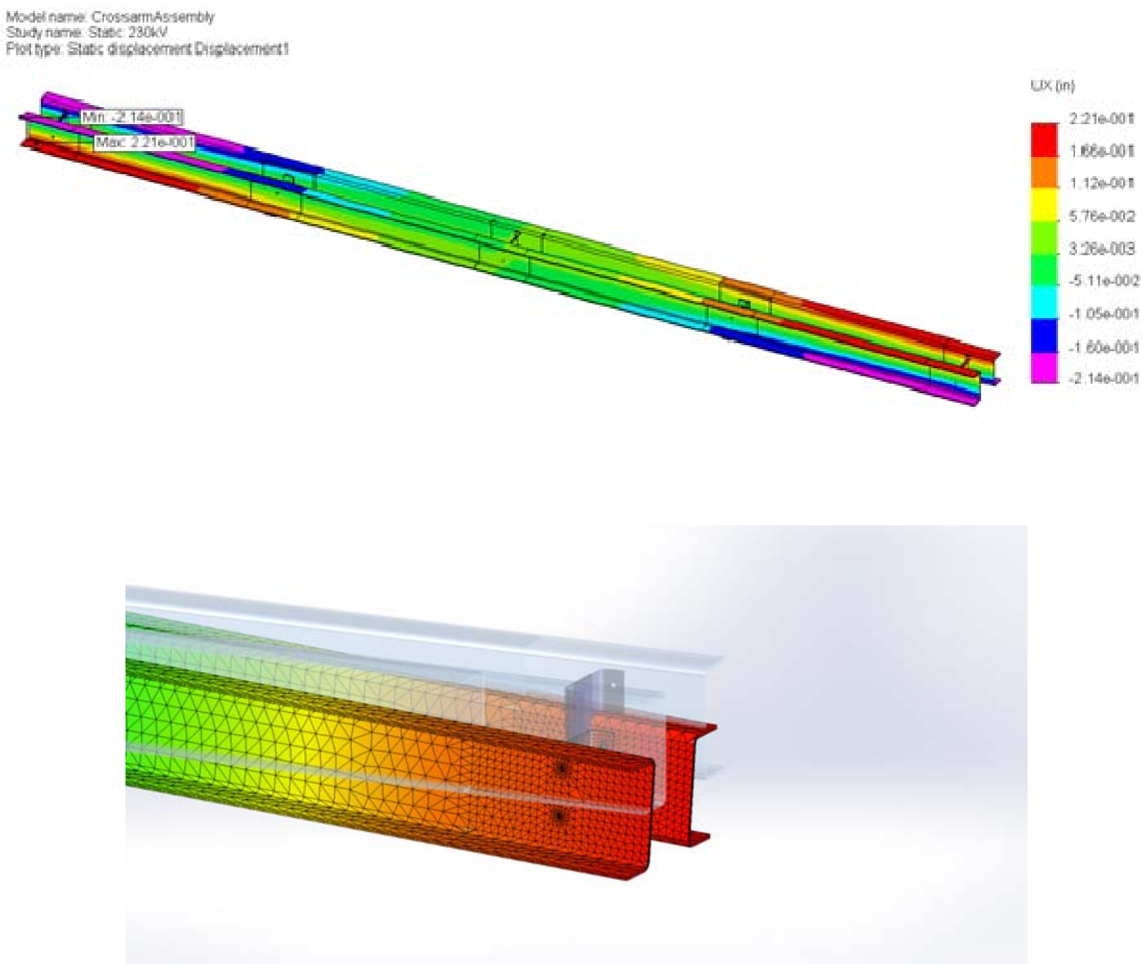
Picture 1. Timber/Wood H-Frame

History of Development of Fibre Reinforced Cross Arms for H-Frames

British Columbia Hydro and Power Authority (BC Hydro) - the third largest utility company in Canada and headquartered in Vancouver British Columbia, Canada – identified the need for replacing wooden and steel cross arms for H-frames with something new. This need was released to the public and several ideas and options were submitted to BC Hydro.

FRP Transmission Innovations Inc. submitted and recommended its cross arm solution. After initial consultation and evaluation a twenty year term collaboration agreement was put in place to do joint BC Hydro and FRP TII research and development, first on new fibre reinforced polymer (FRP) cross arms and later on other products that are needed for the BC Hydro transmission system.

Two new designs were developed for H-frames; one was designed for 138 kV configurations and another larger size for up to 287 kV geometry. Depending upon the load requirements the larger cross arm could be used for 340 kV lines as well.



Picture 2. Images of Finite Element Analysis (FEA) [1] of 287 kV cross arm

A comprehensive third party testing program was developed and performed by BC Hydro, several cross arms were installed in the field gaining experience with field installation, providing feedback opportunities for line crews and to evaluate field performance and ease of construction.

Test program

An extensive accelerated aging, electrical, mechanical, and structural testing program was developed and carried out by Powertech, a research subsidiary of BC Hydro. This test program compared regular wood, steel, Fibre Reinforced Polymer (FRP) composite and other specialty composite material cross arms, the results were published in a report [3]. These test programs clearly show the benefits of FRP composite cross arms. Test results also proved the viability of FRP cross arms in showing their resistance to lightning strikes, bearing structural loads well, and long term durability.

Field installation experience

Field installation was carried out as part of the regular cross arm replacement program and feedback from line crews were collected when they installed several 138 kV, 230 kV and 287 kV H-frame cross arms. Regular cranes as well as helicopter lifting of cross arms were done during these live installations.

Picture 3. Live (energized) installation of FRP Cross Arm with Crane Lift

Picture 2. Live (energized) installation of FRP Cross Arm with Helicopter Lift

Picture 3 Transmission Line Maintenance Technician on the top of FRP Cross arm installing hardware on live (energized) line

The result was that line crews love to work with the new cross arms. Some reasons they expressed:

1. Light weight. It is easy to lift by two persons, easy to move as lifted on the ground.

2. Light helicopter could be used for lifting providing cost effective installation.

3. Fibre reinforced composite cross arms are electrically non-conductive. When installed on live energized lines they do not zap the crews or cause a fault if intermittent phase to poles or phase to phase contact is made, unlike steel or wood cross arms - there is no induction in the FRP cross arm and there is no electrocution hazard. Crew felt safe during live installation. They are safe from accidental live conductor related flash over or other forms of electrical contact from the cross arm.

4. The surface is smooth but not slippery. Personnel can sit on it and there is a comfortable position for leg support at the lower flange. There are no splinters or other surface items that can potentially harm personnel.

5. Easy to field drill and field cut when needed.

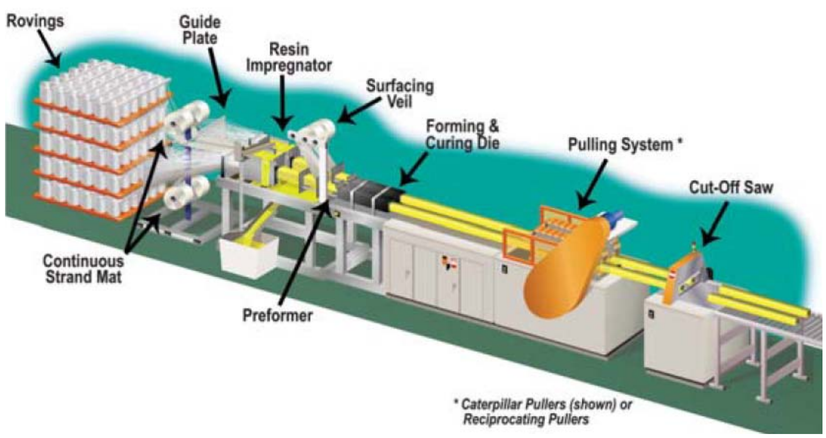
6. Identical hardware used for wood or metal cross arms are used for the FRP cross arms. The only additional item they found useful but not essential in their tool set is a socket extension so they can tighten pole connecting bolts outside the flange plain with 360 degree rotation.

Long term performance

Using new materials and components always raises questions of the long term performance of such items. Accelerated aging test performed by independent laboratory confirmed that FRP TII's two component polyurethane composite cross arms expected life span is over 75 years. This life span is much better than wooden cross arms or galvanized steel with no additional corrosion intervention after the galvanized coating is gone, which is about 35 years in most urban environments.

Manufacturing

FRP TII is a Canadian company and has a strategic alliance partnership with Creative Pultrusions Inc. (www.creativepultrusions.com) in the USA. This well regarded facility produces high quality pultruded products, specializing in high pressure injection of polyurethane resin pultrusions. CPI has been in business for forty years and manufactures our cross arms, creating high technology, sustainable and good quality American manufacturing jobs. The plant is located in rural Alum Bank, Pennsylvania.The facility operates on a 24 hour, seven days a week work schedule, shutting down only for holidays and maintenance. The facilities are climate controlled and are well maintained by their facility engineering staff. The plant is also centrally located for transportation connections, which makes it easier to respond to urgent supply demands and helping utilities in urgencies supporting their recovery needs.



Picture 4. Schematics of Pultrusion Process in Manufacturing of Cross Arms

Picture 5. Factory Drilling of Holes for Hardware Connections for 287 kV H-frame Cross Arm

Cost benefit of using FRP cross arms

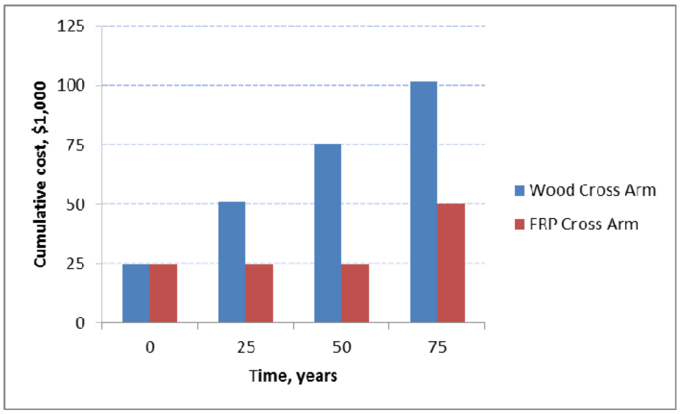
The largest cost of replacing cross arms is actual replacement cost from crew time going to site (which could be quite expensive if helicopter only site access is the only way due to rough terrain), wooden cross arms need to be replaced in about 25 to 40 years depending upon environmental conditions and the original quality of timber. FRP cross arms provide the possibility to skip up to 2 replacement cycles compared to wooden cross arms. In overall life cycle cost analysis this is a very significant savings.

There is a very simplified life cycle cost calculation here. More detailed site, jurisdictions and utility specific models could be developed easily.

Example of cost saving with 75 year life expectancy of FRP TII cross arms

Assumptions:

- Wood cross arm costs about the same as FRP cross arm all the time.
- During 75 years a wooden cross arm has to be replaced every 25 years
- Replacement cost of a wooden or FRP cross arms are about $25,000 (non-emergency planned cross arm replacement. In case of emergency replacement required cost could be easily twice as much)
- Initial installation: $25,000
- First replacement of wood cross arm after 25 years of first installation (cost is at the initial installation cost): $25,000
- Decommissioning chemically treated cross arm in special disposal $500
- Second replacement of wood cross arm after 50 years of first installation (cost is at the initial installation cost): $25, 000
- Decommissioning chemically treated cross arm in special disposal $500
- Third replacement of wood cross arm after 75 years of first installation (cost is at the initial installation cost): $25, 000
- Decommissioning chemically treated wood cross arm in special disposal $500



Picture 6. Cumulative Cost of Wood and FRP Cross arms over 75 years

	Treated Wood Cross Arm	FRP Composite Cross Arm
First Installation	$25,000	$25,000
First replacement of wood cross arm at 25 years	$25,000	
Disposal of chemically treated timber cross arm	$500	
Second replacement of wood cross arm at 50 years	$25,000	
Disposal of chemically treated timber cross arm	$500	
Third replacement of wood cross arm at 75 years	$25,000	
Disposal of chemically treated timber cross arm	$500	
First replacement of FRP cross arm at 75 years		$25,000
Recycling of FRP Cross Arm		$100
Sum	$101,500	$50,100

Using FRP TII Cross Arms and skipping 2 replacement cycles could save the utility over $50,000 on one structure. On 1,000 structures this is a $50 million savings over 75 years. The saving covers many times the cost of the FRP TII cross arms!

<u>Asset management advantages</u>

FRP TII cross arms could be manufactured in relatively short order providing good quality structures in large quantities needed for utilities. Current lead time could be from as low as 3 weeks.

FRP TII cross arms are environmentally inert there is no leaching of chemicals into the environment. At environmentally sensitive areas using FRP TII cross arms is very important. Some environmental groups embraced FRP TII structures in bogs, wetlands and similar regions.

In case FRP TII cross arms have to be disposed (preferred option is recycling) they could go to general landfill [4]. Nothing from the cross arms will contaminate the environment.

Vandalism is a concern for some transmission operations. FRP TII cross arms proved to be quite resistant to ballistic projectile damage (gun shots). At testing many bullets simply bounced off from them. Even very close range large size bullet damage of the cross arms do not cause structural failure. [5]

In warm high humidity environments where treated wood does not last very long, steel corrodes very quickly, FRP TII cross arms are a very attractive choice in this situation.

Raptor protection

At some transmission operation areas raptor protection is a particular concern, when they land on energized steel transmission cross arms their wings bridge over distances between conductor phases and metal cross arms causing injuries and loss of wild life. Utilities have to pay significant penalties; also it is a public relations challenge when dealing with wildlife death or injury. Using FRP TII cross arms, due to their electrically non-conductive nature such accidents and issues are preventable.

Conclusion:

New Fibre Reinforced Composite Cross arms were developed jointly by FRP Transmission Innovations Inc. and BC Hydro. These new structural elements were extensively tested in the laboratory, and have been used in the field for several years, showing great promise for wide use all over the world.

Bibliography

[1] BCTC 287kV H-Frame Crossarm Finite Element Analysis Report, 2008 by Creative Pultrusion Inc.

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[3] Powertech Laboratories, "Testing and Performance Evaluation of BC Hydro Cross Arm Alternatives – Transmission Innovations Cross Arms," BC Hydro, Vancouver, BC, Canada, 2011.

[4] FRP Transmission Innovations, "Recycling and Disposal Information of FRP Transmission Innovation Cross Arms, Cross Bracings and Poles," FRP TII, Vancouver, BC, Canada, 2012.

[5] FRP TII, "Ballistic Withstand Test of Cross Arms," FRP TII, Vancouver, BC, Canada, 2013.

For additional information please visit FRP Transmission Innovations Inc. website at

www.transmissioninnovations.com