Carbon Fiber and Composites Manufacturing

U.S. Department of Energy
Manufacturing Automation and Recycling for Clean Hydrogen Technologies
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'ex scientia excellentia'

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Overview - Topics

- The Hydrogen Economy “Headlines”
- Implication of Required Scale:
  - Compressed Gas Storage Manufacturing
  - Critical Materials

- End of Life
  - Reclamation of high-value materials (CF)
  - Next Life

Hydrogen Economy Headlines

Massive green hydrogen hub in Utah wins $504M federal loan guarantee

DOE's Loan Programs Office backs a project that will convert renewable power to hydrogen, store it underground and use it to generate [illegible] Utah and Los Angeles.

Saudi Aramco plans new green hydrogen, ammo[illegible]ct

HEMPSTEAD, NEW YORK
PROVIDENCE, RHODE ISLAND
MANSFIELD, MASSACHUSETTS
HARTFORD, CONNECTICUT

NEW HYDROGEN STATIONS IN NORTHEAST USA

First ever gigawatt-scale electrolyser order confirmed for offshore wind-powered green hydrogen project

Europe's Largest Port Plans To Become A Major Hydrogen Hub

POWERING PROGRESS WITH SHELL HYDROGEN

Watch the Shell Hydrogen heavy duty refuelling launch here as we will look at the future of hydrogen in mobility and how, together, we can accelerate the shift to a lower carbon transport system.

Korea Hydrogen Economy Roadmap 2040

LOTTE Chemical Constructs Hydrogen Tank Commercialization Pilot Process Facility: By FuelCellsWorks December 2, 2021

Hydrogen Economy Headlines

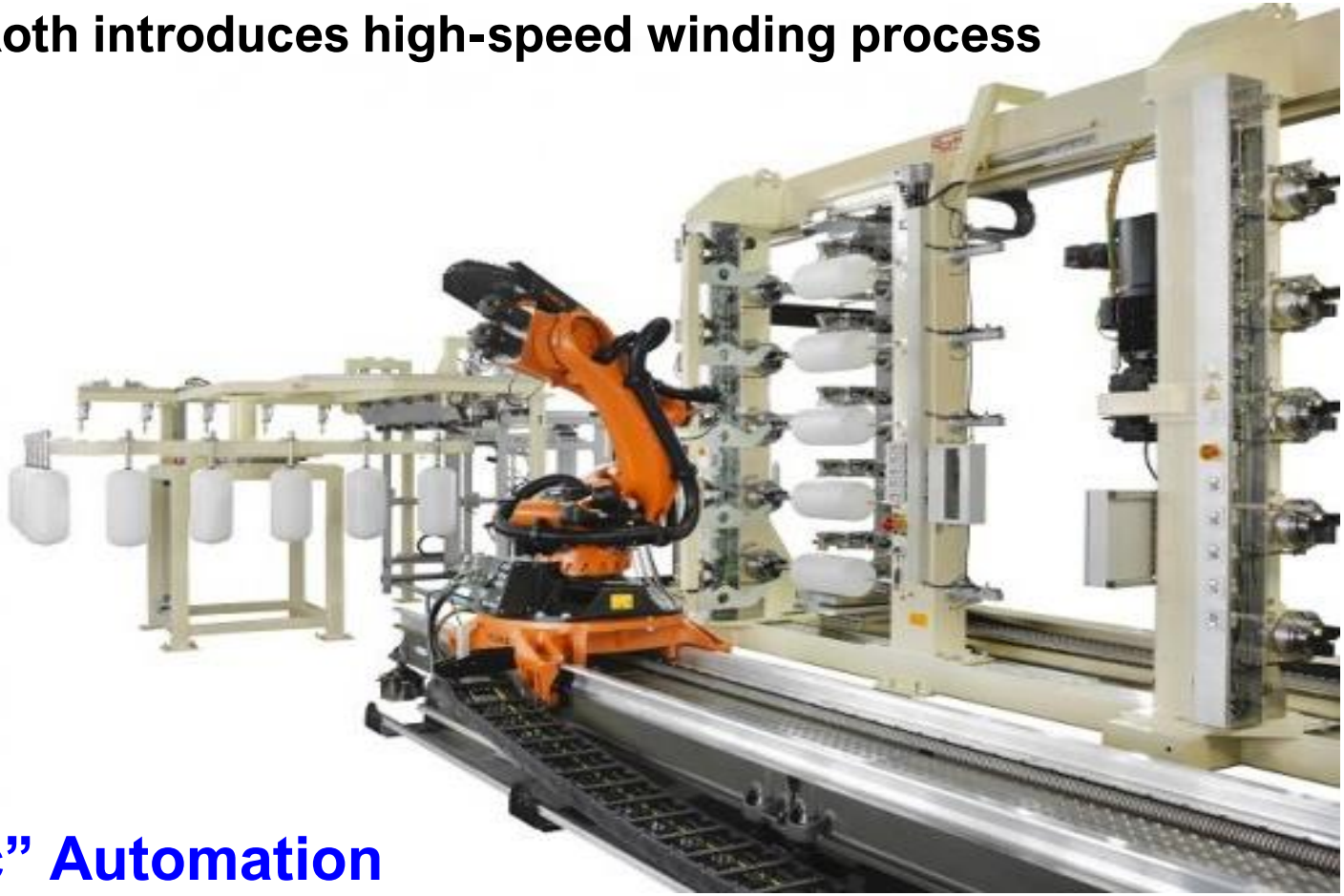
LOTTE Chemical Constructs Hydrogen Tank Commercialization Pilot Process Facility
By FuelCellsWorks December 2, 2021

"Hydrogen storage containers used for hydrogen EVs (FVEC) are core parts requiring **safety and reliability at very high pressures** of approximately 700bar.

LOTTE Chemical announced its eco-friendly hydrogen development road map '*Every Step for H2*' on July 13 stating that it will supply about 30% of the domestic hydrogen demand while achieving carbon neutral growth by 2030, and it also announced its plans to mass produce **100,000 hydrogen tanks in 2025, and expand production to 500,000 by 2030"**

Manufacturing Automation: COPV

Roth introduces high-speed winding process



“Robotic” Automation

COPV Manufacturing: Process / Throughput

Number of COPV Required	100,000	Units/ year	
COPV Volume	52	L	
Composite Mass/tank =	24	kg	
CF Mass per tank =	16.8	kg	*(~ 70% mass fraction)*
Number of Spindles/ Winder =	3		
Machine Hours / annum =	5054	hours	
(3 shift operation/ 81% efficiency)			

Process	Winding Payout Speed			Fiber Lay-down rate, kg/hour	Required Winding Time (Hours/annum)	No. of Winding M/cs required
	meter/sec	meter/min	Ft./min			
"Wet" Winding	0.50	30	98	8.9	62,851	13.00
	1.00	60	197	17.8	31,425	7.00
	1.50	90	295	26.7	20,950	5.00
"Dry" Winding	2.00	120	394	35.6	15,713	4.00
	3.00	180	591	53.5	10,475	3.00
	5.00	300	984	89.1	6,285	2.00

2400 MT composite (net); ~ 1,700 MT CF Capacity

Comparing Dry vs. Wet Winding: Performance

Parameter	Units	COPV Manufacture By	
		"Dry" Winding	"Wet" Winding
Internal Volume	Liter	52	52
Operating Pressure	bar	700	700
Design Burst Pressure	bar	1575	1575
Carbon Fiber		T720SC36K50C (J8X18C1)	T720SC36K50C (J8X18C1)
Resin		Epoxy towpreg	Std. Epoxy
COPV Wall thickness (composite)	inch	0.726	0.730
	mm	18.4	18.5
COPV Mass (w/o Liner)	lbs	52.6	53.5
	kg	**23.9**	**24.3**
Burst Pressure, Average	bar	**1608**	**1275**
Burst Pressure, Std. Dev	bar	**21**	**101**
Burst Pressure, CV	%	**1.3%**	**7.9%**

Takeaways: “Translation”; “Debottlenecking”;
Low CV ~ lower CF consumption

Critical Materials

- Carbon Fiber:
  - Current Global Capacity ~ 115,000 MT/A
  - Projected Global Capacity (2030) ~ 230,000 MT/A

Adequate to meet Global Green Hydrogen Economy Aspirations ?

- Carbon Fibers Suitable for 700 Bar COPV Applications:
  - High Strength [750-850 kpsi]
  - "Higher" Modulus [35 – 40 Mpsi]
  - Tow-size
  - "True Fiber Properties" & Translation
  - Matrix for Designed for Translation &Reclamation

End-of-Life

Consider “carbon-fiber rich” applications coming out of service:

To The Boneyard…?

- Reclamation/ Recovery: (Pyrolysis; Solvolysis)
- Recover carbon fiber in continuous form
  - Property Knockdown?
  - Next-Life Use ?

Thank You