Coming soon: PU tires?

A new, innovative process will soon allow a Chinese company to re-tread large tires for earth movers avoiding the use of natural rubber. A two-component Polyurethane elastomer will be injected in a mould containing the used tire, and a new tread will be cast over the existing sides and substrate. The whole operation will be extremely less capital intensive, less time consuming and by far more energy efficient than the traditional rubber reconstruction.
The whole process has been set up by the US-based Amerityre, who is licensing the Qingdao-based Qingdao Qizhou Rubber Product Co. Ltd. to use its innovative technology. The Cannon Group has been selected to supply the Polyurethane metering and mixing equipment for this large project in China.
The large, dedicated machine required to cast the two-component Polyurethane formulation is manufactured by CTM, the UK-based equipment specialist distributing Cannon machines for the British market. The supply of the casting equipment, start-up, after-sales technical service and the supply of spare parts is jointly provided by a number of companies of the Cannon Group, which is directly present in all the countries where this project has been developed and will be executed. This article presents the basic concepts of this Polyurethane-based tire, the testing results of the first industrial applications, a description of the process and necessary equipment, and a marketing vision concerning the potential applications of this new technology. New tires – and not only for heavy duty vehicles – could be made out of PU very soon now!

AMERITYRE - Tire Technology for the 21st Century

Amerityre was founded in 1995: initially the company developed "closed cell" Polyurethane foam used for low duty cycle applications. These include bikes, wheelbarrows, lawn & garden, and various other applications. In early 2001 Amerityre Corporation began the idea of making a Polyurethane car tire, something that others thought and determined to be impossible. Amerityre made several Polyurethane elastomer tires and mounted them on a small pick-up truck. The tires were test driven for thousands of miles but the tires did not contain any reinforcement materials. In August 2001, Amerityre commenced an endeavour to create a Polyurethane elastomer tire with reinforcement materials. At this point the goal was to produce a Polyurethane pneumatic car tire. After analyzing the performance characteristics of the Polyurethane elastomer materials Amerityre changed directions.
In October 2003 the company decided to design the more challenging "Arcus" tire. The Arcus design can run for hundreds of miles without air. This tire design is comparable to Goodyear's EMT. The "Arcus" tire design is one of the most difficult – if not the most difficult – designs to obtain Department of Transportation approval and is considered to be one of this companies "best" rubber. This is the same tire used on the Corvette and various other models. The focused research and development effort to produce a Polyurethane car tire with plies, beads, and belts culminated in April 2004. Amerityre announced that FMVSS 109 testing had been successfully completed on the "Arcus" Polyurethane car tire. The first tire made out of urethane to ever pass this demanding test, and the material exceeded all expectations. The Amerityre tire ran 51F degrees cooler than rubber on the high speed test. The urethane tire ran roughly 10F degrees above ambient room temperature on the high speed test. Also the urethane tire had 43% lower rolling resistance. This means 10% greater fuel efficiency. Simply put the urethane tire was better than rubber in ALL tests.

Big tires, big opportunities: re-treading the worn out OTR – off-the-road – tires is a very lucrative business!

The Chemistry

Amerityre has formulated a proprietary Polyurethane elastomer material that has the physical properties necessary to be used as a superior car tire material. Two chemicals – Methylene Diphenyl DiIsocyanate (MDI) and Toluene DiIsocyanate (TDI) – are used worldwide to produce Polyurethanes. Through years of experimentation and testing, Amerityre has formulated a MDI-based Polyurethane elastomer that can withstand the heat generated from higher speeds and loads, and compete very favourably with a processed rubber compound on a cost basis and is environmentally safe.

The moulding process occurs when the liquid Polyurethane formula (made up of Isocyanate and Polyol) is combined with a catalyst. This combination causes a chemical reaction that results in the cross linking of the chemicals, which thereafter becomes solid. When the spinning stops, the mould is opened, the tire is removed and the process is repeated.
The Polyurethane compound use in the Arcus car tire is more environmentally friendly than rubber. It is chemically inert and safe for humans, and will be 100% recyclable. The Polyurethane industry has devised several technologies for recovering and recycling Polyurethane waste materials.

Table 1: Specific data derived from the FMVSS 109 "high speed" test performed on the "Arcus" car tire.

Air Pressure (psi)	38/38		38/38			
Ambient Temp (°F)	**89.0**	**93.1**	**90.3**	**93.0**	**93.9**	**94.7**
Test Load (lbs)	970	970	0	970	970	970
Actual Load (lbs)	970	970	970	970	970	970
Test Speed (mph)	0	50	0	75	80	85
Check Time	09:50	11:30	13:50	14:20	14:50	15:20
Test Miles	0	100	100	137.5	177.5	220
Test Cycle Hrs	0	2.0	2.0	0.5	0.5	0.5
Total Hrs.	0	2.0	2.0	2.5	3.0	3.5
Sidewall Temp (°F)	N/A	**105.5** **100.0** **102.1**	N/A	**107.1** **103.3** **103.8**	**109.0** **104.2** **104.0**	**109.0** **106.0** **106.0**

Notice that the Arcus running temperatures range between 100° to 109° Fahrenheit. Rubber tires typically run between 150° - 170° F.

High heat is also the primary mode of failure for tires designed to run flat. Lower operating temperatures will translate into
better run-flat characteristics of the Arcus car tire design, the data in Table 2 shows comparative temperature data derived by Amerityre in testing the Arcus tire design against a rubber extended mobility tire. The Arcus and rubber extended mobility tires were mounted to the front of a Corvette and driven at 55 mph for 2 hours.
The data shows the Arcus car tire ran, without air, cooler than the extended mobility tire.

Table 2: Comparative testing data – Arcus vs. Rubber tire.

	Amerityre PU tire (A)	Rubber Control Tire (B)	Mileage	Tire A (°F)			Tire B (°F)		
				Outside Shoulder	**Center Line**	**Inside Shoulder**	**Outside Shoulder**	**Center Line**	**Inside Shoulder**
Tire size	R247/45R17	P245/45ZR17	**Start***	**85**	**85**	**85**	**95**	**95**	**95**
Tire Name	Arcus	Extended mobility	**10 Miles**	**115**	**110**	**106**	**130**	**140**	**130**
Tire Construction	Radial	Radial	**25 Miles**	**120**	**115**	**110**	**200**	**195**	**205**
Rim Size (in.)	17 x 7.5	17 X 7.5	**50 Miles**	**122**	**117**	**112**	**218**	**195**	**205**
PSI	0	0	**75 Miles**	**134**	**118**	**110**	**222**	**195**	**206**
Tire Weight (lbs)	30.5	29.7	**100 Miles**	**148**	**125**	**114**	**228**	**201**	**221**

The Revolution

The next step forward in the revolution is to invent the technology for mass production.
The manufacturing process developed by Amerityre is not like traditional rubber tire manufacturing in that high external heat is not required: the exothermic reaction that results in the cross linking of the chemicals generates the high internal cure temperature to manufacture the desired Polyurethane compound.
Because of the simplicity of a liquid phase technology, production of Polyurethane car tires requires far less manufacturing equipment than is used in producing a conventional rubber tire. The Polyurethane tire factory of the future will have no Banbury mixers, no calendars, no extruders or vulcanization presses. Amerityre's equipment package is 1/10 of traditional rubber equipment with the same output.

The Process

Amerityre manufactured the prototype Polyurethane elastomer car tires utilizing a moulding machine that centrifugally casts the tire by pouring a predetermined amount of Polyurethane into a spinning mould.
The liquid Polyurethane then spreads out in the mould through centrifugal force. Prior to pouring the Polyurethane elastomer material into the tire mould, the reinforcement materials (i.e. plies, beads, and belts) necessary for tire construction are suspended within the mould cavity and locked into place. Therefore with every tire the plies, beads, and belts will be spaced perfectly.…every time.

The Moulding Equipment

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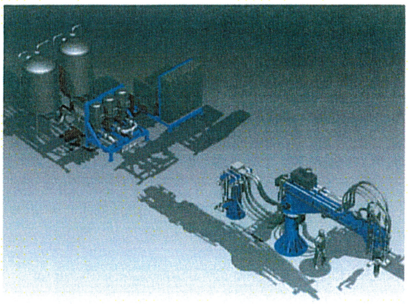


A low-pressure, VERY high-output dosing unit is needed to dispense PUR elastomeric material in a re-treading mould for OTR tires!

This machine centrifugally casts the tire by pouring a predetermined amount of Polyurethane into a spinning mould. Due to understandable concerns to protect this manufacturing method, the details of the spinning mould are released only to the licensees of this technology.
The performances required to the metering machine for this process are peculiar, and very demanding.

The First Major Project, in China

The Qingdao-based Qizhou Rubber Product Co. Ltd. Company showed interest towards Amerityre's new process for a project that includes the re-treading of off-the-road and large trucks tires, in the order of magnitude of 10,000 pieces per year. This huge manufact will have dimensions in the range of 2,500 mm to 3,300 mm of diameter, widths of 650 to 1,140 mm, maximum load from 23,000 to 42,000 kg, for a RIM size from 19" to 36". Working initially with one mould at the time, with open pour method first, the Company plans later to go to closed mould injection, due to the total amount of PU required by a single tire.

A two-component formulation based on chemicals developed by Amerityre, characterized by a gel time from 1.5 to 3.5 minutes, depending upon the chemistry used and the tire dimension, needs a very high-output metering machine and a very efficient mixing head.

Due to the very large shots requested by the largest feasible tires this machine must guarantee a maximum output of 1,500 kg/min with an extremely precise and repetitive shot size. Equipped to provide a process operating temperature of 60 deg C (140 deg F) this machine will initially operate at a much lower temperature, around 37 deg C (100 deg F).

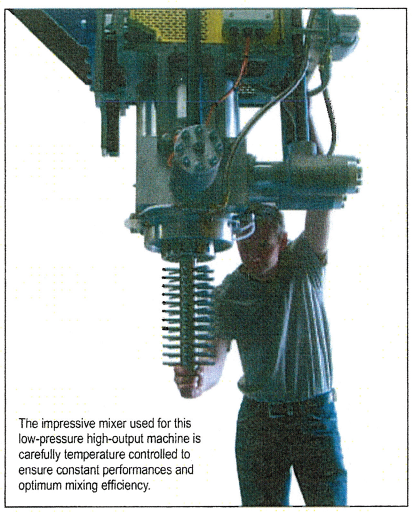
The selection of a suitable supplier for such a critical equipment had to go beyond the availability of a properly working machine.
The American operations of Cannon – a fundamental link for the contacts with Amerityre – are responsibility of Cannon USA, based near Pittsburgh, Pennsylvania.
Prompt and qualified local technical service is a must for a factory that must guarantee a continuous production: the Far East network of the Cannon Group includes a manufacturing centre in Southern China and three service offices in Beijing, Shanghai and Guangzhou, all featuring expert PU technicians speaking the local language and used to the local mentality. This global coverage and the availability of the proper technology were the key to success to secure a contract for the supply of the metering and mixing section of the plant destined to the Qingdao-based Qingdao Qizhou Rubber Product Co. Ltd. Company.
One of the Companies cooperating as local agent for Cannon Solutions (UK) – CTM – has long experience in manufacturing large dosing machines for special elastomeric applications.

The "closed loop" metering machine supplied for this project includes:

1. Two large carbon steel tanks for the chemical components, insulated externally and built with a conditioning jacket, where hot water can keep the chemicals at a temperature of up to 95°C. Their working capacity allows for several hours of uninterrupted moulding operations, at a maximum working pressure of 6 bar. The tanks have a vacuum system to allow for the complete degassing of the components prior to the start of the production, to avoid entrapment of air in the formulation and guarantee for an air-bubble-free tire as a result. Small air bubbles are detrimental for the life of the tire, since they tend to heat up the tread when rolling. Slow speed blade agitators provide thorough temperature conditioning throughout the tank.
2. Two temperature-conditioning units (48 KW for Polyol and 24 KW for Isocyanate) enable heating of a full tank of material from 50° C to process operating temperature

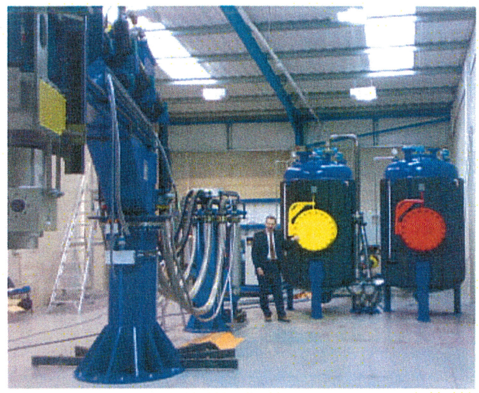
The impressive head holder is more than 4 meters high!

of 60° C in approx 10-15 minutes. In addition to supplying water directly to the component tank, the heaters also supply water to a manifold system for pipe heating.
3. Interconnecting rigid, water-jacketed piping with insulation and flexible joints to and from the metering group.
4. A single 27Kw package chiller cooling unit provides cold water to the heating units of both the Polyol and Isocyanate tank conditioning units so as to aid temperature stability control.
5. A generous pumping system to feed the mixing head: based on large, water jacketed gear-type pumps, it allows for maximum output 1,250 l/min of Polyol and 600 l/min of Isocyanate. These components are handled, at the operating temperatures, to a maximum viscosity of 1,500 cps, and can be fed at a maximum working pressure of 30 bars. Proper sets of digital gauges are installed on the line to ensure that minimum feed pressure to pump is maintained and maximum system pressure of 30 bar is not exceeded.
6. A special mixing head is needed to handle this massive output rate: this model is of a well-proven design and offers greater output versatility when processing at high outputs and or with higher viscosity systems.
Feed pressures are maintained via manually adjustable flow restrictors; this facility is particularly useful when processing materials of very low viscosity.
Manual calibration is possible directly at the mixing head via a calibration plate that mounts directly onto the face of the mixing head for 'wet' weight calibration checking.
An inverter rated 2-pole 2800-rpm motor directly drives the mixing head, so as to be able to not only vary mixer speed, but also run the cleaning and flush cycle at a different speed for maximum cleaning efficiency.
The mixer barrel is fitted with a water-cooling jacket to avoid excessive heat build-up during the mixing phase.
The two mixing head component pistons are mechanically linked so as to avoid opening and closing timing issues.
Hot water from the component Polyol component tank is fed to the mixing head to keep it always at the right temperature and ensure immediate operation when required.



The impressive mixer used for this low-pressure high-output machine is carefully temperature controlled to ensure constant performances and optimum mixing efficiency.

7. Two solvent cleaning systems are foreseen for flushing the mixing head at the end of a pouring cycle: the larger is directly connected to a 200 l drum of solvent (to avoid frequent refilling of a small solvent tank), while a second and completely independent solvent cleaning system is designed for emergency use only.
8. All interconnecting pipe work is suitably sized to avoid excessive pressure drops. A rigid carbon steel piping links the metering group to the mixing head. The feeding pipes from the component tanks are kept as short as possible and jacketed in the same manner as described for the mixing head feed piping. All piping are supplied with water jackets and insulation so as to ensure that no cold spots occur. Heating water from each respective component tank heating system is fed to the respective feed and return pipe jackets.
9. The main power section control panel is sited on the metering group frame. This panel houses the inverters and main switchgear. The main power section control panel is cooled via a heat exchanger connected to the 27 Kw chiller unit. A separate desk type panel houses the control system hardware. All functions will be accessed via a Siemens TP 270 10" touch screen monitor. A Siemens S7 300 series PLC with digital I/O drives the whole machine, ensuring the correct flow of components via suitably sized mass flow meters fitted to each component feed line. Flow, temperature and mass measurement are linked back to the plc processor via a Profibus network. The software programme monitors the desired flow against actual flow and make adjustments via the pump inverters so as to ensure correct output and ratio is maintained at all times.
10. All the process parameters (chemical's specific gravities and batch numbers, output, ratio, theoretical shot weight, actually dispensed mass, temperatures, pressures, alarms, production statistics, etc.) are displayed and stored onto a flashcard data storage system for downloading to a PC in file format Microsoft Excel.



Large components tanks are required, when the moulded part weighs several hundreds kilos..

The equipment has to be commissioned in China later this year, and will start full production of re-treaded tires before the end of 2007. Later Qizhou plans to start the construction of a full Polyurethane tire of large dimensions. This move – if successful – could lead the way to further developments, up to the mass production of certain types of commercial tires.

The Future: PU Tires Under Our Cars?

This new process enables a tire to be made that has no entrapped air bubbles. Now and only now can a "perfect" tire be manufactured again and again. This new process utilizes a very limited manufacturing surface, and requires almost no warehouse space, if the production schedule is well planned. It takes approximately 30 minutes to manufacture a rubber tire.....while only a few minutes with Amerityre's process.
The chemical reaction is exothermic and no external heat is required in the moulding operation.
At $.05 per Kw a 30 pound rubber tire consumes $3.00 in electricity cost. A similar 30 pound urethane tire's electricity cost is only $0.1 There can be tremendous cost savings across the entire manufacturing process.
The capital equipment expense is a fraction of a traditional tire plant with the same output, and the low capital equipment cost enables a non-tire company the opportunity to become one. There are a number of factors still opposing to the massif use of Polyurethanes in automotive tires: the grip, first. But not necessarily the PU layer should be used in contact with the road... there are ways around it! And there are projects, as well. Talk to us: we're dealing with them, already!

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