The discovery of polycarbonates (PC brand name Makrolon by Covestro AG) by Hermann Schnell of Covestro AG in 1953 opened an era of new material for a wide range of applications. Formed from monomer under chemical processes, PC characters break-resistant, light-weight, transparent, robust, dimensionally stab and high heat-resistant in the form of granules, sheets or film, enabling the material to be applied in the screens of computers, smart-phones and flat-screen displays, DVD or CDs, windows, building structures such as stadium transparent roofs and road noise barriers, automotive glazing and bodywork parts, and medical devices. Especially, merited by extreme robustness, light-weight with glass-like transparency, impact resistance at extremely low temperatures, high dimensional stability and excellently high-resistance with the glass transition temperature up to 148 °C, PC has won favour by the automotive and transportation industry and its applications have becoming more extensive.

A PC-made panoramic roof cuts weight by up to 50 % compared to glass roofs, resulting in a marked decrease in green-house gas emissions. The high impact resistance of PC also offers a vital safety benefit. There is great potential for functional integration, and the design freedom allows new forming possibilities. Utilising a high-gloss PC bezel allows manufacturers to
maximise the glass-like surface area of a panoramic roof. The strength and transparency of Makrolon makes this unique design possible.

For decades, car headlamps were made of glass. From the 1980s the transparent high-performance plastic Makrolon has become the material of choice – being lightweighted, tough and easy to shape. Then in 1998, Makrolon was first applied to automotive glazing for Smart rear window. Now the panoramic roof of Bugatti, solar-powered vehicle roof developed by Webasto AG, the spoiler on Audi A7, the panoramic tilt roof for Volkswagen, the roof of smart fortwo and the multi-functional auto trim strips for Gerhardi are made of a range of PC products. To achieve high resistance to abrasion, acratching and ultra violet exposure/weathering, a coating is an effective way of protesting PC in automotive glazing application. The PC performance on fire resistant can be improved by the addition of fire-retarding additives into the material.

The application of PC can extend to automotive lighting, featuring high heat resistant, low specific gravity, excellent transmission and good impact strength of the material. Moreover, its good flow property enables the lighting parts with thin wall design. Another possibility is using injection moulded thermal conductive PC as heat sink for LED lighting. Not only can it offer thermal conductivity as high as 22 W/m-K, it also features light weight, high degree of mouldability and competitive production cost. The high thermal conductivity of PC could also be found valuable to cooling batteries on electric cars.

PC components are commonly made by the injection moulding, which can be simulated by Computer-Aid Engineering (CAE). Moldflow is one of the standard CAE software packages for simulating the behaviour of PC in the whole process of injection moulding, starting from filling (inject melted PC into the mould cavity to form the component shape), cooling (from the melt temperature as high as 300 °C to around 80°C before eject the part from the mould) and warpage (deformation after part ejection). Moldflow can achieve high accuracy which can help to avoid injection moulding related problems such as excessive warpage, sink mark, short shot and high internal stress inside the component across the production process right in the design stage. Moldflow can also simulate thin wall, two component, gas-assist, sequential, injection-compression and film-insert moulding.

At the design phase, it is possible to evaluate the part performance under static, thermal and linear/non-linear loading conditions with the aid of mechanical CAE analysis. For automotive applications, analysis can extended to crash, noise and vibration hardness and creep. CAE thermal analysis can help to shorten the lead time in production for thick lens used in automotive lighting.

In summary, endowed with excellent mechanical properties, transparency and mouldability, PC is a promising material for automotive components such as PC window, interior and exterior component. Not only it can reduce the weight of vehicles, but also help cutting fuel consumption and green-house gas emissions, while keeping strength, safety and style.CAE simulation can evaluate the performance of PC-made automotive components in the manufacturing and application stages, minimising defects and design errors. More extensive applications of PC on vehicles are on the horizon.

IMechE Hong Kong Branch thanks Mr. Jeff Ho, Senior Engineering Specialist, Polycarbonates, Application Development of Covestro (Hong Kong) Limited and his Covestro colleagues for their generous delivery of the lecture.
*** END ***

Encl.
WHT
IMechE Event – Covestro Features

Application of CAE Simulation in Developing Automotive Polycarbonate Parts

October 20th, 2017

Jeff Ho
Main production sites
Key data 2016

Employees
Key data 2016

Covestro has a workforce of around 15,600* employees worldwide.

Employees are primarily in production, marketing, sales and administration, in research and development.

* Converted into full-time equivalent
Group results
Key data 2016

EBITDA: earnings before financial result, taxes, depreciation and amortization

€11.9 bn  €2.01 bn  €0.8 bn
Sales  Core volume growth  Adjusted EBITDA  Net income

+7.5%

October 20  Application of CAE Simulation in Developing Automotive Polycarbonate Parts

RESEARCH FOR TOMORROW'S WORLD
Key element of the strategy

Innovation

Teams of inventors at Covestro constantly work on new materials, production and finishing processes as well as solutions for applications.

Solid basis

Innovation

Around 1000 employees in research and development worldwide

Large innovation centers in Europe, North America and Asia

Approx. 260 million EUR spending for research and development

Cooperation with universities, incubators, customers and suppliers around the world

Needs-based project pipeline through systematic innovation process and consistent industrial marketing
Long tradition
Innovation – 1937-2000

1930's

1937
Otto Bayer discovers polyurethanes

1939
Kuno Wagner invents crosslinking agents for light fast polyurethane coatings

1953
Hermann Schnell discovers polycarbonates

1954
Kuno Wagner invents crosslinking agents for light fast polyurethane coatings

1959
Moltopren® adopted by fashion industry

1962
Polyurethane rigid foam launched as insulation for cooling devices

1967
Bayer presents the first car made almost entirely from plastic

1969
Moltopren® adopted by fashion industry

1970
Makrolon® used in optical storage media

1982
Special grade of Makrolon® used in optical storage media

1985
First Bayblend® flame retardant grades for business machines

1990
First auto-motive glazing application for the Smart rear window

1991
Introduction of memory foam in mattress industry

1995
Introduction of Makrolon® based films for high security documents

2000's

2001
Construction start at Covestro integrated site at Shanghai, China

2010
Significant investment in expansion of Shanghai site

2011
Shanghai TDI plant with new gas-phase technology

2012
Introduction of microcell technology, with improved insulation efficiency

2013
Replacing epoxy resin by PU resin for wind blades

2014
INSQIN® waterborne PU for synthetic leather and other coated fabrics

2015
First bio-based cross-linker (PDI)

2016
New facility for foam components based on CO2 at Dormagen site, Germany

October 20 | Application of CAE Simulation in Developing Automotive Polycarbonate Parts

INTERNAL
Portfolio
At a glance

Polyurethanes
- Raw materials for rigid and flexible foams

Polycarbonates
- Granules and sheets for a wide variety of applications

Coatings, Adhesives & Specialties
- Raw materials for coatings, adhesives and specialties

Basic Chemicals

Polyurethanes (PUR)
Products and solutions

Flexible foam
- Upholstered furniture
- Mattresses
- Car seats
- Flexible
- Hard-wearing
- Lightweight
- Readily moldable

Rigid foam
- Insulating materials for buildings and cooling devices
- Insulating
- Rigid
- Lightweight

Thermoplastics
- Sports and leisure
- Automobile components
- Tough
- Flexible
- Resistant to cold and heat

October 20 | Application of CAE Simulation in Developing Automotive Polycarbonate Parts

INTERNAL
### Coatings, Adhesives, Specialties (CAS)

**Products and solutions**

<table>
<thead>
<tr>
<th>Raw materials for surface coatings</th>
<th>Raw materials for adhesives and sealants</th>
<th>Raw materials for specialties</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Automotive/transportation,</td>
<td>• Shoes, textiles</td>
<td>• Cosmetics</td>
</tr>
<tr>
<td>• Flooring</td>
<td>• Furniture</td>
<td>• Medical devices</td>
</tr>
<tr>
<td>• Furniture</td>
<td>• Automotive/transportation</td>
<td>• Textiles</td>
</tr>
<tr>
<td>• Infrastructure</td>
<td>• Construction</td>
<td>• Sports and leisure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Durable
- Protective
- High-gloss/matte
- Easy to process
- Low emissions
- Widely adjustable
- Gentle on the skin
- Flexible
- Functional

---

### Polycarbonates (PCS)

**Products and solutions**

<table>
<thead>
<tr>
<th>Granules</th>
<th>Sheets</th>
<th>Films</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Computers</td>
<td>• Roof structures</td>
<td>• Automotive glazing</td>
</tr>
<tr>
<td>• Smartphones</td>
<td>• Windows</td>
<td>• Bodywork parts</td>
</tr>
<tr>
<td>• Flat-panel displays</td>
<td>• Conservatories</td>
<td>• Medical devices</td>
</tr>
<tr>
<td>• DVD/CD</td>
<td>• Partition walls</td>
<td></td>
</tr>
</tbody>
</table>

- Break-resistant
- Lightweight
- Transparent
- Dimensionally tough
- Heat-resistant

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**October 20**

**Application of CAE Simulation in Developing Automotive Polycarbonate Parts**
Polycarbonate

It is extremely robust, lightweight with glass-like transparency and is impact resistant – even at extremely low temperatures. It has a high dimensional stability and is easily molded, yet has excellent heat resistance with a glass transition temperature of up to 148°C.
Modified Polycarbonate or Blend

Apec®
Apec® the high heat polycarbonate is most suitable for applications that must withstand high temperatures and exhibit toughness, impact resistance and high transparency.

Bayblend®
Bayblend® (PC+ABS; PC+ASA blend) offers an ideal combination of mechanical and thermal properties for automotive, electrical/electronic, household, sports and IT applications.

Makrolon®
Makrolon® polycarbonate comprises a broad portfolio of lighting, optical, medical and food contact, flame-retardant, impact-modified and glass-fiber reinforced grades which generate high-performance and sustainable properties.

Makroblend®
Makroblend® (PC+PET; PC+PBT blend) is ideal for applications requiring the toughness of polycarbonate coupled with improved chemical resistance.

Applications
Panoramic roof benefits from polycarbonate glazing

OEM: Bugatti
Industry: Automotive & Transportation
Application: panoramic roof of a car
Product: Makrolon®AG2677 polycarbonate
Technology: Automotive Glazing

- High toughness
- Good heat resistance
- Glass-like transparency, optical quality
- High dimensional accuracy and stability
Applications
Lightweight polycarbonate glazing roof

OEM: Webasto AG
Application: Webasto AG solar-powered vehicle roof
Product: Makrolon® AG2677
Technology: Automotive Glazing

✓ Weight reductions up to 50 percent compare to glass.
✓ Better insulation, reduce energy consumption for heating.
✓ Boost the travel range of electric vehicles

Applications
Premium material for premium cars

OEM: Audi
Application: Spoiler
Product: Makroblend® UT235 M (PC+ PET blend)
Technology: Two component molding

✓ Strength, UV protection and chemical resistance to gasoline and cleaning agents.
✓ Paintable, high-quality, Class A surface with uniform surface quality to match adjacent metal parts, and a low-gap design.
✓ Very low coefficient of linear thermal expansion (CLTE), high heat resistance, improved flow and an excellent surface.
Applications

Single-part tailgate with integrated backlight

Supplier: Covestro
Application: One-part tailgate with backlight
Product: Makrolon® polycarbonate
Technology: Injection molding

✓ Complete, one-part tailgate design with backlight module.
✓ Seamless outer skin.
✓ Potentials for cost reduction by simplifying assembly and logistics.

Applications

Large roof bezel uses polycarbonate

OEM: Audi, Volkswagen
Application: Panoramic tilt roof
Product: Makrolon® 2605 polycarbonate
Technology: Injection compression molding

✓ Glass surface twice as large as a traditional sunroof.
✓ One-piece, U-shaped panel.
✓ Deep, black gloss effect and a glass-like, scratch-proof surface.
✓ Three-dimensional glazing components.
Applications
Auto interiors with a personal touch

Supplier: Gerhardi
Industry: Automotive
Application: Multi-functional auto trim strips
Product: Makrolon® polycarbonate,
    Bayblend® (PC+ABS; PC+ASA blend),
    Makrofol® polycarbonate film
✓ Matte and high-gloss structures
✓ Attractive colors with gloss effect
✓ Outstanding coatability
✓ Excellent metallization
✓ Scratch resistance
✓ Production efficiency with film insert molding

Applications
Automotive lighting

Product: Apec® (high heat polycarbonate)
✓ High heat resistance
✓ Lower specific gravity
✓ Excellent transmission
✓ Good flow properties
✓ Good impact strength
Applications

Heat sinks

To meet the need for efficient cooling, Covestro supplies a high-performance Makrolon® polycarbonate for injection-molded heat sinks. This Makrolon® based grade offers a thermal conductivity up to 22 W/m·K

- Reduced weight of LED light engine
- Strong heat-transferring capability
- High level of design freedom
- Cost-effective production

Other possibilities
CAE Analysis Used in Automotive

Injection Molding Process CAE Simulation

Standard injection molding process

• Filling
• Cooling
• Warpage
CAE Analysis Used in Automotive
Injection Molding Process CAE Simulation

Molding defects…
• Warpage
• Sink mark
• Short shot
• High internal stress

CAE Analysis Used in Automotive
Injection Molding Process CAE Simulation

Special molding process
• Thin wall molding
• Two component molding
• Gas assist molding
CAE Analysis Used in Automotive

Injection Molding Process CAE Simulation

Special molding process
- Sequential molding
- Injection compression molding
- Film insert molding

Structural CAE Simulation

- Static analysis
- Thermal expansion
- Linear/non-linear
CAE Analysis Used in Automotive

Structural CAE Simulation

• Crash simulation
• Noise & vibration harshness (NVH)
• Creep

CAE Analysis Used in Automotive

Thermal CAE Simulation

• Thickness optimization for Lens
• Heat transfer analysis
BY 2050 THE FLEET OF PASSENGER CARS MIGHT INCREASE FROM AROUND 900 MILLION TODAY TO OVER 2 BILLION.

Source: Shell Passenger Car Scenarios until 2040, 2014

Mobility
Global trends

Our answer:
Products from Covestro help to construct lightweight vehicles, reducing fuel consumption.
Renewable energies – Solar Impulse

Sustainability

SUN IN THE TANK

Covestro is among the sponsors of the Solar Impulse project – flying without fuel.

- Ultra-lightweight polyurethane foams for the cockpit and batteries
- Extremely thin polycarbonate sheets for cockpit window
- Specialty adhesives for composite material

Purpose

At a glance

To make the world a brighter place.

- We develop state-of-the-art polymer materials, that can do more.
- We help push boundaries by supplying innovative and sustainable products, technologies and solutions for key industries and modern life.
Thank you for your attention

Jeff Ho
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covestro.com

Forward-looking statements

This presentation may contain forward-looking statements based on current assumptions and forecasts made by Covestro AG.

Various known and unknown risks, uncertainties and other factors could lead to material differences between the actual future results, financial situation, development or performance of the company and the estimates given here. These factors include those discussed in Covestro’s public reports, which are available on the Covestro website at www.covestro.com.

The company assumes no liability whatsoever to update these forward-looking statements or to adjust them to future events or developments.
Evening Lecture

“SIM-TO-REAL” FOR CARS

Computer Aided Engineering (CAE) permit both time and cost savings in process and product development. With the outstanding properties of polycarbonate together with CAE simulation, vehicle components like this one have reduced weight by up to 50 %, contributing CO₂ emission reduction and the stylish appearance.

Please come and join our technical lecture to learn more about CAE analysis for polycarbonate in the automotive industry.

Date: 20 October 2017
Time: 19:00 to 20:30
Venue: N001, The Hong Kong Polytechnic University

For registration, please scan the above QR code or visit IMechE webpage: http://nearyou.imeche.org/near-you/north-east-asia/hong-kong/events

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