Mass balanced raw materials for sustainable cast elastomers

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Abstract

Sustainability and circular economy are key strategies of Covestro. Benefitting from internal knowledge and resources in terms of alternative raw materials, Covestro has developed a consistent and valuable mass balance approach for its cast polyurethane products. This mass balance concept is based on alternative sourcing and strict tracking of raw material usage in our production plants. Our formulations, being a prepolymer, formulated polyol or chain extender, could then be identified on the market, by our customers but also technology end users, as a sustainable alternative. A global certification launch has already been initiated and will enable Covestro to offer mass balance certified products starting from 2023 globally.

Introduction

As a molder of cast polyurethane elastomers, what techniques exist for improving the sustainability of the final product? One technique which has been explored is the addition of post-industrial and post-consumer cast polyurethane elastomer waste to new cast polyurethane elastomer parts. This method involves the collection of elastomer waste, mechanical shredding and grinding of the waste, and the reincorporation of the waste into new parts by using commercially available regrind dosing equipment with a conventional cast PU elastomer casting machine[1]. A recent example of this technology was developed for mining screens, which involves redesigning cast polyurethane mining screens to allow for mechanical recycling of the mining screens at the end of life and then reincorporating this recycled content into new mining screens. While there are certainly merits to the mechanical recycling approach, there are practical limitations to this approach as well. In the mechanical recycling approach, there are limitations to the total concentration of recycled cast polyurethane elastomers based on machine processing constraints and performance requirements of the elastomer in the end application.

The integration of alternative feedstock derived materials into existing value chains is an additional method for improving the sustainability of the final cast polyurethane elastomer. The mass balance approach is a chain of custody method that allows conventional fossil based and alternative feedstock based raw materials to be mixed in production by the chemical supplier but kept separate from an

accounting perspective. This mass balance approach can track the alternative feedstock materials through the value chains and allows attribution of alternative feedstock, like bio-based raw materials, to selected end products, such as prepolymers, polyols, and chain extenders that are relevant to the manufacturing of cast polyurethane elastomers[2]. The mass balance approach can be also be used together with the mechanical recycling approach to offer enhanced sustainability for cast polyurethane elastomers. The purpose of this technical paper is to review the mass balance approach as it relates to the relevant raw materials used for cast polyurethane elastomers and how Covestro will look to implement this methodology in commercial products.

Key attributes of the mass balance approach

The mass balance approach for chemical value chains is defined by the 'chain of custody' method which is used for the accounting of fossil based versus alternative feedstock-based raw materials used in the manufacturing process. Having traceability of the concentration of alternative feedstocks makes the mass balance approach quite convenient for the end user. By adopting this 'chain of custody' method, alternative feedstocks can be mixed with traditional fossil-based feedstocks but kept segregated by bookkeeping. Another benefit of the mass balance approach is that it allows the value chain to integrate alternative feedstocks into existing manufacturing processes, without the need for additional investment for physical infrastructure. While the concept of mass balanced raw materials is an emerging area within the polyurethane industry, it has already been adopted in a diverse range of industries including palm oil, soy, sugar, cotton, timber, and biofuels[3]. Both the Forest Stewardship Council and the Better Cotton Initiative have implemented the mass balance approach for sustainable initiatives.

The defining feature of the mass balance approach is the method of bookkeeping. This style of bookkeeping is referred to as the 'chain of custody' method, which enables the value chain to track the alternative feedstocks. Figure 1 shows a visual representation of the mass balance 'chain of custody' method, below.

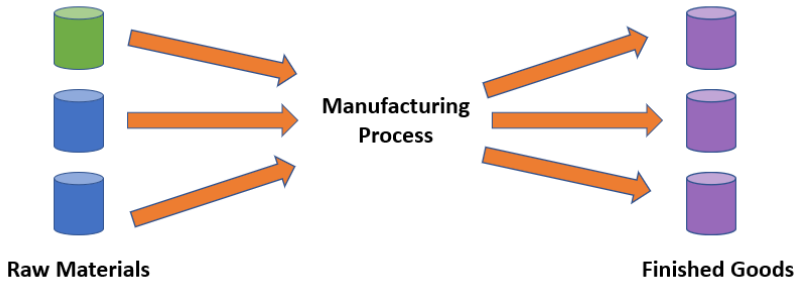

Figure 1 - Mass balance 'chain of custody' model

Figure 1 demonstrates a generic mass balance model with various raw material feedstocks entering the value chain on the left, mixing in the manufacturing process, then resulting in an output that may contain varying ratios of the alternative feedstocks. Since these feedstocks will be mixed during the manufacturing process, and not physically segregated, it becomes impossible to determine the precise

ratio of alternative feedstock to fossil feedstock in any given finished product. In order to compensate for the lack of physical traceability, this mass balance approach allows the total inbound quantity of alternative feedstocks to be attributed to the finished goods through auditable bookkeeping. By using this bookkeeping method, a specific quantity of alternative feedstocks can be attributed to a finished good, even though the physical concentration of these feedstocks cannot be determined.

Transparency through certification

The use of the mass balance approach relies on accurate bookkeeping to ensure traceability of the incoming raw material feedstocks, which are then attributed to finished goods. In order to provide transparency across the value chain, chemical suppliers can use certification programs to give confidence to the attributions of alternative feedstocks in the finished goods of their products. Covestro is now using the International Sustainability & Carbon Certification (ISCC)'s system for mass balance. ISCC is a globally recognized certification system, which offers solutions for the implementation and certification of sustainable, deforestation-free and traceable supply chains of agricultural, forestry, waste and residue raw materials, non-bio renewables and recycled carbon materials for the mass balance approach. The ISCC's certification system is applicable to the complete value chain and enables traceability for alternative feedstocks along the entire value chain. Figure 2, below, illustrates how ISCC's certification can be implemented at each stage of the value chain.

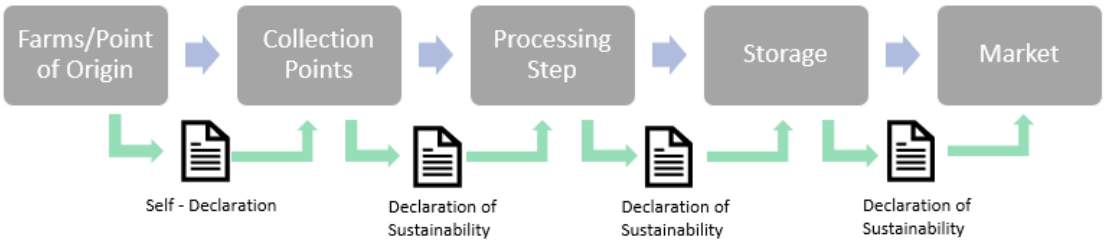

Figure 2 - Example of ISCC's system across a value chain

According to the ISCC, they have issued over 33,000 certificates for over 4,500 system users, in over 100 countries around the world[4].

What does mass balance look like for Covestro?

Isocyanates are a critical monomer for polyurethane prepolymer manufacturing, so these raw materials see special attention for developing alternative feedstocks. Bio-based feedstocks for isocyanates are one promising technology that lends itself towards incorporation into prepolymers via the mass balance approach. As a first approach, isocyanates derived from crops are qualified for MDI and TDI based prepolymers, but next generation feedstocks will look to incorporate waste-based raw materials as a

precursor. A typical process for the incorporation of bio-based feedstocks into MDI prepolymer production in illustrated in Figure 3, below.

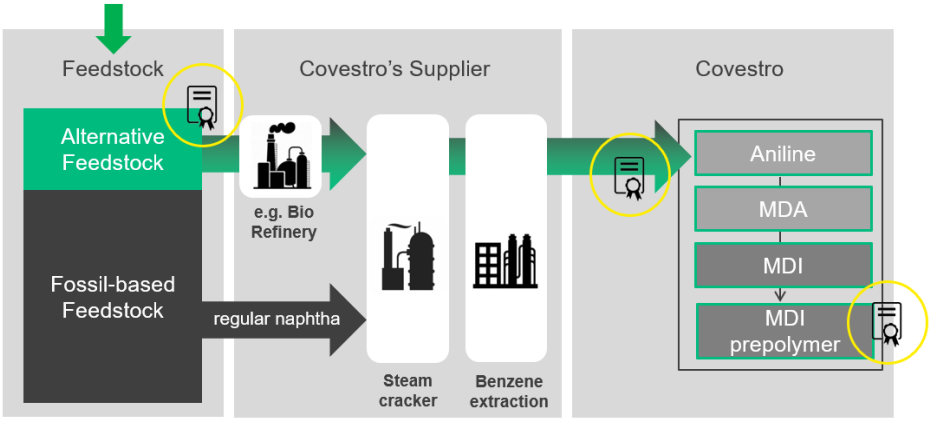

Figure 3 - Process diagram for the incorporation of bio-based feedstocks for MDI prepolymers

Traditional MDI production relies on aniline that is sourced from benzene, a raw material that is derived from petroleum. In the bio-based alternative, unrefined sugar can ultimately be converted to aniline, eliminating the need for a fossil-based petroleum precursor. This unrefined sugar can be sourced from feed corn, straw, and wood which is then converted by microorganism (*Cornyebacterium Glutamicum*) catalysis to aminobenzoic acid, which is then catalytically decarboxylated into bio-based aniline[5]. This is one route to create a bio-based MDI which can then be incorporated into MDI prepolymers via mass balance.

The first batch of a bio-attributed TDI via mass balance is set to be delivered to a customer in the first quarter of 2022, with end uses in mattresses, pillows, and mattress toppers[1].

In addition to utilizing the mass balance methodology for isocyanate production, Covestro also will incorporate mass balanced alternative feedstocks for polypropylene glycol (PPG) polyols, polyester polyols, and polytetramethylene ether glycol (PTMEG) polyols for use in prepolymer synthesis and as co-reactants in cast polyurethane systems. Bio-attributed 1,4 butanediol is also being investigated as a potential for mass balanced chain extenders for cast polyurethane manufacturing. As mentioned previously, the key method for mass balance verification is the ISCC certification, which will accompany the prepolymer, polyols, and chain extenders that carry the mass balance designation. Depending on the attributed bio content values of the individual raw materials used for the formulation, a final attributed bio-based content can be assigned to the cast polyurethane elastomer, as illustrated in Figure 4 for a 2 component system, below.

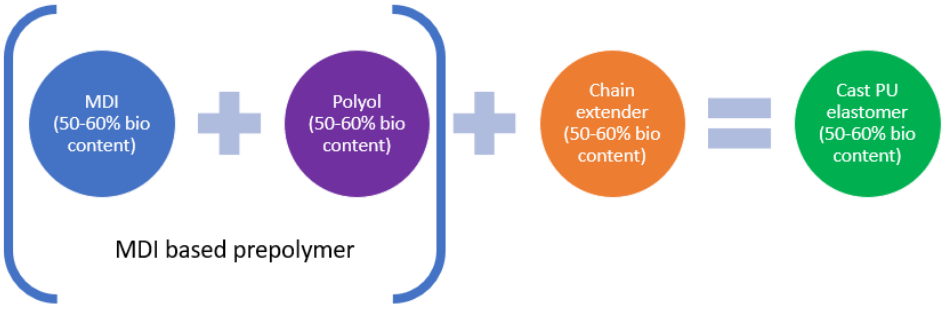

Figure 4 - An example of bio based attribution for a cast PU elastomer

Conclusion

The incorporation of raw materials from alternative feedstocks for cast polyurethane using the mass balance bookkeeping method offers another method for cast elastomer manufacturers to implement sustainable solutions into their product lines. This mass balance approach allows the cast elastomer manufacturer to incorporate bio-attributed raw materials, without any additional investment, and with corresponding certification to verify the reported values. Mass balanced materials for the cast polyurethane elastomer industry will become another tool for molders to adopt sustainable practices, and by doing so, lowering the carbon footprint of their end products.

References

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