Harmony in Innovation: Integrating Sustainable Practices into Chemical Reaction Engineering

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Highlights

- Renewable energy transforms chemicals production; Casale integrates best practices in designing in laboratory for green technologies development.
- Sustainable development harmonizes resource use, technology, and institutional change for future needs.
- Laboratory experiments tailor made for the development of green technologies are an important asset for technology development.
- AmoMax®-Casale is the first ammonia synthesis catalyst validated for green conditions with sustainable reaction engineering practices.

1. Introduction

The rise of renewable energy is poised to revolutionize chemicals production. Countries like Australia, Chile, and Brazil are surpassing forecasts in green energy adoption, signaling a shift toward more sustainable processes where green electricity is the leading or only source of energy. However, this shift introduces significant challenges, particularly in dealing with the variability and seasonality of renewable energy. Reducing greenhouse gas emissions linked to industrial activities hinges on transitioning the energy production sector towards cleaner and carbon-neutral methods of electricity generation. Within this context, companies such as Casale are actively embracing sustainability as a mission to reduce plant footprint and optimize resource utilization. As part of its commitment to addressing energy transition challenges, Casale prioritizes sustainable approaches in plant design. This includes the incorporation of green and blue technologies aimed at minimizing environmental impact and advancing towards a more sustainable future [1]. In this context, sustainability practices are becoming a strong driver in the design of a plant, green reaction engineering is essential to transform the current solutions in sustainable technologies driven by digitalisation, energy utilization, waste reduction and recycling, consumer demand. To achieve a balance among the economy, ecology, and society, strategic and thoughtful sustainable designs are essential, and new laboratory practices need to be developed. Sustainable practices in reaction engineering entails a methodological approach focused on optimizing resource use, product lifecycle, and societal benefits in alignment with the principles of sustainable development.
For this reason, in Casale were developed laboratory solutions that meet the above needs to help the transformation of the current technologies. The utilization of the AmoMax®-Casale helps the transformation maximizing the resources in a sustainable approach and helps a fast transition towards green applications.

2. Methods

Sustainable metrics and sustainable practices were applied in the investigation of the AmoMax®-Casale catalyst. To ensure the AmoMax®-Casale catalyst's suitability for green applications, extensive testing was conducted under stationary green and dynamic green conditions at laboratory scale. New laboratory protocols were developed to be aligned with the SDGs goals and to define new sustainable practices in reaction engineering. Casale Developed a dedicated laboratory set-up that helps the transformation of sustainable solutions by perform dedicated experiments to meet the actual challenges posed by the green technologies. Indeed, the new laboratory set-up has the aim to maximize the resources and find enabling solutions for the design on green ammonia plants. The new laboratory set-up was designed to run in full automation mode and to collect data easily to be understood and used. Moreover, to meet the new demands given by the energy intermittency a test protocol to validate gray ammonia synthesis catalyst for green application was developed.

3. Results and discussion

Catalytic tests were designed to meet the following sustainable metrics: energy saving, recyclability, reduction of utilization of raw materials, resources optimization. In particular for the resources optimization, a long-term stability test was conducted over extensive hours at high temperature (referred to T_{max} in Figure 1) to isolate the effects of temperature from dynamic conditions. The deactivation, in terms of catalytic activity measured at high temperature, is reported in Figure 1 with an orange line.

To optimize the resources, a stability test that lasted for many hours at high temperature (called T_{max} in Figure 1) was done to separate the effects of temperature from dynamic conditions.

A Cycles with controlled T_{max} with a constant heating and cooling rate of 110°C/h (1.83°C/min) was performed. In this phase, a series of temperature cycles with ramp up/down to the higher temperature identified (T_{max}) reached in the catalytic bed were executed. More than 600 cycles reaching the T_{max} were executed and compared with the long-term stability tests. The behavior of the catalyst within temperature cycles is reported in Figure 1, marked with the blue line.

A comparison between the relative activity drop during the long terms test at T_{max} and temperature cycling tests is reported in Figure 3 and revealed that:

- With cumulative hours spent at high temperature, the data obtained are aligned, with a similar decrease in %NH_3 relative activity (-7.6% for long term tests at high temperature and -6.9% for temperature cycles). Assuming a logarithmic trend for both the data sets and comparing the slope of such trendlines, it can be observed that the velocity of catalyst deactivation is equal, even if the absolute value of NH_3% decrease seems to be slightly different.
- According to these results, it seems that the cycles damps catalyst deactivation due to the temperature (less time spent at high temperature).

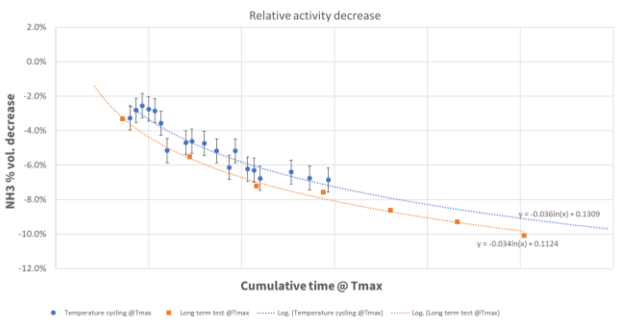

Figure 1. Comparison between Long Term Stability Test at T_{max} (orange line) and Dynamic conditions Test- Cycle at T (blue line) at laboratory scale. Trendlines are reported in dot lines for both tests.

4. Conclusions

Plant design meeting sustainability goals focuses on creating industrial facilities that minimize environmental impact while maximizing efficiency and social benefits. The integration of renewable energy into ammonia production requires a deep understanding of power profiles and the ability to manage variability and seasonality, and the impact on catalyst activity. The development and rigorous testing of specialized catalysts, such as AmoMax®-Casale, are essential steps in overcoming these challenges and achieving reliable and efficient green ammonia production. Through these efforts in sustainable practices in laboratory experiments and in reaction engineering, the chemical industry is ready to embrace greener practices, paving the way for a more sustainable future.

References

[1] https://casale.ch/sustainable-solutions/

Keywords

Sustainability practices, ammonia synthesis, laboratory experiments, technology validation,