Process Intensification and Throughput Increase

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Abstract
Globalization and the need for continuous process improvement are driving process intensification and throughput increase. Stress Engineering Services, Inc. (SES) is committed to supporting its clients with design, analysis, testing, and engineering services at all states of a client’s efforts associated with process intensification and throughput increase. Through its multi-disciplinary approach, the experience team at SES pulls together the right combination of expertise to support any client in making the transition from traditional processes to new processes of the future.
Background
Process intensification is a topic at the forefront of industry conversations about performance improvement. The goal of process intensification is to reduce the volume or scale of production while maintaining the integrity or performance of the end product or good that results from the process. While the chemical processing industry has already taken strides toward process intensification, others such as food, pharmaceutical, and consumer products industries are on the leading edge of their own efforts toward following suit.

Process intensification offers the opportunity to achieve many benefits, such as:

- Increased throughput with a smaller manufacturing footprint
- Lower capital expenditure and lower operating costs
- Improved process control and process efficiency
- Greater process safety
- Improved product quality

The throughput increase and a small manufacturing footprint are achieved by using a continuous process versus a traditional batch or semi-batch process. Thus, process intensification requires development effort and risk mitigation to ensure technical success.

Continuous Processing
Continuous processing is attracting significant attention as a plausible solution for many existing processes. They are viewed as a way to improve efficiency and quality by helping manufacturers to achieve the following measureable outcomes:

1. *Smaller footprint and lower capital cost*: Continuous processing requires fewer holding and processing stations. In a continuous processing environment, it is possible to carry out processes such as reactions and blending on a smaller scale by utilizing the energy of the moving feed stream. Multiple units can be run simultaneously to generate the desired throughput. These factors result in a smaller footprint and lower capital costs.

2. *Improved control and product quality*: Continuous processing has the benefit of operating the process in a steady-state, thereby reducing variability. The lack of transients provides more control and consistency, so product quality is consistent with no batch-to-batch variability as compared to traditional batch processes. There is much more homogeneity in the process providing improved and consistent product quality.

3. *Improved process safety*: Additional advantages of continuous processing include greater process safety and the opportunity to perform reactions that cannot be run under batch methods. Since this is a steady-state process, the risk of runaway transients is minimal.

For continuous processing, scale-up is typically simpler, leading to much shorter commercialization time. In some cases, commercial-scale production is achieved in the same equipment used for development by performing longer runs. In other cases, continuous processing units are used in parallel to achieve large scale production.
Mixing Processes
Mixing is a key process in several industries and applications. Mixing can be carried out in batch and continuous processing. A traditional batch blending process involves mixing components in a tank, typically one at a time. This approach requires holding tanks and, due to batch-by-batch processing, is generally limited in throughput. An alternate to batch blending is continuous blending; this is an effective approach to achieve high throughput, reduce cost, and reduce waste. In a continuous blending process, the components are mixed together in a continuous stream which eliminates the need for bulk storage vessels. Higher throughput, reduced capital cost, reduced operating cost, and reduced facility are achieved through the process. A continuous mixing process is also more conducive to product changes and Clean-in-Place (CIP) technology. CIP is of great importance to the food and pharmaceutical industries.

In a continuous process, the feed streams are combined in a moving fluid stream. Often turbulence in the flow stream is not adequate to mix the components/feed streams properly; a solution is to use properly sized static blenders. The sizing and location of the static blender is a key aspect of inline blending. An improperly placed mixing element can lead to inefficiencies, product quality issues, and reliability issues (Figure 1). Computer-based predictive analysis is applied to design and determine proper placement of mixing element.

![Improperly Designed Inline Blending](image)

**Figure 1: Results of a series of simulations for the development of inline blending equipment**

The development of a continuous blending process poses several challenges. To minimize the trials for process development, to minimize material consumption during trials and to mitigate risk, computer-based predictive methods are applied to develop an understanding of the process and establish the process boundary. Continuous processing also requires an understanding of several aspects such as:

- **An understanding of pumping requirements**: If the pumping requirements are not understood the risk of damaging the equipment and components such as pumps is increased.

- **Reduce material use by minimizing trials**: A continuous process requires a continuous stream of raw materials and any extraneous trial-and-error can lead to significant waste of raw materials.

The cost and time to develop a process can be minimized using informed decisions based on science and fundamental laws of physics. Computer-based predictive analysis combined with customized testing can be applied (Figures 2a and 2b).
Figure 2a: Customized testing for blending

Figure 2b: Computer-based predictive analysis for mixing
SES Commitment

SES is committed to supporting its clients to get it right the first time as they work toward making the transition from batch to continuous for process intensification. SES has the tools, experience and expertise to support the various stages of development, as shown in Figure 3.

Data Gathering
- Develop requirements, current knowledge

Basic Engineering
- Conceptual engineering, energy/material balances, overall layout, basic size determination

Economic Analysis
- Preliminary cost estimation, economic feasibility

Detailed Engineering
- Process design, structural design, design of controls, verification/validation testing, bench scale testing, documentation, knowledge capture

Procurement & Construction
- Sourcing, fabrication, oversee construction, start up support, documentation, knowledge retention

Figure 3: Development steps

SES is backed by a multi-disciplinary organization and specializes in using a combination of analysis and testing methods for solving complex problems (Figure 4). The staff at SES is versatile and has a fundamental understanding of various processes, such as mixing, heating, cooling, and filling. The science-based approach reduces cost, time and minimizes risk and waste to develop and deploy a new process. The key elements of the SES approach are:

- **Process simulation**: Computer-based predictive methods of varying degree of rigor are applied to understand and predict process behavior and optimize asset performance so that safe, competitive and reliable processes can be designed and implemented.
- **Testing support**: The process development and equipment development work is supported, verified and validated using customized testing. Product samples for consumer feedback are also generated during this stage of development.
SES has successfully applied science-based methods to evaluate, analyze, develop, optimize, and troubleshoot packaging, product designs, processes, equipment, and reduce cost and time-to-market. These methods include customized testing, computer-based predictive analysis, and science-based calculations. SES specializes in helping clients adopt new technology to achieve improved efficiency.

For process deployment, SES’ services are leveraged by clients for:

- *Throughput improvement*: Using modeling and simulation, technical basis and process limits are identified. Design of experiments based on modeling and simulation provide detailed understanding of process limits and boundaries.
• **Hardware**: SES has expertise in developing equipment specifications and procurement of equipment.

• **Custom equipment development**: SES’ multi-disciplinary expertise coupled with analysis and testing is used to design, develop and build specialized equipment for lab-scale and pilot-scale testing.

• **Documentation**: SES’ expertise and experience in developing specifications, test planning, and test setup provides the necessary foundation for successful knowledge capture and transfer.

Harbi Pordal, PhD, is a principal at SES and specializes in solving flow and thermal problems using numerical, analytical, computational, and experimental methods. Dr. Pordal has experience in process scale-up, technology transfer, new process development and throughput improvement.

Clint Haynes is Vice President at SES and has years of experience with production processes and equipment. Specific to the process industry, Clint specializes in production line audits, review of equipment and processes.