

Close to process changes in textile finishing industry - a key to LCM for SMEs

Jutta Hildenbrand^{1,*}, Joachim M. Marzinkowski²

¹Chalmers University of Technology, Energy and Environment, Division Environmental Systems Analysis, Gothenburg, Sweden

²University of Wuppertal, Safety Engineering/Environmental Chemistry, Wuppertal, Germany

*jutta.hildenbrand@chalmers.se

Abstract German textile finishing companies are predominantly SMEs and these companies' managers often have a negative expectation towards measurements for environmental protection as they expect increasing costs. Changes in the production that lead to a higher efficiency offer a possibility to overcome this attitude and support these companies on their way to a more sustainable production. Within collaborative research projects carried out with industrial partners, an approach has been developed and tested that uses evaluation of enhancement proposals close to the production regarding their environmental and economic implications to back up decisions about processes with sound data. Information about environmental burden and costs is displayed transparently for the decision maker and the accompanying evaluation gives directions for process enhancements and supports decision makers and motivates them to search for transfer possibilities.

1 Introduction

A set of production processes forms the essential basis of all activities in companies. Though these processes are often regarded as core competence, an analysis of the existing practice can expose shortcomings regarding process control and efficiency that compromise the environmental burden caused by the enterprise as well as its cost-effectiveness. Because process steps are organised in networks with feedback loops and interactions and the basic conditions vary continuously, deficiencies are superimposed and remain undetected for a considerable period of time.

Thus, an approach to enhance the environmental and economic performance of an enterprise can be derived starting with an in-depth analysis of existing processes that can be used to provide a basis for process models which include structure and

exchanges for production processes and for peripheral supply and disposal processes. The analysis can also help to identify deficiencies if the actual process conditions are compared to conditions that are considered optimal from a scientific or procedural point of view. Enhancement proposals that take into account the identified deficiencies can be deduced following heuristic methods. In the projects with textile finishing companies, changes were suggested that were located close to the production processes and were also interlaced to the production to the extent that they used a specific process output from a plant and processed this flow to provide an input for the original production process. This approach was chosen because of several expected benefits. Filtration of waste water at high temperature, which was enabled with this approach, brought savings of thermal energy for heating-up softened tap water, savings of dissolved supplies that are otherwise discharged, a reduction of tap water and waste water and a reduction of process duration.

One or more enhanced states of production are then modeled to calculate energy- and material flows for the entire system similar to the model for the existing state. For a comparison of environmental burdens, a life cycle approach is mandatory to include upstream and downstream processes that are carried out outside of the analysed company. This procedure helps to identify shifting of burden and trade-offs for different impact categories. Changes that are suggested to enhance the process' eco-efficiency can then be compared to the existing state to emphasise concurrent benefits regarding environmental burden and cost-effectiveness, but also to reveal deficiencies that were overlooked in the first proposal and can be amended in a second round.

The inventory data from process models are used for an impact assessment that uses a normalisation and sorting steps and leads to midpoint results. Changes in costs and in environmental burden can be presented to the management in parallel to provide evidence that environmental protection can be favourable also from a business perspective. Information about environmental burden and costs is displayed transparently for the decision maker and the accompanying evaluation gives directions for process enhancements and supports decision makers. The close to process changes could be used to change the production and acquire a higher efficiency with a limited effort and the knowledge gain motivates to search for transfer possibilities.

2 Production processes in textile finishing industry

Processes for the treatment of textiles with the necessary subsequent washing and rinsing steps are often carried out according to an empirical knowledge base. The process result can not always be achieved in an efficient way and the actual process state deviates from an ideal state with minimal resource demand and emissions. To overcome this deficiency, information about the process has to be collected and systematically connected with tools to analyse environmental burden and costs. When existing processes are applied for a long period of time, conditions regarding input (e.g. raw material quality, ancillary material) output (e.g. product quality) and throughput (attrition of plants) may change, but the method of operation is not always adjusted. Therefore existing processes tend to be less efficient and are a worthwhile target for enhancement approaches.

2.1 Starting points for enhancement proposals and feasibility test

Theoretical models for a mathematical optimisation are not available for this kind of processes, though they are frequently applied in various industry branches. It is however possible to analyse the process goals and define the technical conditions which help to achieve these goals, e.g. temperature and pH-value to enhance the diffusion process, turbulent flows and minimised carry-over to subsequent treatment steps. A comparison to existing process conditions helps to heuristically derive enhancement proposals that are tested with laboratory size equipment and then installed into the process.

2.2 Evaluation of enhancement proposals

During the laboratory tests, process models are established for the existing state and the enhancement proposals that serve as a base for the evaluation of costs and environmental burden. For the design of models a petri-net based software, UMBERTO 5.5 from ifu Hamburg GmbH, could be applied successfully. The interaction with peripheral processes and feedback loops has to be implemented in the model, which can be done also with other software solutions.

Process balances for enhancement proposals compared to the existing state help to clarify relations between resource demand, emissions and process costs, thus

providing an incentive for process managers to include environmental aspects in process design.

Besides the costs for raw material, ancillary and disposal of waste water to sewers that is calculated in the model, additional costs that are not related to mass- and energy flows but are period oriented have to be considered. For most processes, these are costs for personnel and investments. Personnel costs are included directly, whereas for the investment from depreciation, interest, insurance, maintenance and license fee are combined to calculate an annual amount. More than one calculation method can be used in a combined approach, e.g. a comparison of annual costs and a pay-back period to estimate also financial risks. The costs are displayed separately for different originators, e.g. material, energy, waste and waste water treatment, personnel and investments.

The environmental evaluation is carried out according to the life-cycle assessment approach with an identical functional unit but if mostly with extended process chains to include upstream and downstream processes. While costs for supplies like heat or electricity cover the economic implications for a production process completely so it is not necessary to retrace the production of the supplies, this is not the case for the environmental implications. The heat supplying process has to be included in the process model, albeit a generic module from a software database is sufficient since the supplying process is not in the focus for enhancement proposals but remains unchanged. The results are displayed separately for a selection of impact categories following the suggestion for Baseline categories by CML [1]. To condense the results, a grouping step to emphasise different overall importance of the impact category is used that was suggested by the German Environmental Agency UBA [2]. The grouping takes into account geographical and temporal range of an impact, distance to target and the relative amount of the emissions compared to a basic load for the region where the emission appears.

The results are displayed with bar charts that reflect the environmental priority by using distinct patterns and the relative importance by scaling the bars with the highest relative contribution as a reference point. The charts are used together with the cost charts to report the results of the comparison and also form a basis for further enhancement proposals as shortcomings and advantages of intermediate stages are revealed.

The procedure can be repeated for several project stages and can also be used to evaluate the final implementation.

This approach has been successfully adapted to companies in the textile finishing industry in a joint research project carried out with several partners from industry and academia [3]. An important application in this project was the enhancement of a counter-current washing machine used for reactive-dyed cotton fabric. The

process target is the removal of hydrolysed dye together with supplies and impurities from the fabric. In the initial stage, two passages were necessary for medium and dark coloured fabrics. Target were therefore a reduced water demand, enhanced washing efficiency to save the second passage for all batches. The enhancement started with a check of flow rates and temperature in the first phase which showed a high potential for savings. Cost comparison showed that annual savings of more than 100,000 Euro could be achieved without changes in the process layout only by adapting flow rates and the washing speed. A subsequent implementation of vacuum suction unit to extract the liquor that replaced traditional squeezing rolls lead to enhanced mass transfer which yields a higher washing efficiency, thus resulting in a better washing result. A second passage could be skipped for almost all fabrics. Cost comparison showed a payback period of less than a year, while the environmental impacts showed a reduction of resource demand and Global warming potential. The results could be linked to the process change.

3 Results and discussion

3.1 Process models help to foster the knowledge about relations between resource demand, emissions and process parameters

Processes are unintentionally run in an inefficient mode because information is scarce and the complexity with feedback loops and interaction makes it difficult to predict the effects of changes. Though the existing state may show deficiencies regarding the process result, it is often preferred to a change with uncertain outcome. Models can reveal relations between process parameters and results, thus showing also influences on product quality.

3.2 A parallel analysis of costs and environmental burden shows incentives for process managers

The relation between resource use and process cost become apparent and shows advantages of an efficient production that are immediately available for the company. Unlike the benefits that are derived from a positive image, these can be

achieved directly even if customers do not value the effort. The cost reduction is therefore a strong incentive for managers to implement processes with a higher efficiency. Since the cost reduction can be directly linked to a lower resource use and reduction of emissions, inhibitions towards environmental measurements as a cost driver can be countered with sound information.

3.3 Application of widely used charts form a common ground

The application of bar charts and additional displays is a familiar tool, thus providing easy access to a new point of view. Clear results and enhanced knowledge base for the process managers are supposed to inspire a transfer of the approach to more processes, more companies within the branch and comparable processes in more branches.

The approach is basically used in a bottom-up mode, taking into account individually designed process steps. The effort to provide process models that are suitable for enhancement proposals is therefore comparatively high, especially at the beginning of a project. In later stages, experiences from other processes can be transferred.

Benefits that can be achieved by integrating two or more processes in a network can also be evaluated by the approach, but they will be detected only if the system boundary is chosen accordingly. Enhancements that affect an entire production site, like the establishment of a heat exchanger network, might be overlooked in this process-oriented approach and must be carefully balanced in the models.

4 References

- [1] Guinée, Jeroen B.: *Handbook on Life Cycle Assessment - Operational Guide to the ISO Standards*, Kluwer academic publishers 2002.
- [2] Umweltbundesamt (Ed.), Schmitz, Stefan, Paulini, Inge et al. *Bewertung in Ökobilanzen. Methode des Umweltbundesamtes zur Normierung von Wirkungsindikatoren und zur Auswertung nach ISO 14042 und 14043*. UBA-Texte 92/99, 1999.
- [3] Marzinkowski, Joachim M., Hildenbrand, Jutta; Rabhi, Ahmed. *Verbundprojekt: Prozessintegrierter Umweltschutz durch Aufarbeitung von Abwasserströmen und Rückführung in den Prozess (PIWATEX 2): Teilvorhaben 1*. Project report, available at <http://edok01.tib.uni-hannover.de/edoks/e01fb08/573694621.pdf>, 2007.