DECISION MAKING PROCESS FOR THE DESIGN OF EMULSION PRODUCTS DURING EARLY DESIGN STAGES CONSIDERING APPEARANCE, RHEOLOGY AND STABILITY

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The design of emulsion products is especially complex because decisions are highly interrelated, product and process have to be considered simultaneously and in many occasions compromises have to be made. In this work a methodology for decision making during early design stages with emphasis on the definition of the design problem and product conceptual design is presented. First, the needs of stakeholders are classified and translated into specifications to define the design problem. Second, it is decomposed in simpler sub-problems, here called general limitations which are classified in three categories: emulsion rheology, appearance and stability. Thirdly, from the analysis of phenomena behind limitations, general solution strategies to solve them are proposed. These strategies are general paths not related at first to a specific compound or processing. Examples of them are: selection of emulsifier system to enhance O/W or W/O emulsions, increase particle or droplet concentration, increase energy input during processing, among others. Solution strategies can be related later to families of compounds and processing technologies. While passing from one design stage to the other, need statements are translate successively from specifications, limitations, solution strategies and components. In each stage possible contradictions within the design arise and solutions and trades-off between them have to be found to pass to the next stage. The methodology is illustrated with the conceptual design of a moisturizing cream.

1. Introduction

The design of emulsion products such as shampoos, cosmetic creams and liquid detergents, needs a systematic approach to address the design requirements and generate a feasible product design that fulfill them. This is not an easy task. Design requirements are defined based on needs of customer and other stakeholders, which are often described in nontechnical terms and are highly subjective. Additionally, emulsion chemical products are complex systems highly interrelated, for whose design is necessary to consider characteristics of product and process simultaneously [1]. This study shows methods and tools to classified and translate needs into design specifications and introduces a decomposition method that enables the division of the complex design problem into smaller predefined sub-problems. The study also proposed a list of predefined solutions strategies that cover a broad range of solution options for the exploration of the solution space of emulsion products. These methods facilitates the advancement through the design stage and the decision making process.

2. Workflow of the methodology

Cussler and Moggridge [2] proposed a conceptual product design methodology, dividing the design process in four main steps: (1) needs identification, (2) generation of product ideas, (3) selection of the more promising ideas, (4) process design. Based on their proposal a step by step procedure is presented in figure 1 with the difference that in this case product and process are considered simultaneously as suggested by multiple authors.

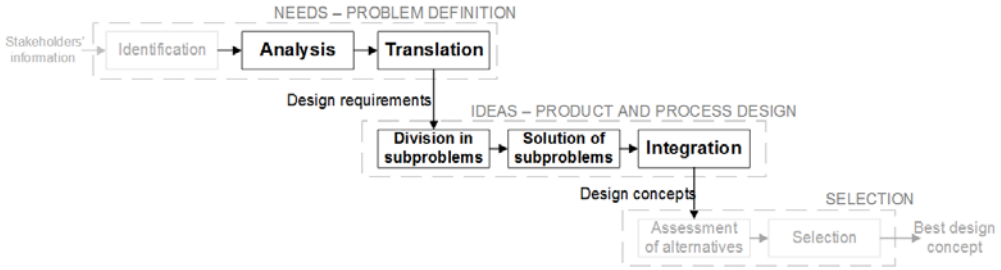

Figure 1. Workflow for the design of emulsion-type chemical products

2.1. Methods for analysis and translation of needs – problem definition

For needs analysis and translation into product specifications the implementation of Kano model and House of Quality is suggested. Kano model classifies needs and identified those that are more important for user satisfaction. It is implemented as suggested by Rejeb et al. [3]. House of Quality enables the translation of needs into product specifications. For its implementation experts and users are consulted. The use of these methods is illustrated in the case study.

2.2. Method for division and solution of sub-problems – product and process design

The decomposition approach enables the division of the design problem according to general sub-problems which can be connected to solution strategies to generate feasible design concepts. General sub-problems and solution strategies are proposed based on emulsion science principles. The connection between them is done with multi-criteria analysis methods and expert opinion. This approach is inspired from a methodology for choice of intensified equipment presented by Commenge and Falk [4]. Limitations and solution strategies for emulsions are presented in Table 1.

Table 1: General sub-problems and solution strategies for the design of emulsion products

	Sub-problems	Solution strategies
Appearance	1. Emulsion lightness	1. Addition of solid particles.
	2. Emulsion lightness over time	2. Change surfactant system (type/concentration)
	3. Color hue	3. Increase/decrease of volume fraction.
	4. Color intensity	4. Change oil phase composition
	5. Color intensity over time	5. Add components to water phase
	6. Emulsion homogeneity	6. Addition of pigments/dyes
	7. Special color features	7. Addition of rheological modifiers
Rheology	8. Newtonian behavior is expected	8. Controlling electrolyte concentration
	9. Shear thinning behavior is expected	9. Controlling pH
	10. Shear thickening behavior is expected	10. Order of aggregation of components
	11. Viscosity is expected to be higher (lower)	11. Temperature during processing
	12. Thixotropic behavior is expected	12. Processing time
	13. Irreversible change of rheology (time/stress)	13. Selection of homogenization technology
	14. Viscoelastic behavior	14. Controlling energy input
Stability	15. Avoid gravitational separation	
	16. Controlling flocculation	
	17. Controlling coalescence	
	18. Controlling Ostwald Ripening	

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