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Motte, Damien; Björnemo, Robert; Andersson, Per-Erik

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

RE-THINKING THE LATER PHASES OF THE MECHANICAL ENGINEERING DESIGN PROCESS

DAMIEN MOTTE, ROBERT BJÄRNEMO

*Division of Machine Design at the Department of Design Sciences
Lund Institute of Technology at Lund University
SWEDEN*

and

PER-ERIK ANDERSSON

A literature survey by Motte and Bjärnemo (2004) has revealed that, during the last fifteen years, major research efforts have been focusing on the designer, especially concerning the cognitive aspects of the design activity, including creativity, the problem solving process, knowledge, visualization, and external support systems like sketching and computational tools. But this has so far only concerned the conceptual design phase. Very few research contributions concerning the later phases of the design process have been found. Yet, as in the conceptual design phase, the subsequent design activities, like embodiment and dimensioning, are fundamentally supported by the designer, who is at this stage also facing manifold issues: The problems may be better defined, but the demand for creativity remains high; The problem-solving activities are guided by many principles, but are still heuristics in nature. It is our conviction that the knowledge that would derive from the study of designers could be utilized for the improvement of the design process with reference to the later phases of the process.

Our four-year research plan is structured as follows. The first part is explorative. It aims at describing the embodiment and detail design phases based on the study of designers' activities and identification of common and specific actions and behaviors. The designer will be observed within a four-level model: 1) the designer placed in his or her daily work environment; 2) the tactics and strategies applied during the whole embodiment and detail design activities; 3) the operational, cognitive activities during design, especially problem solving; 4) the basic cognitive elements: induction, deduction, abstraction, perception, pattern recognition, attention, intelligence, etc. (these elements are not design-specific, and thus are beyond the scope of the

study reported here). The first level needs to be studied “in the field”, either directly by means of ethnography or indirectly by interviews or surveys, while the second and third levels are observed during controlled experiments. This pre-study will lead, in the best case, to a rough design process model, but is at least expected to reveal some key characteristics of the process, prelude to further improvements. The second part of our work will consist in validating, or not, the findings (model or key characteristics) with repeated experiments or simulations. These data will serve as the basis for the third part of the project, which will be dedicated to the generation and test of an improved design process model, computer-supported or not.

The cognitive, tactical and strategic aspects of the embodiment and detail design activities are currently being studied (second and third levels). Six experiments have been run so far, involving three students and three experts. Each of the participants had to solve the same problem: a support device for a hydraulic piston. The first findings concerning the problem-solving process (Motte *et al.* 2004a) show that the designer, though following a fairly structured approach, iteratively applies the activities of information search, problem understanding, solution finding, and evaluation/decision. The activity of solution finding, characterized by synthesis, is balanced by an activity of mechanical modeling of the problem. Analogies, in the sense of comparing a current problem to a similar one, are more developed by the experts than by the students.

At a higher level of activity (see Motte *et al.* 2004b), the most striking findings are that the experts dramatically reduced the solution options by an early choice of standard components. This led to an early focus on the spatial restrictions and interface compatibility problems. On the other hand, the students reasoned about abstract mechanical structures, without defining the components until late in the process, and thus faced complications later on. Finally, we discovered that for both experts and students, the detail drawing activity is always a source of correction: this may be due to the constraints of proportionality and exhaustiveness, as well as to the need for rigor in the drawing, both of which contribute to disclosing hidden or neglected embodiment product problems.

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