Applying Robust Design in an Industrial Context

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The ability to develop and manufacture products of high quality is a decisive competitive parameter for any production company. The costs of non-quality, i.e. not fulfilling the functional requirements for a given product, are considerable, often manifesting as scrapped products, product recalls, lost sales, customer complaints and delayed product launches. Over time, the responsibility for obtaining consistent product performance has moved upstream in the development process, motivated by the saved costs of discovering and removing design errors prior to large investments in manufacturing tools and production facilities. An extensive set of frameworks, tools and methods are available for ensuring and improving product quality. The research presented in this thesis focuses on the Robust Design Methodology – which is a collection of methods and tools intended to support the design engineer in creating products with consistent performance, despite influences from manufacturing variability and use conditions. Although Robust Design is claimed to be applicable during the early phases of product development, surveys have shown (Thornton et al 2000; Gremyr et al 2003; Araujo et al 1996) that it is only used by a small minority of production companies and it has been criticised for being too complex to use and only being applicable during late-stage design optimisations. This project addresses these issues and contributes to the industrial understanding and application of Robust Design methods and principles, by attempting to remove the existing barriers for widespread industrial use of the Robust Design Methodology. The research finds, through the definition of an impact model linking non-robustness to profit loss in an organisation. The link is made through a series of causal factors such as overly tight tolerances, high scrap rates, missed launch dates, and product recalls. All of these causal factors are considered as symptoms of non-robustness and are used in an applicability assessment to gauge the potential benefit of implementing Robust Design in an organisation. One particular symptom has been investigated in greater detail to partially verify the impact model, namely the ‘Misapplication of R&D resources’. In one case-company it is shown that R&D resources used to make late design changes after ‘Design Verification’, where the design is ideally frozen and prepared for production, was up to 400% more than used during the design and development phase! On deeper investigation of the change notes, it is shown that over 60% of these are related to kinematic and mechanical interface issues. With such apparent robustness issues embedded into the geometry of designs seen throughout industry, Robust Optimisation, which is the main focus in academia, is quite futile. There is a need to lay out the foundation for the Robust Design Methodology (RDM) using the approaches of kinematic design and design clarity, two fundamental methods to be added to RDM providing the guidance for designing robust mechanical architectures. Furthermore a set of 15 robust design principles for reducing the variation in functional performance is compiled in a format directly supporting the work of the design engineer. With these foundational methods in place, the existing tools, methods and KPIs of Robust Design are reviewed and positioned within a framework, which also identifies the need for quantitative, leading indicators of robustness, which are now further developed in the so-called Six Theta® framework. However, the lack of adoption of robust design is not simply due to the lack of simplicity, education and coherence around the available tools and methods, but also the organizational change management that is key to any successful implementation. After identifying four companies seen as front runners in terms of robust design implementation, all from different industries but based on mechanical design, a series of interviews were conducted to identify best practice procedures. The analysis and results showed that there is no single solution and each company had a different approach, which worked for their company culture and the nature of the products they were developing. As a result different implementation archetypes are created so that R&D managers are able to choose and take inspiration for the archetype that they think best fits their company. The methods Kinematic Design and Design Clarity are applied in a case project in a consumer electronics company to give an indication of the effects. The data suggests that there is a potential for a substantial reduction of late-stage design changes in comparison to the original benchmark studies prior to the methods being implemented.