INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 99 MUNICH, AUGUST 24-26, 1999

IMPROVING CONCEPTUAL DESIGN QUALITY BY USE OF QFD & DFMA PROCESSES

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Keywords: Concept design, Design quality, QFD, DFMA

1 Introduction

This paper will consider how Quality Function Deployment (QFD) and Design for Manufacture and Assembly (DFMA) processes can be used to improve the design quality of products at the concept stage. We appreciate that both QFD and DFMA are techniques that have been used for some time by mature product developers, and the successes achieved using each have been widely reported. Here, though, we will share our experiences of using these tools with novice designers, i.e. student engineers.

The use of both QFD and DFMA has proven to be a valuable approach for ensuring that a balanced consideration of design quality is maintained in design project work. The projects described have been carried out with products manufactured by small to medium sized enterprises (SME's), where we have found significant opportunities for product improvement. The quantitative nature of DFMA analysis results allows the novice designer to identify clear targets for design improvement and to measure the effectiveness of any new solution, whilst attention to QFD ensures customer requirements are still being satisfied.

Often, SME's are not aware of many of the best design practices and so are not able to meet the demand for continuous improvement of their products. However, we consider that if novice designers are able to successfully utilise design tools like QFD and DFMA and achieve improvements in design quality, then SME’s have no excuses for ignoring the benefits they could bring to their own product development activity.

2 Approach

The purpose of employing QFD and DFMA is to improve the design quality of existing and, frequently, mature products. Our use of these tools with novice designers satisfies part of our desire to develop engineering students as practitioners of Design for Quality (see [1]). With this aim in mind, we must attend to improving Big-Q *and* Little-q qualities (see Figure 1 taken from [2]). Customer expectations are satisfied by Q qualities. Using QFD, we establish how the salient features of the existing product are satisfying the customer requirements, and assess how the current design performs with respect to competitor products. In this way, we identify the Q qualities that are demanded and establish a benchmark measure of customer satisfaction. The product life supporting qualities are characterised by q qualities, e.g. producability, assemblability, serviceability. These requirements may also be treated using QFD, where the “voice of the customer” reflects the needs of the internal customer.

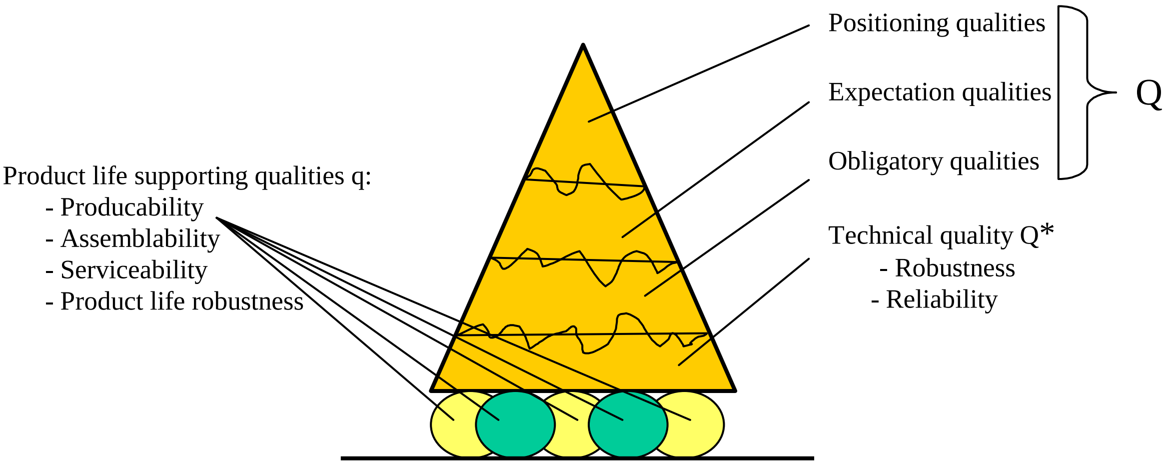

Figure 1. Product Quality [2]

Using DFMA, we are able to consider improvement in quality associated with the production life phase of the product. This approach has been used for individual components, sub-assemblies, complete products and even product families. Attending to the needs at each level requires different levels of analysis. However, our experience with novice designers is that the quantitative approaches offered by DFMA tools, like TeamSET™, enable them to make informed evaluations about the quality of the product design. The ability to evaluate the design efficiency, manufacturing and assembly metrics of the existing product provides target measures against which alternative schemes can be compared. For novice designers, the use of metrics creates confidence in the results, and enables them to quickly learn what characteristics of a product create most difficulties in the production phases. The benchmark targets also show the novice how much change they should expect to make. For example, the recommended maximum threshold for design efficiency is 60%. If design efficiency is assessed as 10%, then it indicates tremendous scope for improvement in this dimension. Whereas, a design efficiency assessment of 55%, would indicate little scope for improvement.

The systematic evaluation approach offered by DFMA tools, gives critical insight into the strengths and weaknesses of the existing product design in its production life phase. When this evaluation is combined with the analysis of need arising from the QFD and benchmarking exercises, the designer will have a very good idea where to focus the search for new product concepts. Solutions, which resolve the inadequacies highlighted by the QFD and DFMA evaluation, will form the basis of new product concepts with improved design quality. Only by maintaining a close eye on both Q and q qualities will acceptable results arise.

3 Results

This approach has been used in several design review projects involving a range of different products. Although the products are principally automotive products manufactured by supply chain SME's, we are confident that the approach is equally applicable in other product sectors. Student engineers, who often have little prior knowledge of the products they have to evaluate, carry out the evaluation work. The co-operation with industry allows access to the product hardware, production facilities, and employees who can provide specific product and process information and experience as well as substantial knowledge of customer expectations. The following studies typify the results achieved:

3.1 Case 1: Door Module Assembly

This review of a current vehicle door design led to a new approach of using a door module assembly. The module assembly utilises a polyurethane reinforced reaction moulding, which incorporates the regulator track and inserts for locating components. The module acts as a base to which the door components are assembled. The module is located into the door using push-fit fasteners and screws. The door module assembly offers a 60% reduction in on-line assembly time, has 50% fewer parts and provides a 10% weight saving.

Not only did this solution provide clear improvements in the production life phase, the reduction in weight achieved has the knock-on effect of allowing additional features to be included in the door, e.g. side impact bar, without increasing the weight of the vehicle.

3.2 Case 2: Rear Sub-frame

This review of a current rear sub-frame design showed that it was made from 23 mild steel parts welded together and galvanised. The proposed re-design was made from two squeeze formed aluminium alloy side members, adhesively bonded and screwed to an extruded aluminium alloy cross member. This solution offers 59% reduction in the number of parts, 50-70% reduction in direct costs, 30% reduction in weight, and all without any detriment to the torsional and bending rigidity of the structure.

Once again, the solution provided clear improvements in the production life phase whilst offering weight benefits without compromise structural performance. More importantly, the solution provided an all aluminium sub-frame that was fully in keeping with the desire to create an all-aluminium vehicle.

3.3 Case 3: Throttle body

In this product review the original Q qualities that were identified and measured were deemed to be good but the q qualities had scope for improvement. The focus for redesign was therefore aimed at manufacture and assembly cost reduction whilst maintaining function. The original design used a die-cast aluminium body and butterfly valve that required machining with pressed in spindles and bearings. The design had 50 parts and assembly time was 2🗁 minutes, using 9 assembly stations.

The redesign proposed a change to injection moulded PBT thermoplastic, eliminating secondary machining and allowing other components to be incorporated. Key qualities of stiffness, thermal stability and chemical resistance were maintained along with a drop in the overall mass. Part count reduction of 72% was achieved, with total component cost reduction of 24%. Assembly time was halved with the elimination of 2 assembly stations.

4 Observations

Whilst the use of QFD and DFMA at the concept stage has been reported by others [3,4], the results reported here have been achieved by inexperienced design engineers with limited product and manufacturing process knowledge. However, they have been able to create a diverse range of new concept proposals, which provide all-round improvements in design quality. By using QFD and DFMA together, this approach ensures that both Q and q qualities are considered simultaneously during the new concept search. Importantly, these design process tools help direct the solution search and enable the improvements to be measured by quantitative comparison against the existing product. Finally, we have found that the approach breaks the usual incremental improvement design process that is evident in SME's and encourages more innovative and creative design solutions to be offered.

However, we are disappointed that the SME's we have worked with seem unwilling to adopt the approach themselves. Most do not have a tradition of product development and have acted merely as suppliers to OEMs. Yet most are under pressure to deliver higher quality products at lower prices. We have observed that a great deal of SME's have products which can be significantly improved by the application of DFMA, however, we would not suggest this is undertaken without a full requirements analysis using QFD. Whilst the exercise is beneficial at component and product levels it can also be used in rationalising whole product families. This often requires major conceptual leaps but offers the incentive of greater quality improvements. The results we have generated with novice designers have been thought provoking and innovative for SME's. We believe we have often shown them simple and achievable routes to product innovation.

5 Conclusions

The combined use of QFD and DFMA to evaluate existing products provides a systematic approach for identifying where design quality can be improved at the concept stage. This approach is particularly appropriate to SME's where modern design practices are poorly understood and yet there is a continuing demand for the improvement of their products.

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