INTERNATIONAL DESIGN CONFERENCE - DESIGN 2004
Dubrovnik, May 18 - 21, 2004.

DESIGN 2004

METHODS OF MONITORING THE TESTING STATUS OF VARIANT RICH PRODUCTS

G. C. Baumberger, U. Lindemann, U. Pulm, M. Skull, R. Stetter and W. Kaindl

Keywords: variant management, early evaluation, design of experiments

1. Introduction

Development projects in automotive industry usually concern a lot of participants and stakeholders. Numerous requirements referring to customer wishes, technical progress, safety demands, etc. have to be met and embodied in product design. Development projects are highly distributed and several packages are completely handled by subcontractors and system suppliers. Moreover the illustrated situation is aggravated by shortened time to market and increasing number of projects, models, and variants. Consequently, automotive industry is facing a lot of arising problems such as a more and more complex system integration, increasing development expenditures, as well as an increasing number of after sales call backs [Kühne 2003].
Hence there still seems to be a need for an improved yet practical quality management of development projects even though many methods have been applied in enterprises already. Therefore improvement measures should have a strong focus on real conditions in industry and treat problems such as high distribution and the resulting need for intensified coordination and collaboration [Lindemann, Pulm, and Stetter 2002].
At this the design of experiments especially in case of high variant products was in the special regard of the presented research. The systematic planning and performance of product tests is an important element in existing quality management methods. Yet little attention was paid how to cover an entire variant spectrum with product tests economically [Pulm, Maurer, and Lindemann 2003]. Hence the selection of testing relevant product variants is necessary which shall be provided by the proposed method in a systematic way.
Furthermore the several testing activities of distributed suppliers have to be coordinated and brought together. Thus an information instrument should be worked out giving an overview on required product tests, the allocation of organisational resources as well as on test results. By this means the overall testing status in a development project shall be made transparent, hence supporting milestone decisions such as type approval, start of tool making, SOP etc.

2. Object of research

The introduced work refers on the results of a common research project with a German automaker dealing with the coordination and controlling of distributed development projects. The provision of a method reporting the testing status is one aspect in an integrated concept of collaboration and project monitoring tools, such as an information platform, a requirement specification system, and a protocol system [Baumberger, Pulm, Lindemann 2003].

2.1 Scientific method

The concept of building up a testing status information system pursued two directions. On the one hand a reasonable and appropriate testing schedule had to be conceived in order to reduce unnecessary effort and complexity of the tests to be executed. The focus was on variant managing strategies [Schuh1989] and Design of experiment methods [Kleppmann1998] to identify testing relevant variant parameters as well as to bundle tests concerning a certain experimental setup.
On the other hand requirements and possible contents of the project status had to be clarified. This referred to questions such as which kind of tests have to be performed, which parts and prototypes have to be tested especially, what are required test results, and which milestones or approvals depend on positive test results. An extensive questionnaire was drawn up and interviews with the testing department staff were conducted here. Finally the two approaches were brought together and a tool for planning, monitoring, and documentation of product-related tests was built up.

2.2 Product example

During the whole research project a car seat served as product sample to emphasize problems related to high variety and outsourcing and to evaluate applied methods in a still pretty defined scope. The car seat generally is composed of a metal frame as basis structure, foamed upholstery, a fabric or leather cover, and facings as well as several functional variants and accessories such as optional seat heater, drawers, and adjustment elements. The product variety (shown by a variant tree in fig. 1) mainly results from differentiation between left/right seat, normal/sport seat with manual/electrical adjustment, an optional seat heater respectively lordosis, and several equipment variants (drawers, lights, facings). Cover variants can be distinguished into a fabric and two leather types in a simplifying way.

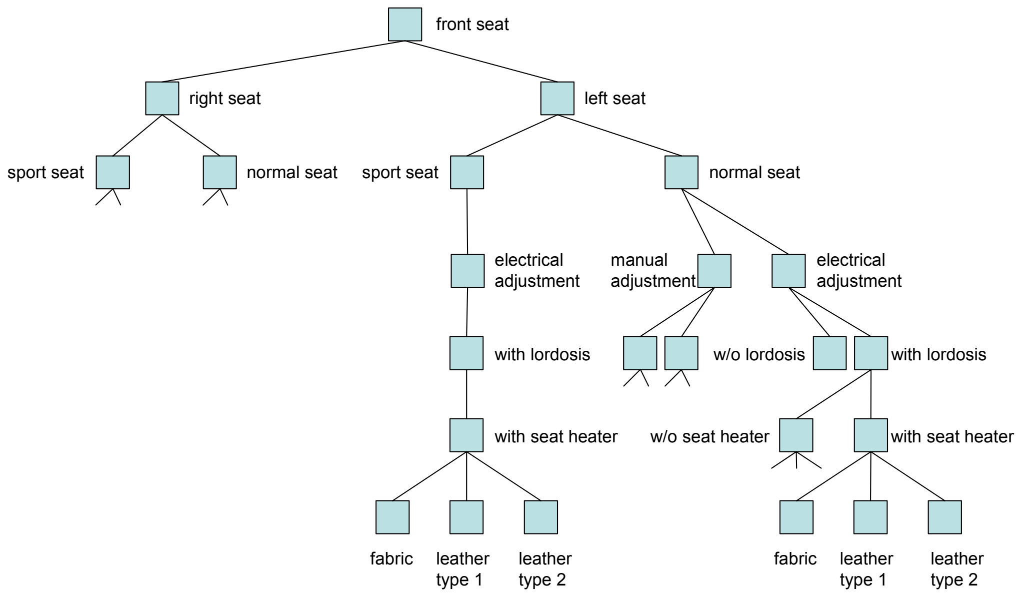


Figure 1. Structural variant tree of a car seat (abstract)

To reduce these variants, a seat building set was designed over different car types and configurations. This building set is characterised by a standardized seat design concept including a platform seat structure. Yet this concept has to be elaborated in every new car project and extensive product test have to be executed as well. This detailed seat design including the tests is in the response of several subcontractors. Since there is a need for controlling this distributed design and testing progress a tool for monitoring the testing status shall be developed.

2.3 Starting situation

Within the regarded enterprise there already exists a testing status monitoring system. This is called "testing wallpaper" due to the fact that all necessary tests, schedules and results of one seat design project are illustrated on a huge chart. The tests themselves and their regulations regarding execution, necessary results etc. are described within the project related requirement specification. The technical release status results from the overall testing status recorded at this chart. Alike difficulties with meeting certain product requirements or failed test can be highlighted.

For a single seat project this method is working reasonably well but in case of monitoring different projects handled by several contractors at the same time, coordination and controlling gets increasingly challenging. E.g. it is not possible to revert to information and test results from other design projects. Consequently, experiences from the past can hardly be applied at occurring problems and know-how is usually internalised in the staff dealing with these tests for a long time. Furthermore there is no link to current test results and reports in detail and the display format is not very handy. Regardless of computer support common practice is to print the chart results and complete them manually. Last but not least automated analysis and controlling is not supported and the system is not introduced companywide.

Other than that mentioned product variety and resulting testing complexity is not regarded in an appropriate manner. Particularly the question, which variants have to be tested as physical prototypes and which spectrum of seat variants can be released subsequently is not treated in detail and is rather based on the experience of the staff planning and realizing a certain test than on systematic consideration. Even information on kind and configuration of tested variants is lacking widely within the current testing status. Hence the context between testing design (planning) and testing status (realisation) is not becoming apparently and shall be made more transparently in the future.

2.4 Objectives of the research

As described above, the main objectives of conceiving an improved method for defining the test design and a tool for monitoring the testing status shall be

- to support an adequate and transparent selection of necessary test set-ups (prototypes) in respect of the variant spectrum to be tested and
- to document test information and results by an appropriate information system.

In particular the test design shall enable the approval of the entire seat variant spectrum without testing each individual seat variant with as one experimental set up. For that purpose it is necessary to select the most critical variants. The notion of the introduced approach is if these critical variants meet the corresponding requirements all variants of the product spectrum would do so likewise (as shown in fig. 2).

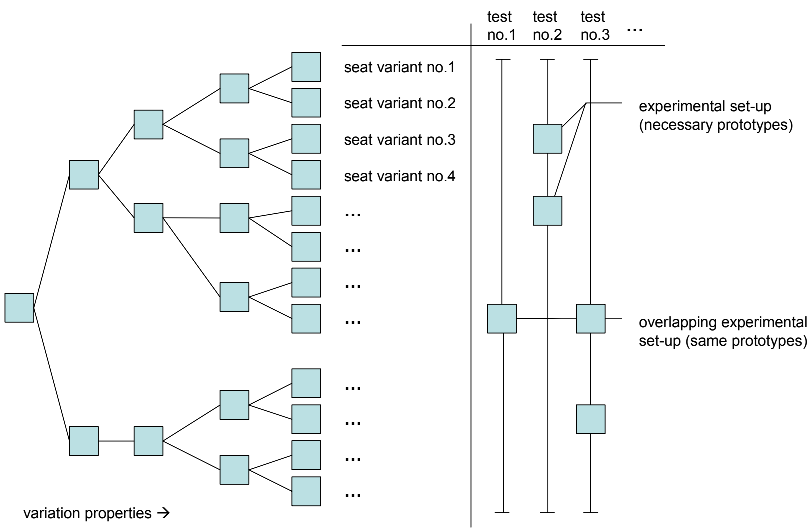
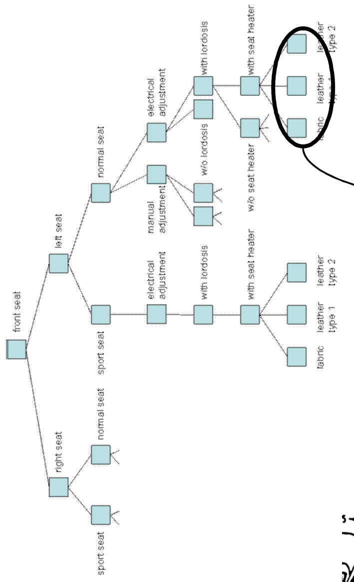


Figure 2. Identification of required test prototypes

Admittedly it is necessary to really pick out the very relevant variation parameters which have a substantial influence on the test result. By planning the test design more carefully and systematically a well-founded conclusion shall be made possible which variants are covered by tests and which are not (that means have to be tested separately). This is especially important in the face of product liability.
Furthermore the test sequence has to be planned more carefully. In certain conditions experimental set-ups can be reused for other tests. Hence overlapping in test design shall be utilised and the number of necessary experimental prototypes may be reduced further.
Eventually the testing status shall contain information on the necessary prototypes (configurations and scales) as well as information on test execution (dates, schedules) and results (reports, records, release status etc.). This way a stronger link between test design and test status shall be accomplished in the future. Within the following two chapters it shall be described in detail, how this is conceived.

3. Test Design

Within the test design as first part of the method, necessary test set-ups shall be planned and optimised by determining a reasonable test sequence.
When predefining the test design one might consider initially which kind of tests must be executed. Usually any requirement concerning tests and approval is included in the requirement specification or put down in directives such as ISO standards. In the case at hand it is similarly and all required tests are defined in an extra test specification. Acoustics, comfort, stiffness and vibration, adjustment forces as well as strain and stability requirements (endurance, abuse) will be tested. These tests might be distinguished between functional (component as well as assembly/car related) and safety tests. For example there are special tests for the seat heater including warm-up measurement and endurance run, tests for the entire seat (atmospheric change test) or the entire car (such as road trials). Special requirements may apply for safety tests such as crash tests and it may be required that all variants of a certain seat have to be tested. A special test which shall serve as a case study to exemplify the method is the measurement of the H-point of the seat. At this the coordinates of the hip joint point (H-point) are recorded by means of a torso model (simulating human weight and posture). The applied method of planning a test design for the H-point measurement is illustrated in figure 3 (for each test an individual representation is necessary).
Starting from the described test specification one may copy the required tests and their general specification into the test design planning instrument. Likewise the test criteria, i.e. parameters to be measured, and admissible values have to be defined clearly. For instance the H-point measurement is to define a certain reference point which has to be within a defined range of x-, y-, and z-coordinates.
If the test criteria are clear cut, influencing coefficients of that test criteria can be determined. For example the thickness as well as stiffness of the upholstery have an effect on the z-position of the H-point (e.g. the higher the thickness the higher the H-point). There might be added a weighting as well which represents the degree of exertion of influence. This is particularly important in case of mutually influencing coefficients.
If the influencing coefficients or possible interactions are unknown respectively the weightings cannot be estimated, they should be rated by methods of statistical process analysis [Kleppmann 1998]. It seems to be even possible to apply the methods of full/fractional factorial test planning for the entire test design of high variety products. At this, the influences of product changes (finally that means variety too) as well as their interactions on test results might be examined statistically by comparing several prototypes with a characteristic, statistically determined variant configuration and determining the effect on the test criteria systematically. But these tests might get very complex with an increasing number of variants and moreover the number of necessary test is pretty high (though Shainin methods might help to reduce the number of influencing coefficients consistently, [Kleppmann 1998]).
In case the test influencing coefficients and there weights are known, they have to be linked with the respective product components and variants (fig. 3). A variant tree seems to be suitable to give an overview about different parts and their variety [Schuh 1989]. E.g. the kind of upholstery, the cover, and the existence of a seat heater are obviously linked with the test criteria “thickness” and “stiffness”.



Product components	Variants	Seat stiffness	Seat thickness	Maximum set-up	Minimum set-up
Cover	*fabric*	1	1	x	
	leather1	2	2		
	leather2	3	3		x
Upholstery (foam)	*sport*	(3)	1		x
	normal	(1)	3	x	
Seat heater	*with*	-	3	x	
	w/o	-	0		x
	Weight	0.8	1		

Influencing coefficients (Seat stiffness, Seat thickness); Prototypes (Maximum set-up, Minimum set-up)

○ no influence
↑ strengthening influence
↓ easing influence
0-3 degree of influence

Test	Test criteria	Seat stiffness	Seat thickness
H-point test	*x-coordinate*	○	○
	y-coordinate	○	○
	z-coordinate	↑	↑

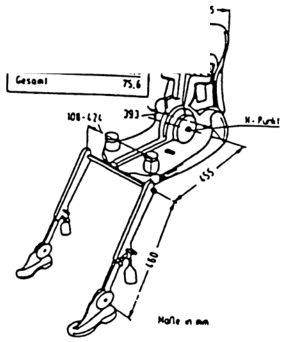


Figure 3. Test Design Matrix (example: H-point-measurement)

Now the degree of influence of the single variants on the test criteria has to be quantified. This can be realised by comparing variants and influencing coefficients by means of a design structure matrix (fig. 3). E.g. the cover variant “fabric” is not as thick/stiff as the cover variant “leather2”. Likewise the seat heater is raising the “thickness” significantly. As regards the upholstery, a sport seat is not as thick as a normal seat but stiffness is higher. Here the weight of the several influencing factors must be considered. In this case the upper boundary H-point position thickness is more relevant than stiffness. Consequently it gets a higher weight.

Finally a “maximum” and a “minimum” set-up have to be determined. These prototypes will be tested afterwards. If both prototypes meet the requirements concerning the H-point, all seat variants would do so, because they lay in-between. Apparently one single maximum or minimum test value/set-up cannot be determined in every case – then more tests (e.g. fractional factorial tests) are necessary.

If all prototypes are determined, one can try to reduce the number of testing set-ups further by optimizing the sequence of the tests. At first one has to identify similar set-ups over several tests by comparing the particular prototypes on the basis of their specific variant characteristics. This way overlapping can be filtered out and one prototype might be used for different tests. Thereafter the test sequence has to be defined. For that purpose one has to decide whether a test is more or less stressing or even destructive. In this case the tests were classified into 5 categories in which A-tests are ordinary measurements without any seat changing influences, B-tests are atmospheric change tests, C-tests are endurance runs, D-tests are part-destructive tests (but parts still may be substituted afterwards) and E-tests are seat-destructive tests. If mutual impact can be excluded, A-tests should be executed at the beginning (to make measurements as reliable as possible) and E-tests in the end.

Now the necessary prototypes and the test sequence are determined and tests can be executed. It is necessay to monitor and control the progress of the testing program, which the testing status is for.

4. Testing status

Within the testing status the accomplishment of experiments shall be tracked and the tested prototypes as well as the test results have to be made transparent to all related participants in a distributed development environment.
At first the tests including the respective testing variants have to be supplied in the right sequence. They have to be charted in vertical direction according to the testing design described above. In horizontal direction different information on the tests and their execution will be plotted. That includes information on construction status, required parts/prototypes as well as any other necessary resources, furthermore there is information on the required and intended releasing status, dates and periods permitted (including a project and testing schedule) and who is responsible. Last but no least testing results are recorded and include short notes on the actual test (including a statement whether the intended release status was achieved or recurrences are necessary), links to detailed reports and test values, and a general status statement (for the entire seat respectively certain seat variants). Besides, access to testing and status reports from the past or from other projects is possible. The testing status was realized as a computer application on the basis of MS Excel which features the design of the tests as well.

5. Conclusions

In the contribution at hand a method and a tool for planning and monitoring the tests of variant rich products were introduced. Both help to cope with challenges that have arisen from increasing product variety and organisational distribution. The first method focuses on a test design which helps to select crucial variant characteristics and to plan the experiments accordingly. That was illustrated on the example of the H-point test. Furthermore the grouping of different product variants was regarded concerning the bundling of different tests on one setup (at the level of highest commonness). Finally information on participants and responsibilities, required parts and experiment capacities, milestones, testing results, and related comments were integrated in a common information platform for the monitoring of the project status. This way a statement shall be enabled, what parts of a product are approved (concerning variants) and what is their design status (concerning project schedule). Next steps will be to integrate the introduced tool into the information platform concept for distributed development processes as described by [Baumberger, Pulm, and Lindemann 2003].

Acknowledgement

We thank the Deutsche Forschungsgemeinschaft for funding this project in the scope of the transfer centre "Coordination and Controlling of Distributed Development Processes".

References

Baumberger, C., Pulm, U., Lindemann, U., "Coordination and controlling of distributed product development processes", Proceedings ICED 2003, Stockholm, 2003, (CD).
Kleppmann, W.; "Taschenbuch Versuchsplanung", Hanser, Muenchen, 1998.
Kühne, F., "Risikoanalyse in der Flachbaugruppenfertigung", Interaktiv – Fraunhofer IPA, Vol. 3-2003, 2003, pp 12-14.
Lindemann, U., Pulm, U., Stetter, R., "Effective Strategies for Distributed Product Development", Proceedings IDPT 2002, Pasadena CA (USA), 2002, (CD).
Pulm,U.,Maurer, M., Lindemann, U., "Early evaluation of product properties for individualised products", Proceedings MCPC 2003, Munich 2003, (CD).
Schuh, G., "Gestaltung und Bewertung von Produktvarianten", VDI Duesseldorf, 1989.

Georg Christoph Baumberger
Technische Universität München, Produktentwicklung
Boltzmannstrasse 15, 85748 Garching, Germany
Telephone: 0049 89 289 15150, Telefax: 0049 89 289 15144
E-mail: baumberger@pe.mw.tum.de