ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

ASSUMPTIONS FOR INCREMENTAL INNOVATIONS IN SMEs

Robert WATTY
University of Applied Sciences Ulm, Germany

ABSTRACT
Innovation is an precondition for the success of companies in today's markets to differentiate from their competitors. Particularly 'radical' innovations are addressed in numerous research contributions, product contests and advertisements, although they are related to less than 10% of the innovations, carry a high risk of failure and often require a high investment in research and development.
Small and medium enterprises (SME) are often very successful in specialized market segments and with incremental innovations adapted to the needs of their customers. Prosperous product development in this context demands intense knowledge about the targeted market, competitive products and demanded objectives for new products as well as an appropriate development process starting.
This paper addresses the research question how to improve existing products in SMEs by incremental steps. It describes the context of radical and incremental product innovation, explains preconditions for the adoption of innovations, suggests an approach to systematically implement incremental product development in SMEs taken from Kaizen and describes a case study applying and verifying this approach in a SME.

Keywords: incremental innovation, development process, SME

Contact:
Prof. Dr. Ing. Robert Watty
University of Applied Aciences Ulm
Mechanical and Automotive Engineering
Ulm
89075
Germany
watty@hs-ulm.de

1 INTRODUCTION

It is a commonly accepted perception that innovation is an essential precondition for the success of companies in today's markets (e. g. Weber, 2012, Tan and McAllone, 2006) that also results in a growing number of papers addressing this topic in international conferences of diverse areas of expertise from design science to psychology. Companies have to develop and offer innovative products to their customers to differentiate significantly from their competitors. Particularly 'radical' innovations are addressed in numerous research contributions, product contests and advertisements, although they are related to less than 10% of the innovations (Smith, 2009), carry a high risk of failure (Cooper and Kleinschmidt, 2011) and often require a high investment in research and development.

Small and medium enterprises (SME) are often very successful in specialized market segments and with incremental innovations adapted to the needs of their customers. Prosperous product development in this context demands intense knowledge about the targeted market, competitive products and demanded objectives for new products as well as an appropriate development process starting with comprehensive requirement definitions.

This paper addresses the research question how to improve existing products in SMEs by incremental steps. It describes the context of radical and incremental product innovation, explains preconditions for the adoption of innovations, suggests an approach to systematically implement incremental product development in SMEs taken from Kaizen and describes a case study of the incremental improvement of a wood splitter in a SME practically applying and verifying this approach.

2 DEFINITION OF 'INNOVATION'

The term 'innovation' originates in classical Latin, where 'res nova' (new thing) and 'novitas' (newness, novelty) was changed to 'innovation' (alteration, renewal) by the roman judicial scholar Tertullian. The meaning in today's general language use is based on Scottish economist Adam Smith (1776) in 'Wealth of Nations', a fundamental work in classical economics and the Austrian/American economist Joseph Schumpeter. In '*Capitalism, socialism and democracy' (1942)* Schumpeter describes innovation as 'the opening up of new markets, foreign or domestic, and the organizational development … illustrate the same process of industrial mutation ... that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism.' Thus the creation of novelties requires substitution of the existing and is the foundation of capitalism in general or a growing economy more specific.

Nowadays 'innovation' has been defined by researchers and practitioners in different ways. The narrowest perspective uses innovation and invention synonymously and characterizes innovative products or processes just as qualitative new and distinctively different from the status quo. From the economic point of view, this approach is based on the economic theorem of means-purpose-relation, where means are offered by new technologies and purposes are demanded by the market. Innovation is a new combination of means and purposes in this context.

This view is stated much more precisely and widened by assuming that the new idea or product is not only the outcome of a creative process, but in particular has to be regarded as 'new' by potential stakeholders, figure 1. Subsequently it has to be adopted by individuals or organizations (Cooper, 1998), the involved parties, and has to be communicated ('Diffusion') by the members of a social system through certain channels (Rogers, 1983). This aspect also regards the psychological fundamentals of consumers behavior (Im et al., 2003) and novelty seeking (Hirschman, 1980). Thus the provider must know the demands and the preferences of the potential acquirer as exactly as possible to fulfill them better than preceding or alternative products.

The economic and the engineering view agree that beyond a purely new 'invention', innovation also requires that the invention 'has reached the market' (Ericson and Kastensson, 2011) or moreover was a 'successful realization … with an enhanced customer or manufacturer benefit' (Binz and Reichle, 2005), referring to Schumpeter´s 'capitalism'.

Product innovations take place in a context, figure 1, that must be regarded during the innovation process. The object and the outcome of an innovation process is a product, an idea or a process, in general hardware and software. Hardware can be a technical system as well as spare parts or packages, whereas software not only comprises computer programs but also information about e.g. maintenance and usage, the development of services or a new manufacturing technology related to the product.

Thus gathering requirements to a new product at the beginning of the product development process means collecting information about the entire life cycle of a product in order to improve all items related to theses phases.

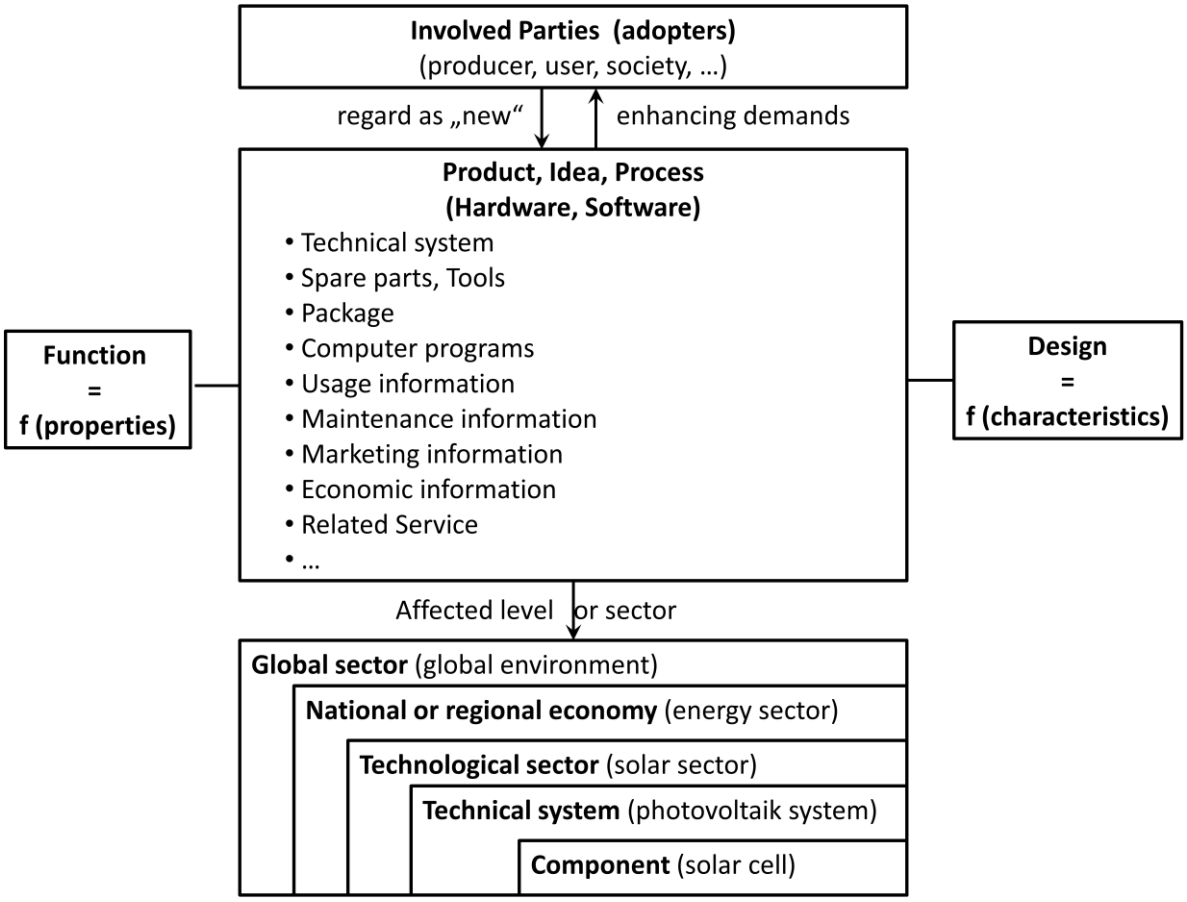

Figure 1. Context of product innovation

From the systems theory point of view, a technical product is the output of an engineering process generating an artificial deterministic system (Hosnedl, 2008) that fulfills the needs of the target market or user. Thus the demands of involved parties must be collected carefully and regarded during the development process in order to achieve them. Moreover this step also comprises the attitude towards the product. Innovative products must be recognized as "new" by the adopters according to the definition of innovation and to the characteristics particularly discussed in section 3.

Moreover the affected level or sector of the product have to be taken into account as well. The product level is based on the structure of a product, its components and their interconnections, whereas the sector describes the product environment. The technological sector e. g. in the field of solar technology develops very fast and the development of new products necessarily requires at least using the current state of technology. Comparatatively the technological field of e. g. wood splitters is very mature, didn´t change over the last 20 years and nearly the same technology is used by all competitors. In both fields of technology a change or further advancement of technology will be regarded as "new" by customers and the product may be regarded as "innovative" according to section 3. The same influences appear concerning the economical sector or the global sector that is targeted by a new product. The economical sector requires intense knowledge of the sales market and the global context is important to place products that are e. g. socially and ethically accepted. The extent of innovations can vary as well. Some innovations just affect single components (new display in a mobile phone), others change the global environment (first satellite phone system).

Following Hosnedl (2008) products realize properties (e. g. performance, stability, manufacturability, quality) through their characteristics (measurable criteria, e. g. dimensions, shape, weight) that are defined in the design process. Properties are often related to the function, characteristics to the design of a product. The main and clearly visible part of technical products is often hardware, but the software

is often equal important as well, e. g. computer programs, information about the usage, design, ergonomic aspects or even evaluation information about the innovative aspects of a product itself.
In summary a innovation can be defined as **the outcome of a creative process that is regarded as new by the targeted involved parties and is successfully enhancing their demands.** The outcome will be called generally 'product' in this article below.
There are two basic types of innovation – 'incremental' and 'radical' innovation, also named 'exploit' and 'explore' (Ericson and Kastensson 2011) in the context of product development or 'evolution' and 'revolution' rather related to organizational innovations and changes (Greiner 1994). Incremental innovations continuously improve features or cost of an existing product, radical innovations comprise comprehensive changes of existing products or provide completely new products. Leifer (2000) assumes one or more of the following criteria for radical innovations:

- *an entirely new set of performance features*
- *improvements in known performances features of five times or greater*
- *a significant (30% or more) reduction in cost*

Thus radical innovations demand revolutionary changes in product properties and often require fundamental changes of a product or process and furthermore of the related market or industry, table 1.

Table 1. Impact of innovation

	Incremental innovation	**Radical innovation**
Technology	existing / low changes	new / high changes
Product categorie	existing / low changes	new / high changes
Complexity	low	high
Project risk	low	high
Time and effort	low to moderate	high
Development process	standarized	unique
Consumer benefit	low to moderate; existing	high; new
Application of product	similar	modified
Company / competition benefit	Low to moderate	high
Strategy of company	Low	High
Infrastructure of company	low	high
Targeted market	Existing	Existing or New

Radical innovations require comprehensive changes in the strategy and the infrastructure (e. g. production lines or distribution channel) of a company, they often demand fundamental technological knowledge and research and intensely challenge the core capabilities and the manpower of development departments. On the other hand they strengthen the position of a company in their market, open new markets and enable the rapid further development of a company.
Innovation takes place in different phases of the product life cycle, figure 2.
The life cycle of a product starts with the primary innovation process that is often radical and leads to a new product or even product segment. The competition between competitors in the market requires further development in the phases of growth and maturity with a usually decreasing share of product innovation and increasing share of process innovation to gain a dominant design expansion at reasonable costs. Decreasing sales afterwards require a fundamental but incremental redesign to re-invent the product or the radical substitution of the product in order to obtain sustainable profit.
Thus radical product innovation takes place in the beginning of the lifecycle and under certain conditions at the end of it, while radical process innovation is important to continuously improve the manufacturing process during the lifespan of a product as soon as prices and sales revenues are decreasing. The main target of both product and process innovations along the lifecycle are to optimize the adoption of the product by potential customers.

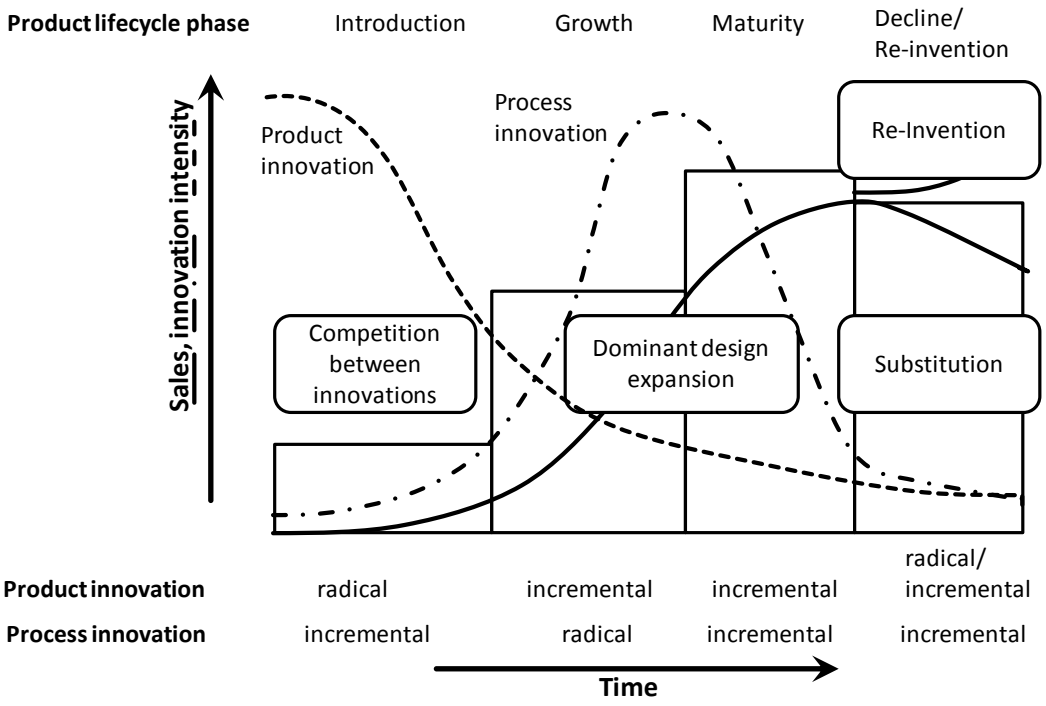

Figure 2. Innovation at different stages of the product lifecycle (modified from Ehrlenspiel (1995))

3 ADOPTION OF INNOVATIONS

Rogers (1983) defines five characteristics of innovations perceived by the involved parties, figure 3, that must be regarded in order to support the adoption process:

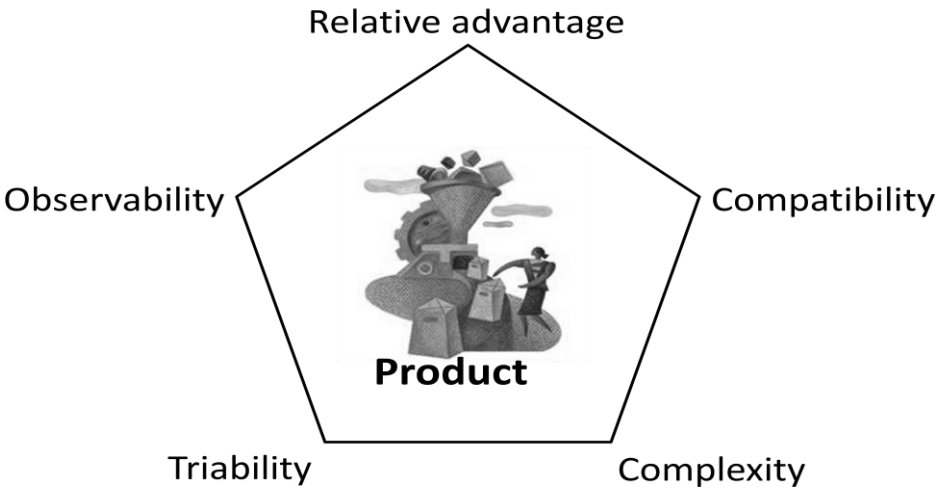

Figure 3. Characteristics of innovations

- *Relative Advantage* describes the degree to which the involved parties perceive the innovation to be better than the replaced object. The innovation must provide e. g. a better efficiency, performance or usability, a higher prestige or just a more pleasant design in order to motivate potential stakeholders to acquire it. This aspect targets mainly the properties of the product and positively influences the rate of adoption of an innovation.
- *Compatibility* specifies the degree to which an innovation matches existing objects or meets values, demands, past experiences or preferences of the adopters. Missing compatibility hinders or completely prohibits the adoption of an innovation. The change of e. g. a set of values in a society is often a long and difficult process, so that incorporated compatibility supports the adoption of a new product.

- *Complexity* is the degree to which an innovation is experienced as difficult to use or understand. Simple ideas or products are easy to explain and therefore easily and rapidly adoptable. Thus an ergonomic and self-explaining design enables fast adoption.
- *Trialability* describes the possibility to experience the innovation on a limited basis. If potential adopters get easy access to a free sample of the innovation, maybe for a limited time or with a reduced functional range, they will be enabled to realize the properties or the quality of a product and overcome the acquisition barrier more easily.
- The *Observability* is the degree to which an innovation is directly identifiable by potential adopters. Easy visible innovations support the decision-making process, stimulate peer discussions of a new idea and accelerate the information flow about a new product.

4 BOUNDARY CONDITIONS IN SMES

Formally seen, small and medium enterprises (SME) are all over the world defined by the number of employees and economic data. The definition of the European Commission (2003) is exemplarily shown in table 2.

Table 2. Definition of SME (European Commission, 2003)

Company category	**Employees**	**Turnover**	or	**Balance sheet total**
Medium-sized	< 250	≤ € 50 m		≤ € 43 m
Small	< 50	≤ € 10 m		≤ € 10 m
Micro	< 10	≤ € 2 m		≤ € 2 m

Practically more crucial for the capability to innovate is the structure of SMEs that is described by Ehrlenspiel (1995) and Nicolescu (2009), figure 4.

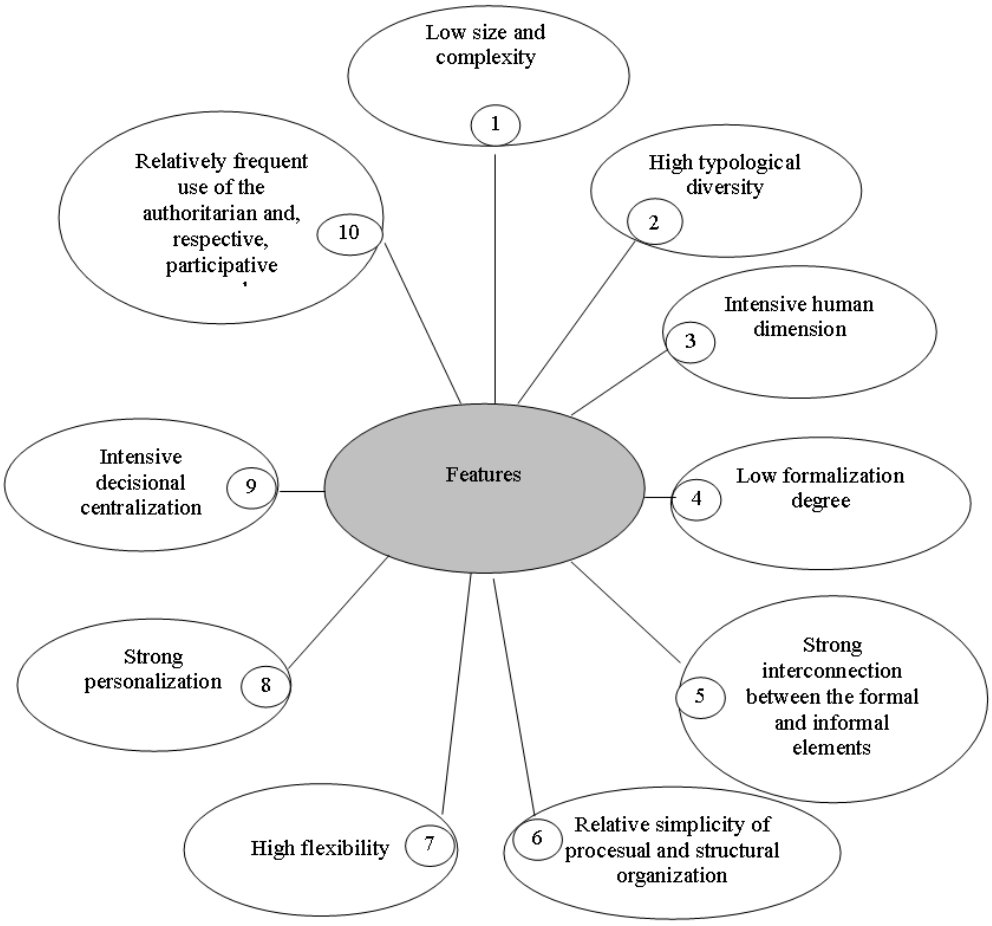

Figure 4. General features of SMEs organization system, Nicolescu (2009)

The most remarkable characteristics are the strongly centralized leadership by the owner, a low rate of academic personnel, a high flexibility based on a simple structure and the ability to make quick decisions. Moreover the products are often specialized to a small but very well known market segment and the manufacturing process is mainly realized with general-purpose machines.

5 SUCCESSFUL INCREMENTAL INNOVATIONS IN SMES

The general features of SMEs, figure 4, and the impact of innovations, table 1, implicate advantages of SMEs to implement incremental innovations concerning high flexibility and the ability to make quick decisions, whereas there may be a lack of actual technological knowledge to implement radical innovations. Large Companies undertake more R&D and smaller companies are more often (80% of the companies) technological followers, but have advantages based on less bureaucracy according to OECD (2000) and show clear advantages in accumulating small or incremental inventions because they can place innovations at the center of their competitive strategy (Scherer, 1991). OECD (2000) states that SMEs succeed by innovating without expensive R&D-investment must be stressed. Design innovation enables SMEs to continuously apply incremental improvements in products "that do not radically change their function or technological base, but allow firms to better meet customer requirements." and facilitate an advantage compared to larger companies because "traditional accounts of R&D largely under-evaluate the subtleties of innovative design which require a deep understanding of product function in relation to customer requirements; a strong command of all technical interdependencies within product components…"
If SMEs concentrate on this strength to improve their products incrementally, they can choose a more technological or a more design-oriented approach or combine both of them in order to differ from their competitors, figure 5:

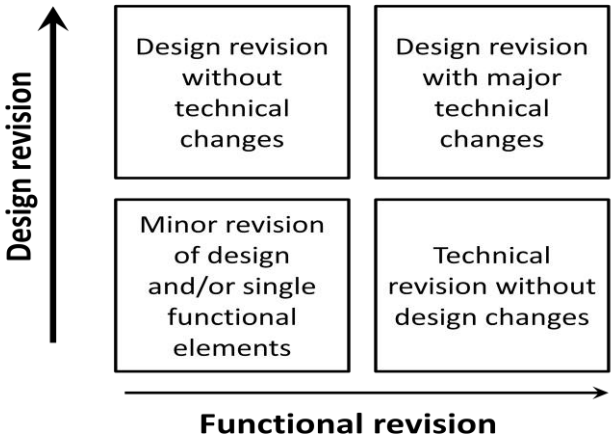

Figure 5. Objectives of incremental innovation

In all four cases, successful innovation often requires the explicit definition of the objective at the beginning of the project and the comprehensive integration of customers in the early phase of the development process. Incremental innovations may target

- Aesthetic changes to update the design, e. g. color or shape
- Qualitative improvement (or diminishment) to affect the endurance, costs, manufacturability or operability, e. g. change of material or manufacturing method
- Qualitative improvement for improved assembly, disassembly, maintenance or repair, e. g. better accessibility for replacement of parts or a minimized number of components
- Functional improvement to affect durability, functional properties, weight or costs, e. g. implementation of new technologies
- Customization of product or change of secondary functions to adapt to new target customers or markets, e. g. adding further interfaces or change of colour to customers choice
- Add or remove functions or components to improve usability, cost or flexibility, e. g. add/remove undercarriage for mobility or static operation
- Improve sustainability or energy consumption, e. g. exchange of actuation components or energy intensive materials

It is very important to consider not only a single product but also the product group, other products concerned or the corporate strategy. The new design of a single product may make other products appear old on a fair presentation and replacing the control lever by a touch screen in one product results in different operation technologies and confusion of customers using different products.

6 DEVELOPMENT PROCESS AND CASE STUDY ON INCREMENTAL INNOVATION IN SMES

Development processes in literature usually refer to the development of new products. Thus for use in the case study the approach for the development process was derived from the well known Continuous Improvement Process known from Kaizen with the focus on organizational improvements and software development described by Kinnula (2000) as an example for the process used by Nokia, figure 6.

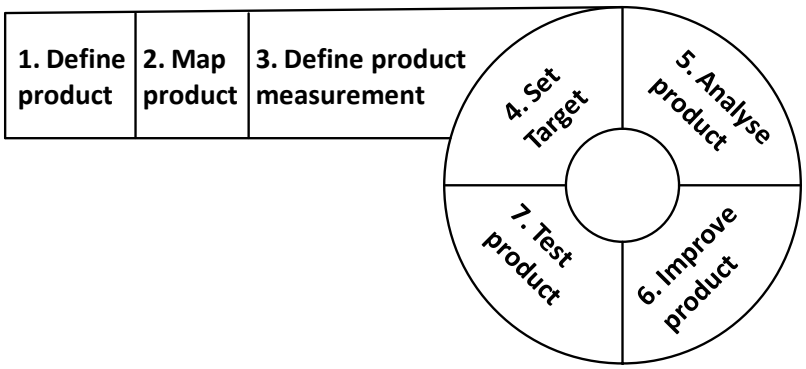

Figure 6. Continuous Improvement Process applied to incremental product innovation [based on Kinnula (2000)]

This process was applied for the redesign of a horizontal wood splitter for professional use, figure 7. The manufacturing company is a typical medium-sized SME with 60 employees manufacturing garage doors and forestry equipment. The general manager is responsible for technological and commercial aspects and personally taking care of product improvements. The structure of the company is highly centralized and very flexible with a workshop able to implement and test product modifications immediately. The market for wood cutters is well defined, competitors are well known, many customers known personally and the feedback of products properties therefore very directly.

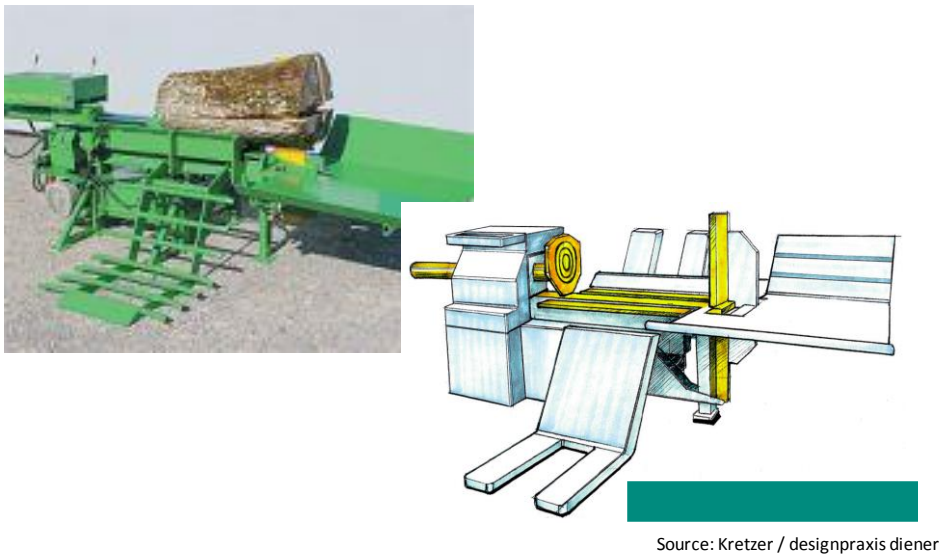

Figure 7. Horizontal wood splitter – existing and redesigned (case study)

The incremental innovation process for the wood splitter was carried out according to the steps described in figure 6:

- **Define product** The product to be improved was an horizontal wood splitter “SK 900/20” with 20 tons of splitting force. The wood cutter has been build for 20 years with minor changes.

- **Map product** A comprehensive functional analysis of the actual product and a comparative study of the competitive products was carried out, the function structure of the wood splitter was developed, the operating process watched on-site.
- **Define product characteristics** Product characteristics were derived from the technical data and from the comparative study. Technological parameters like the feeding rate or weight were derived as well as qualitative parameters like colour, shape, the hydraulic oil for the power unit or the illumination for road traffic. The result was a list of characteristics of the actual product completed by a description of the actual manufacturing process and the product documentation.
- **Set target** According to figure 5, the target of the development process was defined as a design revision with major technical changes. The design revision comprises a distinguishable new design with different colours, shapes and graphics as well as improved ergonomics. The technical improvement mainly targets functional changes of handling and drive train, reduction of costs, optimization of the manufacturing and assembly process, an improved sustainability and the addition of new functions. General target were a new frame used in a building set and a new meaningful name for the product. All targets for the development process were collected in a suggested improvements list based on the list of characteristics.
- **Analyse product** The wood splitter was subdivided into its parts and each part was assessed according to function and benefit for the overall function. The main parts involved in the operation of the machine and in the wood splitting process were defined for the design process.
- **Improve Product** The function of the splitting process was improved e.g. by a patented wood deposition area with movable fixation for a considerable better handling, the use of bio-hydraulic oil for an improved environmental compatibility, an overheating protection for the drive system including a temperature indicator, a storage box for equipment and an improved production process based on a building set for three types of wood splitters with different forces and the outplacement of the manufacturing of the frame.The design was completely revised resulting in modified shapes and colours to make the wood splitter look much more up-to-date, improve the removal of wood chips and differenciate significantly from competitor´s products. The improvements process clearly indicated a great advantage of SMEs compared to large enterprises. All suggestions for improvements were immediately decided by the general manager. The changes in color and graphics were transferred to related products, e.g. a sawing machine, the frame is usable for all three sizes of wood splitters and the new name “Powersplit” was selected for the wood splitter.
- **Test product** The testing process was also characterized by the SMEs size. All modifications were carried out continuously parallel to the development process and tested effectively and efficient even by customers provided with trial machines.

7 CONCLUSIONS AND OUTLOOK

Product innovation requires the consideration of the product itself as well as the involved parties and affected sectors. Product adopters must be able to recognize the product as “innovative” and their demands should be carefully identified in order to place new products successful on the market.

SMEs often concentrate on incremental product innovations in order to benefit from their advantages, e.g. high flexibility and quick decisions, and avoid high investment in R&D. In the case study of a typical SME producing wood splitters the actual procedural and technological knowledge for a efficient and effective development process was externally acquired in cooperation with the local chamber of industry and commerce and a scientific consulting service.

The intended design revision with major technical changes of a wood splitter was carried out according to the Kaizen process described for continuous improvement of business processes and software. The result of the innovation process according to section 3 is an obvious advantage in handling of the wood, it is compatible to the previous solution and of moderate complexity. The new design and the advantages of the new solutions are clearly observable by trial users and the innovation process was therefore successful and confirmed by requests of the improved wood splitter.

The definition of “innovation” and its adoption could be verified in a typical SME context and the process was successful, but it must be defined more precisely in detail and supported by adequate methods in the future. There are research gaps in “incremental innovations”, and “innovation in SMEs” about fundamentals and procedures if product design or technical function are modified.

REFERENCES

Binz, H., Reichle, M. (2005) 'Evaluation method to determine the success potential and the degree of innovation of technical product ideas and products', in *Samuel, A., Lewis, W. (Eds) (2010) 15th International Conference on Engineering Design: Engineering Design and the Global Economy ICED'05*, Melbourne (Australia), Institution of Engineers Australia/The Design Society, pp. 222 - 236

Cooper, J. (1998) 'A multidimensional approach to the adoption of innovation', *Management Decision*, Vol. 36, No 8, pp. 493 - 502

Cooper, R., Kleinschmidt, E. (2011) 'New Products: The Key Factors in Success' [online], Marketing Classics Press, www.books.google.com/books?isbn=1613112300 (accessed 2013-01-04)

Ehrlenspiel, K. (1995): *Integrierte Produktentwicklung: Methoden für die Prozessorganisation, Produktherstellung und Konstruktion*, München, Hanser

Ericson, A., Kastensson, A. (2011) 'Exploit and explore: two ways of categorizing innovation projects', in Culley, S.J.; Hicks, B.J.; McAloone, T.C.; Howard, T.J. & Cantemessa, M., *18th International Conference on Engineering Design – ICED 2011*, Vol. 3, Copenhagen, Technical University of Denmark/The Design Society, pp. 284 - 293

European Commission (2003): *'Recommendation 2003/361/EC: SME Definition'*, URL: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:EN:PDF, accessed 2013-01-04

Greiner, L. E. (1998) 'Evolution and revolution as organizations grow', *Harvard Business Review*, Vol 76, No. 3, pp. 55 - 68

Hirschman, E. (1980) 'Innovativeness, Novelty Seeking and Consumer Creativity', *Journal of Consumer Research*, Vol. 7, No. 3, pp. 283 - 295

Hosnedl, S., Srp, Z., Dvorak, J. (2008) 'Technical Products and their Attributes – Theory and practical Applications', in Vanek, V., Hosnedl, S., Bartak, J., *Proceedings of the AEDS (Applied Engineering Design Science) Workshop Pilsen*, pp. 121 - 132

Im, S. et al. (2003) 'An Empirical Study of Inate Consumer Innovativeness, Personal Characteristics, and New-Product Adoption Behaviour', *Journal of the Academy of Marketing Science*, Vol. 31, No. 1, pp. 61 – 72

Kinnula, A. (2000) *Software process engineering systems: models and industry cases.* University of Oulo, Finland, URL http://herkules.oulu.fi/isbn9514265084/html/index.html (accessed 2013-05-10)

Leifer, R. et al. (2000) *Radical Innovation*, HBS Press, USA

Nicolescu, O. (2009): *Main Features of SMEs Organisation System, Review of International Comparative Management*, Vol. 10, No. 3 URL www.rmci.ase.ro (accessed 2013-01-04).

OECD (2000): *Enhancing the competitiveness of SMEs through innovation.* Background paper, Bologna, Italy, June 2000, URL www.oecd.org/industry/smes/2010176.pdf, (accessed 2013-05-10)

Rogers, E. (1983) *Diffusion of Innovations*, New York: Free Press

Scherer, F.M. (1991) Changing perspectives on the firm size problem, in Z.J. Acs and D. B. Audretsch, (eds.), *Innovation and Technological Change: An International Comparison*, Ann Arbor: University of Michigan Press, pp. 24-38.

Schumpeter, J. (1942) *Capitalism, socialism and democracy,*. Harper, New York/London 1942

Smith, Adam (1776) *An Inquiry into the Nature and Causes of the Wealth of Nations*, 1 ed., W. Strahan, London

Smith, D. (2009) *Innovation*, New York, McGraw Hill

Tan, A., McAloone, T. (2006) 'Understanding and developing innovative products and services: the essential elements', in Marjanovic D., (ed) (2006) *Proceedings of the9th International Design Conference - DESIGN 2006*, Dubrovnik, University of Zagreb/The Design Society, pp. 647 - 654

Weber, C. (2012) 'Idea – invention – innovation: strategies, approaches, research challenges', in Marjanovic D., Storga M., Pavkovic N. and Bojcetic N. (eds) (2012) *Proceedings of the 12th International Design Conference - DESIGN 2012*, Dubrovnik, University of Zagreb/The Design Society, pp. 1265 - 1274