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Integrating new technologies and materials by reengineering: selected case study results

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Abstract

Potentials of integrating new technologies, particularly carbon fiber reinforced plastics, are not fully considered conventional reengineering processes. This paper firstly addresses the benefit by integration of functions, reduction of weight and fuel consumption, substitution of rare materials and customer individuality.

Consequently, these aspects have been evaluated in three case studies, comprising representative cultural goods (eg. pipe organs), components of sport-aircraft (eg. ultralight helicopters) and urban-transport (eg. multifunctional stroller-bicycle trailer). Therefore, the following methods have been applied: functional analysis, reverse engineering and measuring technologies.

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1. Introduction

In modern society, sustainability plays an increasingly important role in everyday-life. With consumers' rising demand for environmentally friendly and sustainable products in combination with a trend towards advanced high-tech products materials and technologies need to be pushed to the markets that were characterized as too risky, too expensive or too complex only a few years ago. At the same time, customers request advanced high-tech products. Hence, materials and technologies are pushed that seemed to be too risky, too expensive or too complex.

A promising technology in the field of lightweight construction to improve product performance are carbon fiber reinforced plastics (CFRP). The major challenge is to generate a customer benefit which surpasses high material and production costs. To consider the benefits of integrating CFRP, eg. additional functions, weight reduction or substitution of rare materials, the overall system has to be evaluated for a thorough representation of the cost-benefit ratio.

In this work, three case studies were performed to systematically evaluate the use of CFRP in various fields of application.

2. Lightweight design

Besides the goal of maximization of possible weight reduction lightweight design aims at reducing the use of raw materials as well as operating costs for energy usage. Especially, frequently accelerated or slowed down objects can reduce their operating costs or increase their payload by lightweight design. This is indicated by Newtons second law of motion [1] that states, that the necessary force for acceleration of a body decreases if the mass of the body is reduced.

2.1. Integrating new technologies and materials

For weight reduction in various fields of application new technologies and materials represent a promising solution. Besides metallic lightweight construction materials, eg. aluminum, magnesium, high-strength steels and titanium, CFRP are important lightweight materials.

A study of the *association of german engineers (VDI)* states that the demand for lightweight materials is increasing steadily in the automotive sector. Figure 1 shows that in 1977 until today mostly conventional steel is used for fabrication of cars. It can be seen that in 2035 material usage will be more evenly distributed, i.e. the proportion of lightweight materials increases significantly. In contrast conventional steel usage is reduced by more than 40 %.

New technologies and materials also offer increased customer benefits as described in the following subsection.

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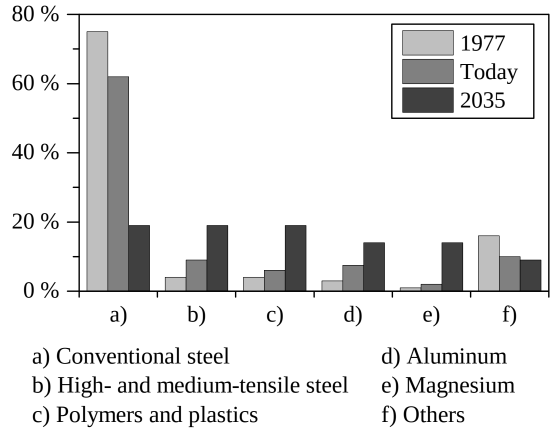

Fig. 1. Material usage of cars from 1977 to 2035 [2]

2.2. Increasing customer benefits

CFRP is used in a large number of industries and in a variety of ways, due to many advantages including long lasting durability and strength. They are used in aerospace, aircraft, automotive industries as well as in sports and medical equipment. However, lightweight design already starts during product conception. The aim is to achieve added value for the customer by weight reduction of marketable products. In general, consumers are willing to accept rising prices for added value, eg. individualization, weight reduction, personal optimization, which enable an increase in turnovers. Therefore, the subsequent sections cover three typical examples for increasing customer benefits.

2.2.1. Integration of functions

Integration of functions can be divided into integration of passive, active or sensory functions into a workpiece. Exemplary passive functions are stiffness, damping, thermal conduction. Functions for vibration and noise reduction as well as gears represent active functions. Furthermore, a structural health monitoring system is an example for for integrated sensory function. [3]

ZF Friedrichshafen AG shows in an axle study the potential of functional integration of CFRP in a passenger car chassis using a wheel controlling transversal leaf spring. In this axle concept, a transversal leaf spring made of glass-fiber reinforced plastics is used to simultaneously fullfill the functions of wheel control, cushion and stabilization. The composite leaf spring axle weighs 13 % less than a complex multi-link rear axle made of steel. [4]

2.2.2. Weight and fuel reduction

The development of carbon fiber construction for aerospace and aircraft applications has successfully replaced heavier materials. The use of composite materials is steadily increasing, especially in structural parts. Exemplary, the Airbus A350XWB is built of 53% composite materials [5], see Fig. 2.

To transfer the advantages of CFRP to other transportation industries, eg. the automotive industry, the following problems need to be solved: high material prices, expensive manufacturing process, lack of automatization, recycling issues. Especially in mass-produced cars, the current use of CFRP is limited due to the constraints mentioned before.

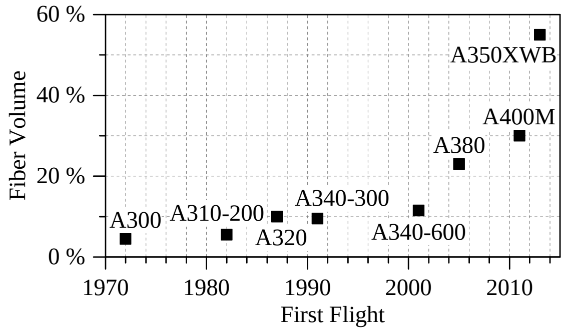

Fig. 2. Application of CFRP in aircraft constructions [6]

Engels [7] shows that decreasing the energy consumption in the manufacturing process of CFRP offers high potentials for the automotive industry. Moreover, significant energy saving potentials during operational times compared to heavy steel cars are possible.

Suzuki [8] calculated that a weight reduction of 36 % of mass produced passenger cars with CFRP decreases energy consumption over the life-cycle of a car by 15 %. As a result environmental impact is reduced.

To increase efficiency, car manufacturers started reducing the overall weight of cars, but stricter legal safety standards demand for heavier body parts. To overcome this bias, car manufacturers have to expand their efforts in research and development of new materials that are both lightweight and high load capacity. While the usage of CFRP today is dominated by the sectors aerospace and wind energy, forecasts indicate a promising growth potential in the automotive industry. [9]. It can be seen from Fig. 3, that a growing demand for CFRP in automotives from 2015 to 2022 can be expected. Nowadays, market pull demands for fuel efficiency. This demand could be satisfied by a technology push in lightweight material production.

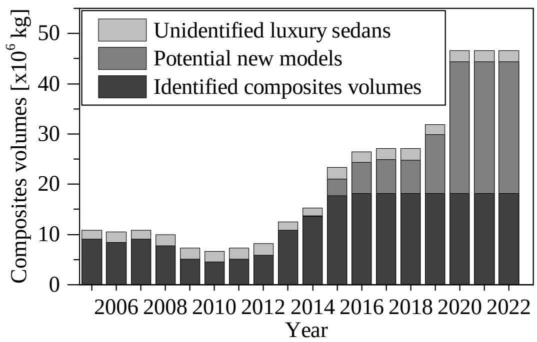

Fig. 3. Composite materials volume for automotive [9]

Moreover, lightweight materials enable the substitution of rare materials. Thus, reducing dependency on limited natural resources paving the way towards a more sustainable economy.

2.2.3. Substitution of rare materials

Scarcity of raw material results in a high risk supply chain that leads to complex, expensive and time-consuming supply processes. Using new materials that are independent of regional availability rare materials can be replaced and competitiveness