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Maintenance of Shape Memory Actuator Systems - Applications, Processes and Business Models

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Abstract

Today products are more and more substitutable due to progress in information technology as well as globalization. New competitors, particularly from developing and emerging countries are putting established companies under pressure, due to lower production costs. In consequence, the prices and thus realizable profits for companies are decreasing. Focusing on the customer value can help to break this trend. In this way, the product understanding is changing. Besides offering products, offering services and combining both is getting more and more important. However, the product requirements are changing and may require new technologies. For small-to-medium-sized actuator applications shape memory alloy based actuator systems are a promising technology. In addition to the advantages in physical and mechanical properties, the integrated sensor function allows a simple condition monitoring and thus easy maintenance processes. Companies can generate new value for customers and are therefore able to improve their competitiveness. The consequence is that companies are offering new business models. For this reason, these actuators are ideal for industrial product-service systems. This paper illustrates the maintenance processes of shape memory based actuator systems using the integrated sensor function. Based on these maintenance processes and suitable business models are designed as well as analyzed. As a result, recommendations for these actuator systems are provided. It is vital to introduce the relevant areas like shape memory alloy based actuator systems, industrial product service systems, maintenance and business models in the field of mechanical engineering first.

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1. Introduction

In today's industry, products are evaluated mostly based on their technical properties. Therefore, products are easy to replace and thus decrease the competitiveness in the long run. In this case, competition focuses almost exclusively on cost. The combination of goods and services allows a differentiation from competition. This makes it possible to reduce the importance of cost as criteria for competition. Nevertheless, it must be taken into account that new technologies may be required to provide IPSS. In the field of small to medium sized actuator applications, shape memory alloy based actuator systems are a promising technology that allow very simple actuator-sensor systems by which companies are able to offer IPSS. Besides advantageous physical and mechanical properties of shape memory alloys (SMAs), previous works have already shown that SMAs have high potential for services [1]. The integrated sensor function or self-sensing of shape memory alloy based actuator systems (SMA-ASs) allows a statement about proper functioning [2] and is capable to provide a condition monitoring of the actuator system [1]. Regardless, investigations on SMAs mainly focus on material, mechanical and control aspects. An evaluation of the service potential based on the material properties of SMAs is missing, as well as investigation of proper processes and discussion of these. Therefore, the purpose of this paper is to develop maintenance processes, which take into account the specific features of SMAs. Additionally, proper business models are discussed, which use these maintenance processes.

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The paper is organized as follows: Section 1 gives an overview on the application of SMA-ASs, discusses industrial product-service systems (IPSS) from a literature perspective. Due to its relevance for IPSS, an overview of maintenance is given. Finally, different types of business models in the field of mechanical engineering are presented. In section 2, maintenance processes of SMA-AS are illustrated with the distinction between a functional and availability-oriented usage of these actuator systems. Section 3 focuses on the resulting business models for SMA-AS, which can be derived from the maintenance processes. In section 4, the recommendation for companies in the context of SMA-AS are discussed. Finally section 5 draws a conclusion and provides an outlook.

Nomenclature

BM	Business model
CRM	Customer relationship management
IPSS	Industrial product-service system
KAM	Key account management
PLM	Product lifecycle management
SMA	Shape memory alloy
SMA-AS	Shape memory alloy based actuator system

1.1. Application of shape memory alloy based actuator systems

New materials such as smart materials enable innovative solutions for various applications. Noteworthy in this field are SMA. SMAs have the astonishing ability to remember their original shape, have an actuator function and can show super elastic behavior. They are characterized by high displacement and forces, high corrosion resistance, and good biocompatibility [3, 4, 5]. Furthermore, SMAs have an integrated sensor function or self-sensing function, which can be used for the control of purposes. [6] Regarding the positioning of SMA actuators, various studies prove this ability [2, 6, 7, 8, 9]. Additionally, Czechowicz [10] concludes that by measuring the resistance of the material, monitoring of fatigue is possible. One important feature of SMA compared to conventional materials is monitoring of fatigue and monitoring of functionality by measuring the displacement. By measuring resistance, conclusions about material condition and material history as well as displacement can be made. Thus, countermeasures can be taken, if the resistance decreases below a certain value and possible breakdowns of the system prevented.

Due to the special sensor properties of SMAs, there is a high potential for a simplified maintenance of these actuators or rather a function ensured by these actuators. This can also help to reduce the complexity of technical solutions.

SMA-ASs are mechatronic actuator systems, which in the simplest case are composed only of a SMA-Actuator. When requirements for control exist, a board is added. If information about fatigue and functionality are monitored based on the sensor characteristics, the board is replaced by a microcontroller. This has interfaces for information processing such as Ethernet or bus interface. Then software is used for information processing and evaluation as last part of a SMA-AS.

For this reason, SMAs are interesting for a wide range of applications, especially valves, locking and unlocking mechanisms or vibration damping applications [3, 11]. Additionally, if the knowledge of the state of an actuator is relevant as well as the complexity and compactness of the actuator system is critical, the use of SMAs is promising almost industry independent. Figure 1 illustrates the wide range of actuator applications, ranging from biomedical applications to telecommunication.

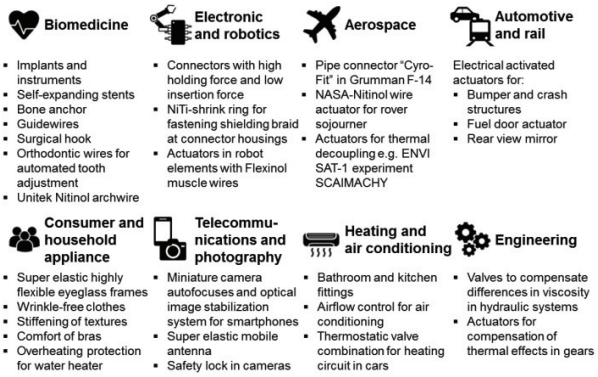

Figure 1: Applications of shape memory alloy based actuators

1.2. Industrial product-service systems

In literature, there are various terms for IPSS, like extended products, product-service system, service engineering, which are all very similar [12]. Rese et al [13] state that IPSS integrate products and services with the goal to create value beyond the value of a single product. Furthermore, their integrated and mutually dependent process of planning, developing as well as delivering goods and services is a unique feature of IPSS. This applies to the entire IPSS life-cycle. To offer IPSS, it is of vital importance to include the customer.

Companies often limit themselves to products and rarely consider the potential of services. According to Meier and Uhlmann [14], service potentials in the field of mechanical engineering are, among others, financing, training, certification, quality assurance, simulation and availability as well as maintenance.

1.3. Maintenance

The high importance of maintenance for companies can be illustrated by their average annual expense. Based on a study of the VDMA [15], the average expense for maintenance is about 4.7 percent of the replacement costs of an investment, which represents - over a lifetime of 20 years - the value for the machine investment.

Maintenance is defined as a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which