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IFAC-PapersOnLine 49-12 (2016) 053–058

Technology based industrial product-services supporting robustness in manufacturing systems

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Abstract: Uncertainty affecting manufacturing systems or networks asks for approaches able to smoothing the negative effects of disturbances coming both from the plant and supply chain levels. Thus, the objective of this paper is to investigate the capability of product-services business models of increasing companies robustness, towards internal and external disturbances in highly dynamic environments. This work is part of the EU project RobustPlaNet, which investigates this topic in the context of three industrial areas, i.e. automotive, aerospace and industrial automation. The analysis is carried out on a case study in the field of equipment reliability in order to demonstrate the formalization of business models for industrial product-services that support systems' robustness.

Keywords: Disturbances, manufacturing systems, product-services.

1. INTRODUCTION

In recent years, manufacturing industries are challenging with highly unpredictable production environment, while trying to be efficient and to fulfill customers' demand with the highest performance. They are part of global production networks and, for this reason, exposed to the influence of the other companies' output variability and to the fluctuations of markets. At plant level, disruptive events, like for example machine failures or lack of materials, influence the behavior of the manufacturing system and may modify the related performance. These deviations cause in turn lowered customer related performances (e.g. service level) and definitely problems in achieving demand requirements. This asks for solutions for improving the ability of production system to handle these environmental changes, while maintaining the requested performance, i.e. being robust. Traditionally, enhancing of manufacturing systems responsiveness towards disturbances is addressed exploiting in-house competences or by paying for outsourced solutions. For example, solutions for mitigating production system reliability disturbances rely in maintenance crew additional training on specific interventions or in equipment overhaul outsourcing. Among the other approaches proposed in literature, the adding, coupling or integrating of services into products offering represents a viable production system robustness enabler. In fact, it promotes the establishment of new cooperative and collaborative buyer-supplier relationships, characterized by interactions/communications schemes which aim at smoothing the negative effects of disturbances acting on the system under investigation. This is made possible by assigning robustness related critical tasks and associated risks to the stakeholders in the user network which have the greater expertise and which can achieve the goal of disturbance mitigation in the most efficient way. For services with shop floor robustness focus – i.e. in which the service provider is the technology provider – this means also overcoming the product-focused technical offering based on transactional relations, towards service-centered selling grounded on long-term relationships and value added proposition (Wiendahl et al., 2004). Operationally, these collaborative relations require B2B business models and related technical enablers, like ICT integrated solutions and advanced hardware.

Thus, the objective of this paper is to investigate the capability of product-services in B2B (Business-to-Business) applications of contributing to increase companies manufacturing systems robustness, towards internal and external disturbances in highly dynamic environments. The paper is focused on the description and analysis of product-service business models, strongly grounded on technologies in their delivery/fruition. In fact, this work is included in the EU project RobustPlaNet, whose main scope is developing innovative methodologies, tools and business approaches for collaborative and robust production system and networks, able to provide technology-based product-services with high service levels in global and unpredictable environments. The project investigates this topic in the context of three industrial areas, i.e. automotive, aerospace and industrial automation. Ad-hoc designed questionnaire are used to gather information from industrial partners and define product-services for the different application domains. In this paper, one of the product-service business model proposed in RobustPlaNet is analyzed in detail. It is conducted in the field of equipment reliability for enhancing shop floors robustness. Hence, in Section 2 we discuss the motivation which leads to identify product-services as a method for increasing the degree of robustness of manufacturing systems. This paves the way to

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.07.549

the description of the formalized framework under which the case study is presented. The related detailed discussion is illustrated in Section 3 and is followed by the selected product-service description and analysis. Section 5 points out the main conclusions and draws possible future work paths.

2. ROBUSTNESS AND PRODUCT-SERVICE

2.1 Robustness in manufacturing systems

A manufacturing system is considered *robust* if it is able to reduce the output variability with respect to the desired target performance when the system is subject to a given set of disturbances. Thus, robustness is defined as the ability of a system to provide the desired output performance at the desired time, in presence of internal and external disturbances. In the RobustPlaNet project is investigated the influence of supply chains on manufacturing system robustness and vice-versa. Here the focus is exactly on the first link. Indeed, manufacturing systems are exposed to a wide set of disturbances. These disturbances reflect context uncertainty and are unexpected and unwanted, since they act negatively on the manufacturing system and on the whole supply chain performances. For this reason, their impacts must be taken under control (Stricker and Lanza, 2014). In order to achieve this goal, it is needed to act on the causes of disturbances, which can be either internal or external.

Internal disturbance sources are originated within the company boundary and influence the behaviour of the manufacturing system, affecting processing times, availability of resources and parts quality. For example, equipment failure can be caused by uncontrolled degradation dynamics of the equipment components (internal disturbance source); acting on this earlier, either the probability or the magnitude of fault occurrence can be reduced, having in turn benefits on production system performance (e.g. throughput). On the other hand, external disturbance sources are driven by variations originated from the environment outside the company boundary, both on suppliers' side and on customers' side. These fluctuations regard volume and part mix to be produced, as well as related processes and materials. For example, supplier delays in component delivery (external disturbance source) cause modification of production plans and other related activities (e.g maintenance interventions). Sharing information related to components forecast, production plans and suppliers capacity helps in reducing the probability of delays and increasing stakeholder responsiveness.

Regardless of the class of disturbances, their impact on system performance can be mitigated by the application of solutions that improve faster adaptability or resilience to changes. At shop floor level the system may be endowed with redundant buffers/transportation system for absorbing part routing variations and volume fluctuations. On the other hand, flexible equipment can meet variable tasks and reconfigurable production lines can adjust their layout and configuration according to variable part mix. In any case, the selected solution embodies a certain robustness level and is characterized by certain costs and benefits, such as time-to-react to the changes. In order to be effective, it must fit the features of the dynamic environment. In fact, the capability of fast reacting to changes must be embedded in the manufacturing system design, equipped by suitable ICT systems for information sharing with the selected network partners. Finally, the robust-oriented solution implementation must be justified by higher benefits (deducted all costs) compared to the status-quo situation.

2.2 Industrial product-services as robustness enablers

Industrial Product-Services are characterized by an integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system (Meier et al., 2010b). The integration of technology-based services into product offering allows for the implementation of robust-oriented solutions (e.g. reconfigurable equipment) in the most efficient way, taking advantages of capabilities and resources located at plant level. Practically, it is implemented by the establishment of collaborations among stakeholders with long-term perspectives. The co-operative relation permits to study the best allocation of the activities and tasks related to the service, according to the capabilities and resources of the single supply chain stakeholders. Within a network, at minimum, product-service provider and product-service receiver work together for achieving the maximum value (Meier et al., 2010b) and thus a win-win situation. For this reason, industrial product-services can be considered as multi-agent systems (Meier et al., 2010c) in which the value is mostly co-created (Rese et al., 2012). This means that how the features and the dynamics of the interactions among stakeholders are designed and delivered – so the underlying business model(s) – determine the product-service success in achieving competitiveness and robustness. In fact, *utility* is a well-known goal, which reflects the ability of a company business model of generating added value – see (Tukker, 2004) for an extend analysis in product-service context –, while the *robustness* is embodied in the quality of the business model design and delivery, in the selected supporting technologies and in the tasks/risks distribution among supply chain stakeholders. Hence, product-service characteristics reflect their suitability for enhancing robustness in manufacturing systems and competitiveness. For example, in the context of capacity selling – i.e. results-oriented product-service (Tukker, 2004) in which a machine tool builder sells parts instead of selling machines (Baines et al., 2007; Beuren et al., 2013) – the information sharing (common feature of product-services), at various level, enables reducing information distortions and asymmetry and, thus, the associated disturbances. In fact, it permits the service receiver to operate with certain capacity flexibility (improvement of *robustness*), without bearing the uncertainties of machines capital lock-out and related technology use (improvement of the *utility*). While, the service provider can maximize the utilization of its available capacity (improvement of the *utility*), applying the same service to different customers, and so maintain his demand as stable as possible (improvement of *robustness*).