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Technology pushed process and product innovation – Joining by Linear Flow Splitting

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Abstract

In order to take full advantage of manufacturing technologies, designers have to use technology specific manufacturing-induced properties. An adequate selection and optimisation of the manufacturing technology and a consequent combination of product and process development can lead to product innovations. Linear flow splitting yields ultra fine grained (UFG) microstructures which are characterised by high hardness, ductility and fatigue strength. These manufacturing-induced properties are particularly suited for rolling contact areas of linear guiding systems. Multi-functional linear systems require an integration of additional functional elements. For the hereby necessary joining, using the mechanisms acting in the linear flow splitting process seems attractive. The paper introduces a mechanical joining process following this technology push approach. Thereby, manufacturing-induced properties and mechanisms induced during the linear flow splitting process are utilised to integrate additional functional elements. Necessary joining operations can be integrated into the continuous flow production, maintaining the technological potential to manufacture large quantities at low costs. Extensive experiments show the applicability of various joined elements and materials for process integrated mechanical joining. The potential for product innovations is illustrated by an innovative linear system. Its core component is an integrated rack as part of a rack and pinion drive of a facade cleaner.

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1. Introduction

Current design methodology is predominantly focussed on the idea of a market pull based product development. On the one hand established approaches given by e.g. Suh [1] or Pahl/Beitz [2] are initiated by a specific stakeholder or market need and lead to the development of a product that satisfies this specific need. On the other hand manufacturing technologies become increasingly important for product design. Especially DfM approaches consider manufacturing technological restrictions already during product design by providing guidelines [3]. Many research activities in the field of manufacturing technologies and processes mainly focus on ways to widen these technology's boundaries like e.g. geometrical restrictions or process accuracy in order to ensure the required product quality or to improve cost-efficiency. Manufacturing technologies are not only characterised by their specific boundaries. They can also initiate product and process innovations by systematically exposing their specific potential. The major challenge consists of methodically tapping this manufacturing potential, starting from occurring mechanisms in existing manufacturing technologies and the material flow in a production chain. New technology pushed manufacturing possibilities have to be identified for subsequent product innovations.

The example of joining by linear flow splitting is the starting point for illustrating the aforementioned approach. Product and process innovations should be found based on the manufacturing-induced properties. It also shows how completely new manufacturing possibilities can be created

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while preserving the original technology's functional and economic benefits. This technology pushed process innovation can then be utilised by the designer for new applications and product innovations.

2. Process chain linear flow splitting: Starting point for innovations

Linear flow splitting is a cold forming technology that enables a continuous flow production of bifurcated sheet metal profiles with the help of successively converging splitting rolls and additional supporting rolls (see section 4). The bifurcation is characterised by two formed flanges originating on the sheet metal's band edges. Severe plastic deformations occurring during the linear flow splitting process produce ultra fine grained (UFG) microstructures especially at the upper surface of the flanges with increased hardness [4] and fatigue strength and low surface roughness [5]. Combined with further manufacturing technologies like roll forming or linear bend splitting in a continuous flow production, multi chambered profiles can be manufactured in integral style at low cost while maintaining a high productivity [6], see Fig. 1.

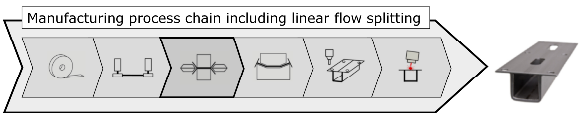

Fig. 1. Process chain including linear flow splitting.

3. Initiating process and product innovations by manufacturing-induced properties

3.1. Manufacturing-induced properties

Manufacturing technologies realise technology specific design elements that are characterised by a set of manufacturing-induced properties [7,8]. Manufacturing-induced properties likewise comprise the technology specific material, mechanical and geometrical properties of the design elements. Generally, the specific property's value depends on the parameters and the relevant effects and mechanisms of the process. The severe plastic deformations in metal forming processes like linear flow splitting have a substantial effect on the resulting manufacturing-induced properties of the manufactured element. Especially the aforementioned UFG microstructures, increased hardness, ductility and fatigue strength are characteristic manufacturing-induced material properties. The two flanges and the web connecting these flanges are typical manufacturing-induced design elements for linear flow splitting. The deformations occur while high hydrostatic stresses act in the deformation zone.

3.2. Product innovation driven by manufacturing-induced properties

The manufacturing-induced properties of the linear flow split flanges, especially the high hardness and low surface roughness because of the UFG microstructure, predestine these design elements as rolling contact areas of linear guides [9,10]. Such beneficially utilised design elements can be identified by matching manufacturing-induced properties to desired functional product properties. The designer's task is to identify these elements and to define how they can be realised using specific manufacturing technologies. In this process, the provided manufacturing-induced properties are key elements. Depending on the product's specific application, the available material, mechanical and geometrical properties have to be advantageously deployed in order to realise the desired product functions at low costs. Matching the technology's aforementioned manufacturing-induced properties like the achievable increased hardness and fatigue strength to the functional properties of rolling contact areas leads to the beneficial utilisation of linear flow split flanges as rolling contact areas for linear guides. In such a way, the flanges are identified as beneficial design elements for integrating the rolling contact areas into profiles of linear guides. Especially integrating new and additional product functions into the linear guides leads to product innovation. By systematically matching the provided manufacturing-induced properties of the linear flow splitting process chain to possible functional product properties and utilising its capabilities for creating complex geometries [11], linear guides can be realised with integrated bifurcations and multiple chambers for various purposes (e.g. for an integral clamping function [12]). Thus, technology pushed product innovations are realised based on the manufacturing-induced properties of the process chain.

Adding additional functional elements can further increase linear flow splitting's potential for technology pushed product innovations. Especially the integration of actuator components into linear flow split linear guides enables the realisation of innovative multi-functional linear systems. For this purpose the actuator components have to be joined into the linear guide in order to realise the desired translatory motion. This leads to an enlarged range of possible applications of continuously manufactured linear flow split components, thus enabling product innovations for completely new applications.

3.3. Process innovation driven by manufacturing-induced properties

A continuous flow production is very beneficial in terms of a cost-efficient manufacturing process. Large quantities can be manufactured at low costs. Hence, as many necessary manufacturing operations as possible, like roll forming, cutting, welding or even joining, should be integrated into the continuous flow production. When manufacturing complex products, usually multiple manufacturing technologies have to be employed in order to realise the desired product functions. Multi-functional linear systems e.g. require several elements necessarily manufactured by different manufacturing technologies. These multiple manufacturing technologies provide the necessary design elements and manufacturing-induced properties, like e.g. a specific geometry or surface finish. Apart from these targeted manufacturing-induced properties usually additional mechanisms can be observed during a manufacturing process like e.g. residual stresses as a corollary of sheet metal forming. Analogous to the distinction between main functions and auxiliary functions [2], these

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