Lasers in Manufacturing Conference 2017

Simultaneous 3D Laser Processing with Mechanical Axes and Galvanometric Scanner

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Abstract

The use of complex shaped 3D parts is a constantly increasing trend to meet modern functional or aesthetical demands. At the same time, the demands on the machine kinematics are increasing with the complexity of the geometries and the processing speed. For many laser based processes it is advantageous to rapidly guide the laser beam focus over the surface with the use of galvanometric laser scanners with almost inertia-free axes. Due to the limited working volume and the fixed beam direction of such devices they are often combined with mechanical axes. State of the art is the sequentially processing of larger or curved surfaces in small tiles by using mechanical axes for successive repositioning. This can lead to unwanted defects in the overlapping regions of the tiles (most relevant for laser polishing) and slows down the overall processing speed (most relevant for laser micro structuring). A continuous processing where both systems are moving at the same time solves this issues.
In this paper an approach for synchronizing the movements of a mechanical 5-axis system with a 3D laser scanner is presented. The approach doesn't require further complex hardware because it mostly based on offline calculations.
Furthermore experimental investigations on the accuracy of the overall system are presented. The final results show that an accuracy of approximately 10 µm can be achieved with using the tested equipment.

Keywords: laser scanner; laser polishing; laser structuring; simultanous processing

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1. Introduction and state of the art

For many laser processes a fast laser focus positioning is mandatory for the overall economic efficiency. Galvanometric laser scanners are state of the art for a fast beam deflection. Thereby the laser focus can be guided in up to three dimensions with velocities of 10 m/s at acceleration above 1000 g.

In industry more and more complex shaped 3D parts are used to fulfill aesthetic or functional requirements. Processing such parts by using laser scanners, e.g. for laser surface treatment, means a challenge regarding system technology. In this case the laser scanner have to be combined with a conventional and, in comparison to the laser scanner, slow mechanical axis system. This is to ensure the accessibility to all areas of the part and to keep the angle of beam incidence as low as possible.

State of the art, for example in the case of laser structuring of 3D parts, is the sequential processing. Large or curved areas are divided into subareas. For each subarea the mechanical system is used to position the part. Repetitively the laser scanner is processing the subarea with steady mechanical axes.

In the overlapping areas this can lead to unwanted defects induced by the process itself or by positional errors. Fraunhofer ILT developed a method for synchronizing multiple mechanical axes with a laser scanner to allow a simultaneous movement of both systems (Flemmer and Willenborg, 2015). In contrast to the sequential processing this avoids the segmentation of areas into subareas and allows a continuous processing. This will lead to more homogenous processed surfaces and reduces the overall processing time. Compared to other systems for simultaneous processing, like “marking on the fly”, this method is not limited to two dimensional processing. At Fraunhofer ILT this method is already in use for laser polishing of 3D parts (Flemmer et al., 2015). In this paper details on the general process principle of this method will be explained. Additionally experimental data on the positional accuracy will be shown. Through a simple adaption of the algorithm, which calculates the superposed movement, it was even possible to increase the accuracy.

2. Transformation and synchronization

The approach for synchronizing the laser scanner with the laser scanner presented in this paper is mainly based on a predictive model. The movement of both systems is predicted as precise as possible, which allows to calculate the superposed movement offline. Therefore the movement of the overall trajectory is divided in a slow and a fast component. The slow movement is realized by the mechanical axes. Their trajectory is defined as interpolation points onto the trajectory (see Fig. 1, right). For 3D processing each point also includes a definition of direction (tool vector). The fast movement is realized by the laser scanner and its trajectory is defined by transforming the overall trajectory by tasking the movement of the mechanical axes into account. This offline transformation allows to consider all the mechanical axes of a machine and eliminates the need for additional hardware.

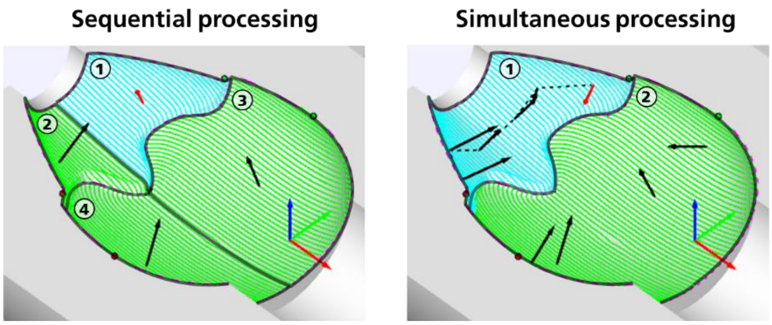

Fig. 1. (left) sequential processing: one position/direction per subarea; (right) multiple positions/directions (interpolation points) per subarea

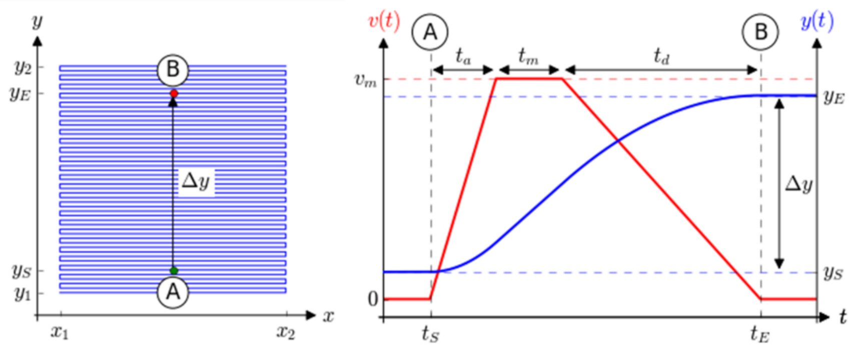

Fig. 2. (left) desired trajectory; (right) velocity profile for the mechanical axes

For ensuring a synchronized movement the laser scanner is sending a digital signal to the controller of the axes when he reaches the first interpolation point. This triggers the start of the movement of the mechanical axes and realizes a feedback between both systems. The mechanical axes come to a stop before the laser scanner reaches the second interpolation point. The laser scanner sends a digital signal once again and the procedure is repeated for all the following interpolation points. By this procedure growing positional errors are avoided.

To minimize the impact that small deviations from the predicted movement have on the final processing result, a special velocity profile is used (see Fig 2., right). This leads to a smooth movement of the axes, reduces the acceleration of the axes and avoid huge local errors.

3. Experimental results

For evaluating the positional accuracy of the simultaneous processing described in this paper, a “DMG Lasertec 50” machine is used. It features a “Siemens 840D” control which handles the mechanical 5-axis system. A test pattern (meandering pattern, 10 x 10 cm²) is processed on an aluminum sheet and the positional accuracy is obtained by measuring the positions of the tracks (30 µm width). While using a scan speed of 4 m/s and a line spacing of 8 µm, a positional accuracy of approximately 285 µm is measured. For ensuring the tracks not to overlap, the laser is switched on at every 65^{th} track only. During processing with the laser scanner two mechanical axes are moved simultaneously.

For synchronizing laser scanner and mechanical axes a digital I/O is used to trigger the start of the movement of the mechanical axes (see chapter 2). Due to the tracking error of the mechanical axes and the internal processing delay of the I/O, the movement of the mechanical axes is delayed compared to the movement of the laser scanner. Taking into account the overall delay by shifting the velocity profile (see Fig 2., right), the positional accuracy can be reduced to approximately 10 µm (4 m/s, 8 µm line spacing).

References

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