LASER PROCESSING OF SINGLE BATCH TUBES FOR E-MOBILITY

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The e-mobility megatrend requires new solutions for production of car body parts. Bent and hydro formed tubes and tube frames are becoming crucial elements in e-car design, but processing these parts presents particular challenges to suppliers of manufacturing equipment. Due to safety tracking requirements, single frame production is one of those challenges. Single frame production means that all frame tubes are processed in a single batch (or lot size one) and then joined to one frame. The sheer number of different tubes to be cut would require a huge amount of fixtures using traditional laser cutting systems. Highly flexible laser machining solutions for processing tubes, which differ in size, shape and cutting task, are necessary.

This article describes a robot-based solution for tube processing under challenging conditions, It shows the steps taken to reach the required system flexibility and accuracy by using a state-of-the-art, fixture-free and robot-based 3D laser cutting system.

Tubular frame for e-vehicles

The case study highlighted here describes the production of a tubular frame for a new e-vehicle. The function of this frame is to carry the electric motor and supporting components, and to isolate against vibrations. There are particularly high demands on the frame, as it has to compensate for the high torques of e-motors of up to 750 Nm and the additional weight of about 150 kg compared to an internal combustion engine. In addition, this frame is part of the crash structure of the e-vehicle.

Such a frame consists of between three and ten single tubes. These tubes are bent, 3D laser cut and then welded into a complete frame. Due to safety and traceability aspects, these tubular frames are produced in a single batch. This means that all individual tubes required for a frame are produced sequentially in a batch size of one and then welded into a finished frame.

In addition to traceability, this process also has an advantage for the automobile manufacturer in that intermediate storage of partially machined tubes is not necessary. Only finished frames are produced.

To further increase flexibility, several different frame types are produced, without fixture changes, in random product sequence on a production line. Thus, the production can be adapted very quickly according to changing demands.

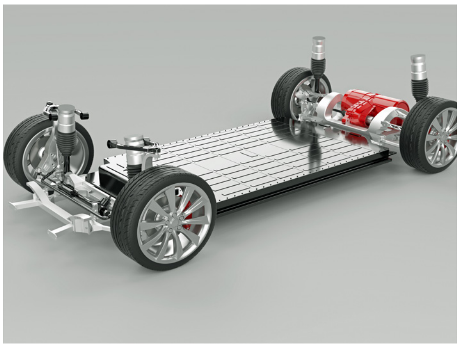

Figure 1: Electric car chassis (© Alex Kondratenko – adobe.stock.com).

This extremely flexible single-batch production places particularly high demands on the production equipment. These specific requirements and the implementation with a focus on the laser processing cell will be discussed below.

In this case study, the production of a total capacity of about 120,000 frames per year consisting of almost 1 million individual tubes is required. The pipes vary in length from 30 cm to 160 cm. The contours to be cut have a required position accuracy of +/- 0.4 mm and a geometric tolerance of +/- 0.2 mm. In addition, production tolerances must be compensated, owing to the upstream bending process, in particular by the individual batch production of the tubes.

Implementation of the new concept

It was calculated that the use of more traditional laser processing methods would require 4 gantry laser systems to implement single-batch production. The associated set-up time, high logistical costs and extra space required made the use of this approach unfeasible.

A new concept for a highly flexible laser system had to be developed to replace the traditional gantry laser system (see Figure 2). The basis is the existing beam-in-motion (BIM) concept, which means that the laser beam is guided inside a laser cutting robot. The absence of a transport fibre allows a very lightweight laser cutting head and thus an extremely accurate and highly dynamic movement of the cutting robot. Access to the complex curved pipes is improved, since there is no undefined moving transport fibre and also no massive and heavy fibre connector on the cutting head.

Instead of complex laser cutting fixtures, handling robots were considered. Thus, the two necessary work steps 'internal material transport' and 'work piece presentation for the beam-in-motion cutting robot' were combined into one functional unit.

A final component, image processing, was introduced to meet new production requirements. The image processing solution should be able to determine the production deviations of the incoming bent tubes and compensate the tolerances.

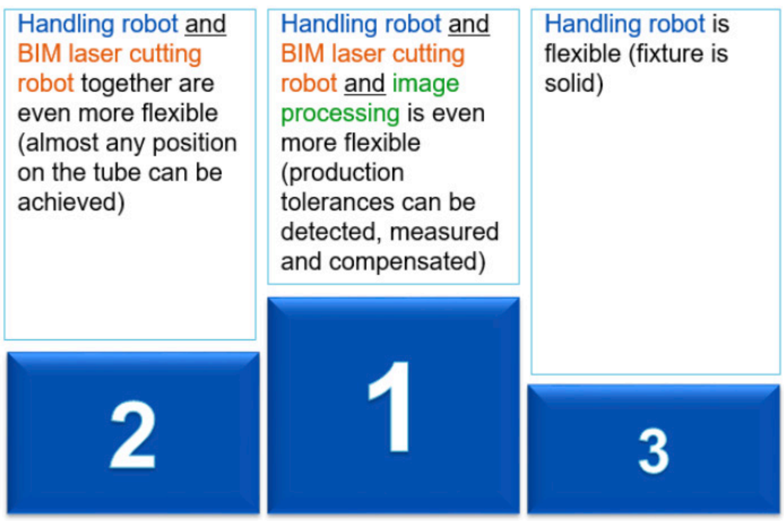

Figure 2: Concept development.

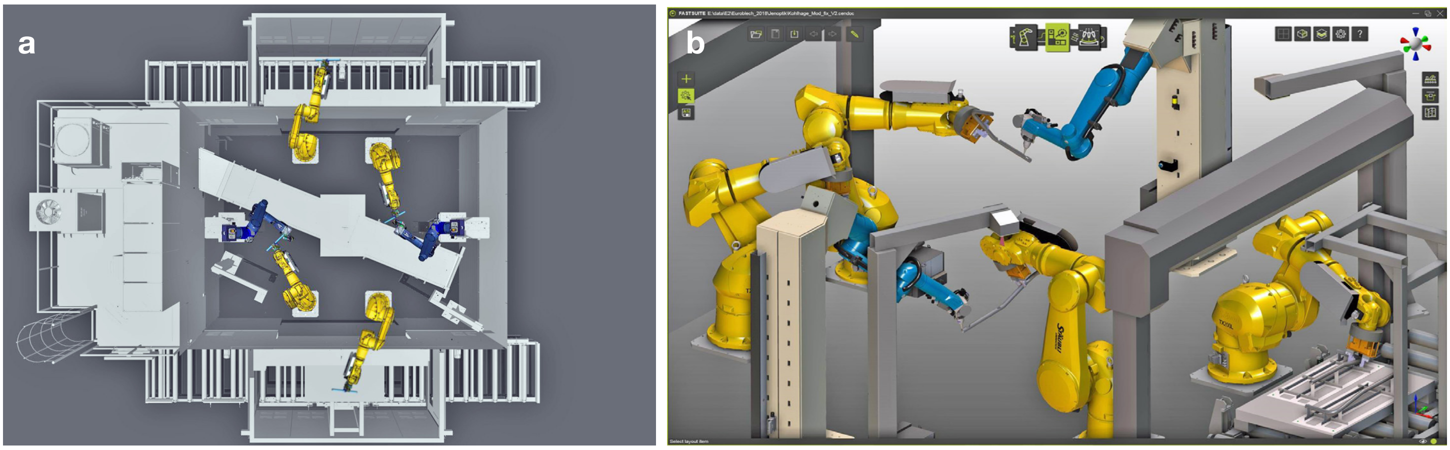

Figure 3: Bird's-eye view (a) and 3-D image (b) of the JENOPTIK-VOTAN® BIM laser processing cell, showing laser cutting robots (blue) and handling robots (yellow).

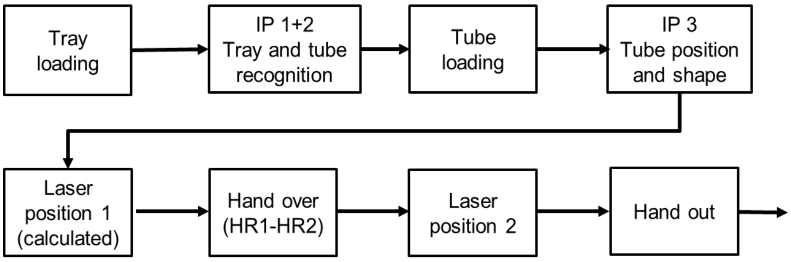

Figure 4: Continual flow process.

The result - a highly flexible laser processing system

Following concept development, a laser cell with two process lines was built. Each process line consists of a laser cutting robot and two handling robots (Figure 3). In the centre of the laser cell is a waste conveyor belt, which transports the cutting waste out of the cell. The incoming material is fed on trays on one side of the cell via a laser-safe lock chamber. On the other side, the processed material is placed on another tray and moved out via the output lock chamber. Other components, such as the laser beam source, laser chiller and control cabinets, are placed on a mezzanine above the machine. This saves additional production hall space.

The process is carried out according to the continuous flow principle (see Figure 4). First, the input tray with the unprocessed pipes is loaded into the machine. The image processing unit 1 (IP1) checks which tray has been loaded and which program has to be started. In addition, the current configuration of the positions of pipes is checked.

Image processing 2 (IP2) checks the correct position of the tubes and passes on a deviation as an offset to the handling robot. This ensures that the tubes are always gripped correctly. The length of the unprocessed tubes is measured to ensure they do not exceed the maximum permissible length. If tubes exceed the maximum the program would not be started to avoid damage to the system.

Once these checks have been made, the handling robot 1 (HR1) takes the tube out of the tray and holds it in front of the cell-mounted image processing 3 (IP3) which recognises the tube in the gripper of the handling robot. The image is compared with a stored reference shape. Any deviation from the reference shape is transmitted as an offset to the handling robot so that it holds the tube in the correct position in front of the beam-in-motion laser cutting robot. If the current tube shape is outside the permissible tolerance range, further processing is aborted.

In the next step, the handling robot 1 (HR1) presents the tube to the beam-in-motion (BIM) laser cutting robot and laser cutting of the first part of the contours on the tube starts. Once this is completed, the tube is handed over to handling robot 2 (HR2), taking into account the previously determined offset value from the image processing. The beam-in-motion (BIM) laser cutting robot then cuts the second part of the contours. While cutting takes place in the second presentation position, handling robot 1 takes the next tube for processing and the image processing performs all diagnostic steps. As a result, the overall system is able to meet the high volume requirements with excellent quality and efficiency.

After successful laser cutting, the handling robot 2 (HR2) moves the finished tube into the designated position in the output tray. If all other tubes of the tray are cut, then the laser-safe output lock chamber closes and the tray can be transported out while the next frame is already being processed in the system.

Summary

Through the use of the three flexible components (handling robot, Beam-in-Motion (BIM) laser cutting robot and intelligent image processing solution) a highly flexible, fixture-free laser processing solution for the required single-batch production of tubular frames was set-up. The required position accuracy of +/- 0.4 mm and the geometric tolerance of +/- 0.2 mm were proven with repeatability tests.

A product change of the tubular frame can thus be made without fixture change and long set-up times. In addition, unavoidable production tolerances during the bending process can be compensated. If the production tolerances are above the permissible range, the laser system reports these deviations and prevents further processing. It thus offers an additional in-time quality check for each individual tube, which is independent of cycle time.

Currently, the first systems are handed over to the end customer for production. With this novel laser cutting system, the automotive industry receives a tool to successfully master the high flexibility requirements of e-mobility.

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