Integration of laser beam hardening in high performance turning machines

Task

The availability of high power diode lasers and a number of recently developed system technology solutions helped to establish laser beam hardening as a potential process to locally protect parts from wear in addition to classical hardening methods. Like many heat treatment processes, laser beam hardening is typically applied outside of the main manufacturing process chain. However, manufacturers prefer a continuous part flow without additional logistics and storage to save time and costs. Here the laser beam hardening offers excellent opportunities.

A leading specialist for drive and control technologies required the partial hardening of the outer surface of a valve for mobile hydraulic applications (Fig. 1). Conventionally the company used an induction hardening process with subsequent tempering. The parts were initially processed in a soft state, and then heat-treated and finally finished in a hardened state. The overall processing from the raw material to the finished valve took approximately 20 hours. It was therefore difficult for the manufacture to quickly respond to changes in demand. This was compensated by sufficient inventory. The production process was also based on batches, which required numerous logistic steps. The investment goal was to find solutions that would overcome these limitations while maintaining the part quality.

Solution

Initial tests proved successful to laser harden the hydraulic components. In discussions with the client it was agreed that the favored solution would be to integrate the laser beam hardening process right into the turning machine (Fig. 2). Since the machine has two spindles it is possible to continue the turning operation almost throughout the entire laser hardening process. The optical path and the process chambers are kept clean by pressurized air and the laser process can be performed simultaneously with the wet cutting operation (Fig. 3). The new technology processes parts from the rod. First the soft processing is performed on the main and the opposite spindles. Then the hardening process and the hard processing are performed in the very same setting. The part leaves the machine after it is fully processed and moves on to assembly.

Fig. 1: Typical application of mobile hydraulics made by Bosch Rexroth AG

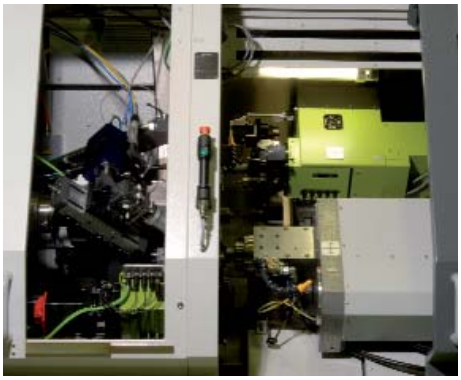


Fig. 2: Benziger turning machine with integrated laser optics in the drive chamber (left)

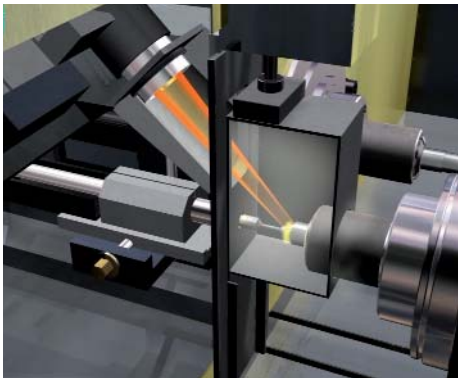
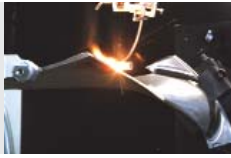


Fig. 3: Image from a process animation, which shows a situation during the hardening process in a pneumatically delivered protection chamber with laser beam and pressurized air nozzle operation



Process management

The laser beam hardening process uses a fiber coupled high power diode laser and is performed while the part is rotating. One laser shot hardens a ring shaped zone around the part without leaving a soft spot. During the process the surface temperature is measured with the camera based temperature acquisition system "E-MAqS" (Fig. 5). The data are supplied to the controller module "LompocPro", which in turn regulates the laser power to maintain a constant surface temperature. The complete manufacturing line consists of two turning machines with integrated hardening modules. An additional machine hardens other parts belonging to the same assembly in an inert gas atmosphere. The laser is located in the center between the other machines and the beam is distributed to those machines using a beam switch. An intelligent switch controller optimizes the beam delivery based on the processing time of each turning machine to minimize downtimes (Fig. 4). The process uses only a single "LompocPro" controller that quickly switches between processes. All critical process and calibration data are stored. The individual components are connected using a profi-bus system. This concept allows the efficient exchange of messages between the laser, the machine tools, the switch controller and the overall process controller.

Results

During the valve manufacturing the lathes machine processes unalloyed steel. The laser treatment affects approximately half the wall thickness of the part, leaving only a small material volume underneath the hardened zone. To nevertheless achieve the required material performance under these conditions, the engineers implemented a self-quenching effect, which is a common method applied during laser beam hardening processes. Compressed air is blown at the processed part to assist self-quenching.

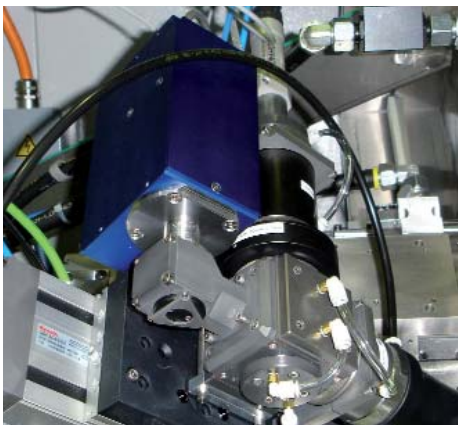


Fig. 5: The laser optics with temperature acquisition system "E-MAqS" is located in the drive compartment of the turning machine

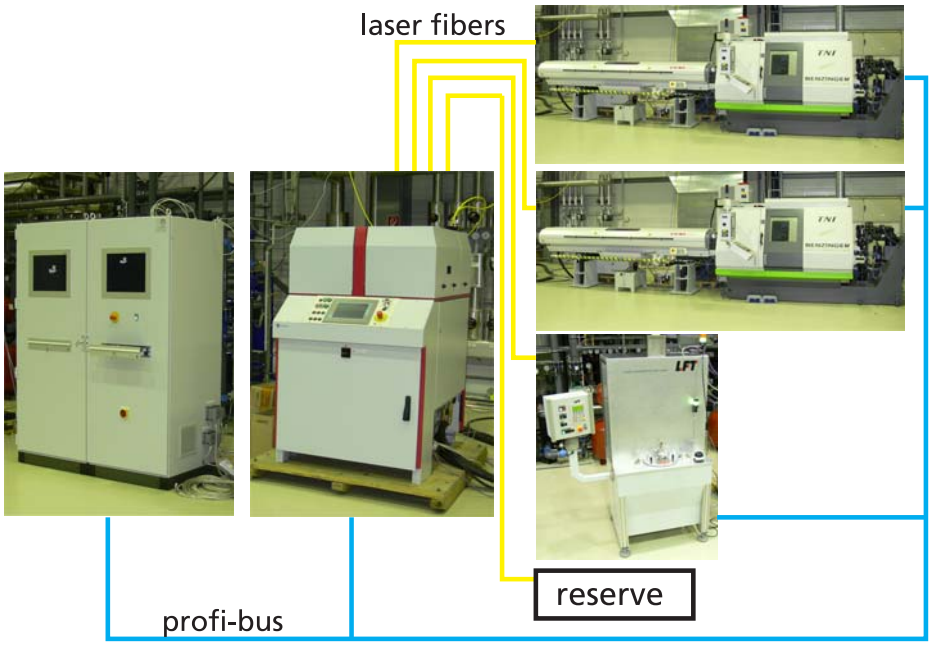


Fig. 4: System installation consisting of a fiber coupled high power diode laser, a controller cabinet for the laser beam splitter and process controller "LompocPro", and two turning machines and inter gas hardening machine

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