Polishing components with a laser beam

Smooth surfaces play just as important a role in tool and mold construction as they do in the automotive or pharmaceutical industries. In order to integrate this design step into an automated production environment, Fraunhofer researchers are using laser light in place of a sanding and polishing cloth.

Processing investment-cast parts can be quite bothersome, as they have to be painstakingly smoothed and shined by hand. This final polish required to produce smooth surfaces has so far been largely neglected in automated production processes. For many years, production engineers waved the issue aside, for there were no suitable methods available. However, this is now about to change. A research facility in one of the laboratories at the Fraunhofer Institute for Laser Technology ILT in Aachen is now for the first time using amplified light to polish metallic components. The foundations for this process were laid by Edgar Willenborg, an ILT scientist who has been researching the laser polishing technique for six years and was awarded the ‘Wissenschaftspreis 2006’ for optical technologies, a science prize given by the Industry Club Düsseldorf and the Science Center of North Rhine-Westphalia for his outstanding Ph.D. thesis.

While laser technology is entering more and more fields of application, and the gap between optical technologies and automated process control has long since been bridged, what was still missing until now was an innovative approach towards the industrial polishing of rough surfaces. Although there have already been several ways to polish materials using light, the method of polishing metallic components with a laser beam is a new and promising technique.
often takes ten to thirty minutes per square centimeter.

Teaching the laser tool to polish at the desired level of quality and reliability was not an easy task. By means of a multistage polishing procedure, in which the worst of the roughness is evened out first before the last of the bumps are removed in a smooth finishing process, the laser specialists are able to achieve very good results even under difficult conditions. “We began by polishing very simple geometrical forms and established that, in principle, the process was also suitable for three-dimensional surfaces,” says Willenborg. The range of polishable 3-D surfaces is now gradually being extended. The Fraunhofer scientists are also investigating different materials that are particularly suited to laser beam polishing. One of the materials being tested is titanium, which plays a role in the field of medical implants.

**No off-the-shelf solution**

In addition to a customized light source that can be moved freely to any position, other necessary system components include suitable processing optics and flexible process control. Researchers are ambitiously paving the way towards their goal of producing a ready-to-use machine tool that can be seamlessly integrated into existing production lines and offers benefits in terms of production costs. However, there will be no off-the-shelf solution even in the future, for all the different parts of the system have to be harmonized and adapted to each application in order to achieve the best possible processing results. “Everything depends on the perfect combination of all individual elements,” Willenborg stresses.

At present, the researchers are primarily working on establishing the right process parameter settings for the polishing of three-dimensional components. The laser station has to reach a certain grade of roughness on the component’s surface in as little time as possible. This surface rate is an important factor in measuring the productivity of the application. The laser beam heats a paper-thin boundary layer less than 0.1 millimeters thick on the metallic surface of the component. Due to the interfacial surface tension of the liquid metal, the component’s surface evens out without the need of mechanical assistance, which means that grinding grooves and scratches are now a thing of the past. The process for melting the surface layer can be set precisely, thus allowing the quality of the finish to be determined. A further advantage lies in the dust-free remelting process. Owing to the absence of mechanical abrasion during laser beam polishing, any environmental pollution through dust or polishing waste is avoided.

**Promises shiny surfaces in a wide range of applications**

The new method is aimed at users who wish to speed up the polishing process and save costs by automating the procedure. However, as Willenborg points out: “Laser beam polishing cannot satisfy extreme demands on surface quality.” It is currently only possible to achieve medium quality, although this is perfectly adequate for many industrial sectors and applications. Laser beams are now able to reduce surface roughness by a factor of 20, which is a considerable improvement over known methods. The few existing research papers on attempts to polish metals with laser technology merely reached a factor of two to three.

Although the ILT has already received numerous requests from industry, users will have to be patient. Before the technique can be released for use in a real industrial environment, further development work is required to design suitable interfaces to the CAD systems which supply geometrical data for the surfaces being polished. There are also certain limitations, such as deeply cut grooves, which are almost impossible for the laser beam to reach. “If the laser beam’s angle of incidence becomes too flat, the result deteriorates,” Willenborg explains. The main priority on the researchers’ agenda are 3-D applications. These will mainly benefit the fields of tool and mold construction, which make particularly high demands on the polishing of die-casting molds for plastic parts. For the laser specialists in Aachen, applications of this type represent the apogee of their specialist skills. The knowledge and technology needed to put them into practice is already there. “Now we just need to tap the full potential of this knowledge,” says Willenborg.

Andreas Beuthner