Flexible Manufacturing with Laser: Problems, Machine Concepts, System Solutions and Experiences

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1. Introduction

In order to remain competitive on national and international markets many firms in the metal working industry are being forced today to adapt their products quickly to the changing market demands /1/. Therefore new methods of cost-effective production must be employed; very competitive production from the flexibility point of view is made possible especially by means of technologies which in former times implied an "exotic touch." In contrast to conventional technology, laser technology requires new planning methods. Based upon the specific demands of laser processing, workpiece design must be thought over completely anew, as must the placement of the work stations and the production structure to which these belong. Only then can this promising technology be applied successfully and economically. Some of these planning steps and intermediate results are presented in this paper. In particular experiences in the planning of laser production systems are treated.

2. Laser Material Processing in Manufacturing

For the area of metal working, aside from a few solidstate lasers whose output lies near the lower boundary of the necessary performance range, only CO₂ lasers with continuous power in the kW range come into application. Coherent light produced in the laser aggregate is directed and concentrated on a given point of the workpiece by means of a deviating mirror and a focusing device. In the focus point, absorption of thermal energy in the material leads to high temperatures that can be used for material working. By means of changing the laser beam power as well as the focused spot diameter this temperature can be controlled. Thus it is possible to adapt the laser to different working processes such as surface treatment, welding and cutting. As the energy is transmitted via the optical path between laser aggregate and workpiece - without direct mechanical contact - the laser acts as a non-contacting, forceless tool which is nearly free from wear.

In regard to its working tasks and its potential for process automation due to ease of control of the laser parameters, laser processing seems to be predestined for flexible manufacturing.

2.1 Laser Cutting

Laser cutting falls into two process groups, flame cutting and fusion cutting. The necessary thermal energy in the focus of the laser beam, which is required in both processes in order to reach the inflammation temperature of the material, is about greater than 5 MW/cm². The laser beam vapourises the material, producing a hole, which then is moved along the cut contour through relative movement of the workpiece and laser beam; thus the cut is formed. In flame cutting, used primarily with metallic materials, oxygen is used as the process gas with ferric materials to effect an exothermic reaction, which allows high cutting velocities. In fusion cutting, best suited for nonmetallic materials, an inert gas such as helium is used.

Figure 1: Scheme of laser processing

As a cutting tool, the laser poses a costeffective alternative to punching and nibbling, as no tool costs are incurred. It is possible to cut very complex contours with sharp corners without warpage at high cutting velocities.

The preceding explanations deal primarily with laser cutting of flat sheet metal, whereby systems on the market represent the present state of the art in this field. The processing problems with three dimensional parts are quite different, as they require multiaxial, high-precision laser beam guidance systems in a large workspace. Laser cutting also has advantages in comparison with mechanical cutting processes as well, such as circular shear cutting, in which the moving shear produces rounded corners as it submerges into the material and a burr edge as the material is torn.
**PRESS TOOL METHOD**

- Design and Manufacture of 2 stage Pierce and Blank Die
- Equipment Required: 11 000 DM
  - Jig Borer
  - Jig Grinder
  - Cylindrical Grinder
  - Universal Grinder and Associated Tooling and Skills
- Operator Training: 5 Year Apprenticeship
- Delivery: 6-8 Weeks
- Buyer: Ferranti Dundee Scotland

**LASER CUTTING METHOD**

- Developed length of component with programming factor: 600 mm
- Average cutting speed: 0.8 m/min
- Approximate time taken to produce one component: 45 a
- Assume average sub contract price of: 45 per hour then cost per component: 2.24 DM
- Break even point with press tool: 4910 Components

**Figure 2: Case study**

**Figure 3: Circular cut**

**Figure 4: Laser cut**

The laser cut of equally thick material exhibits parallel cut edges which are completely free of burrs. Thus further processing of the workpieces is not necessary. As not only laser performance but also mode quality (that is to say, the intensity profile over the unfocused beam diameter) can influence cutting speed and should be considered only as guiding principles. It is only possible to find out final process data in laser cutting experiments with the material to be worked.

**Figure 5: Cutting velocity (Source Rofin Sinar, Hamburg)**

**Advantages of laser cutting:**
- high cutting speed
- small kerf width
- burr-free, nearly parallel cut lines
- high flexibility

**Disadvantages of laser cutting:**
- limited cutting depth
- high investment costs

2.2 Laser welding

In laser welding the introduction of energy into the material is the decisive parameter.

If laser performance is increased above 3 MW/cm², a blue shiny plasma is ignited within the protective gas atmosphere on the material surface, which leads to an increased absorption of thermal energy into the workpiece. Therefore the molten pool is not only produced on the surface but depending upon the laser beam output power, a narrow deep outline with the shape of a keyhole is formed with centrally arranged vapour capillaries in the beam direction due to local evaporation of metal. This is brought about by the pressure of the emerging vapour acting against the hydrostatic forces of the surrounding molten material. With adequate relative movement between laser beam and workpiece, the vapour capillary remains dynamic and stable and moves through the material. Behind the moving capillary the surrounding molten layer solidifies again. Thus due to the melting capillary, laser energy is not only absorbed at the workpiece surface but also at the capillary wall deep inside the material /2/.

By increasing the power density the range of the shielding plasma is reached. Only little laser energy is now introduced to the workpiece, and the welding process becomes uncontrollable. This can be changed when another protective gas and an additional plasma jet for controlling plasma are used. If in order to integrate a laser welding system into the manufacturing of large batch production (e.g. into