Weighing-machine controls powder feeder for single-stage laser cladding

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Using the laser cladding process, the wear resistance of component surfaces can be substantially increased by applying hard coatings. The quality of the coating is mainly dependent on the exact dosing of the coating material fed in powder form to the melt pool. The article describes a recently developed powder feed system which maintains the quantity of powder passed per unit time within a specified tolerance band with the aid of a controller. The dosing principle that is used is based on the continual measurement of the momentary weight of the powder feeder using a platform load cell. After amplification and digitization the output from the load cell is passed to a PC running appropriate software which is used to control the feed rate.

Introduction

Ever since lasers with sufficient power have become available, laser coating methods have been used to improve the wear resistance of component surfaces. Using the laser beam, the coating material, which is continually fed in powder form, is melted directly onto the surface of the substrate material. The use of metals, carbides and oxide ceramics together with the choice of appropriate process parameters enables specific matching of the coating characteristics to the requirements demanded in the application [1 to 3]. For example, turbine blades, valves for internal combustion engines, drilling bits, forming tools and screw feeders for conveying hard materials are coated to increase their endurance and service life.

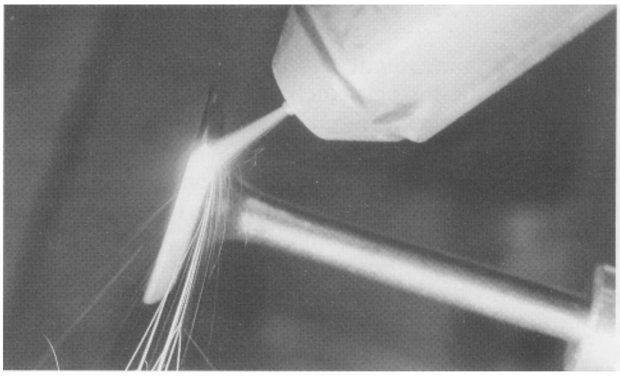

Fig. 1: Laser cladding of a car engine valve with cycle times under 3 s.

Figure 1 shows the application of the laser cladding process to a car engine valve which is being coated in the region of wear with a cobalt-based alloy. The powder material is fed through a nozzle and subjected to the laser beam, melting in a pool and forming a typical coating layer on solidification. **Figure 2** illustrates the coated valve together with an uncoated valve for comparison.

The most popular method of laser cladding is the single-stage process with a continuous powder feed. The main features are a high degree of integration of the additive powder material in the laser process and the large number of available alloys and material combinations that can be used in the process.

The coating quality depends to a large extent on the exact dosing of the powder passed to the melting pool. For CO_2 lasers in the power range up to 10 kW feed rates in the region of 1 g/min to 60 g/min (0.04 - 2.1 oz/min) are required which must be able to be adjusted quickly without any delay. Furthermore, the powder-flow feed quantity should not exceed a tolerance band of 5 %.This means that deviations in dosage must be compensated by the feeder device which should, however, be compact and light for installation in the complete system.

The fulfilling of these criteria is a main requirement for the successful implementation of the overall process which, with continuous measurement of the

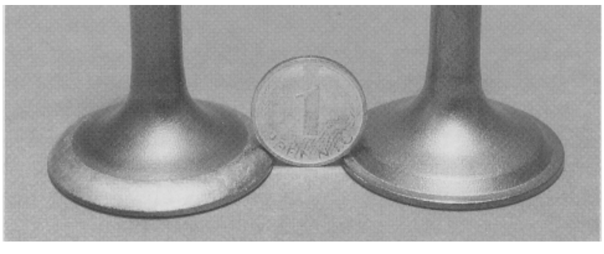

Fig. 2: Laser cladded car engine valve.

melt pool temperature and control of the laser power, work-piece feed rate and powder flow rate, produces constant coating-formation conditions.

The objective of the work described here consisted of the development of a powder feed system taking into consideration the special requirements of laser surface treatment with regard to its mechanical design, performance parameters and on-line measurement and control of the flow rate.

Feeder system with integral measurement and control of the flow rate

Figure 3 is a diagram showing the main components of a laser cladding system with a power feeder. Apart from the actual beam used for cladding (Beam A), a second beam (Beam B) can also be employed for subsequent heat treatment. The actual construction of the system, including the control unit and power supply (to the right of the picture), is illustrated in **Fig. 4**. In this photograph the measuring head of the pyrometer used for non-contact temperature measurement can be seen to the left.

The main arrangement of the powder feeder is shown in **Fig. 5**. The dosing principle applied in this case is based on the time-related collection of a quantity of

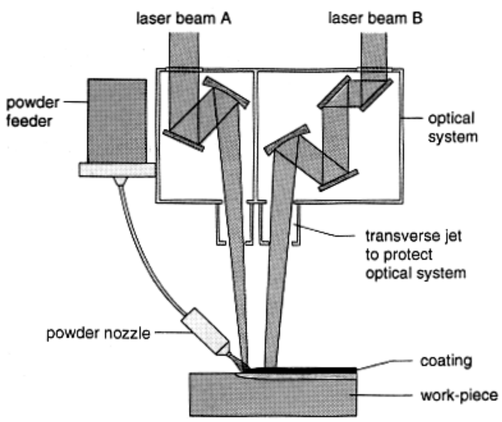

Fig. 3: Diagram of the laser cladding system showing the position of the powder feeder.

powder from the dosage plate by the scraper, independent of the gas flow. This principle originates from a development by the Fraunhofer IWS Group in Dresden. After comparison with other methods, this feeder principle was developed as a practical method and the long-term low-wear characteristics have been proven over a number of years of operation. Uniform powder distribution on the plate is ensured by the static powder pressure in the powder container, the width of the annular powder outlet and by the design and arrangement of the scraper.

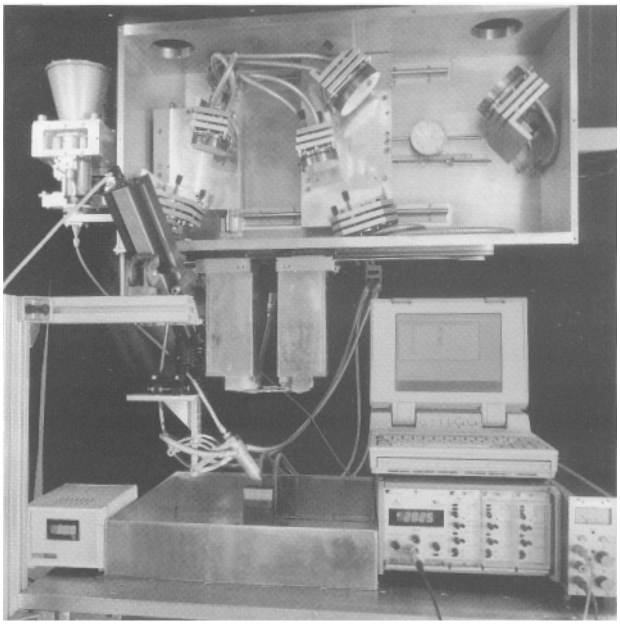

Fig. 4: Photograph of the laser cladding system with the powder feeder at the upper left of the picture.

The feed-rate range can be set roughly by the width of the annulus and the actual dosage quantity set by the plate speed of rotation. The mixing of the powder with the feed gas takes place after dosing in the feeder outlet funnel which is similar to an injector. The gas quantity can be continuously adjusted independent of the powder flow. Typical gas volume flow rates are between 101/h and 601/h (0.35-2.1 ft^3/h).

The powder feeder enables powder to be fed in a range of grain sizes from 20 mm to 200 mm (0.8-8 mils) with a continuously adjustable flow rate between 1 g/min. and 150 g/min. (0.04 - 6 oz/min.). In principle all powders which are relevant for laser technology can be

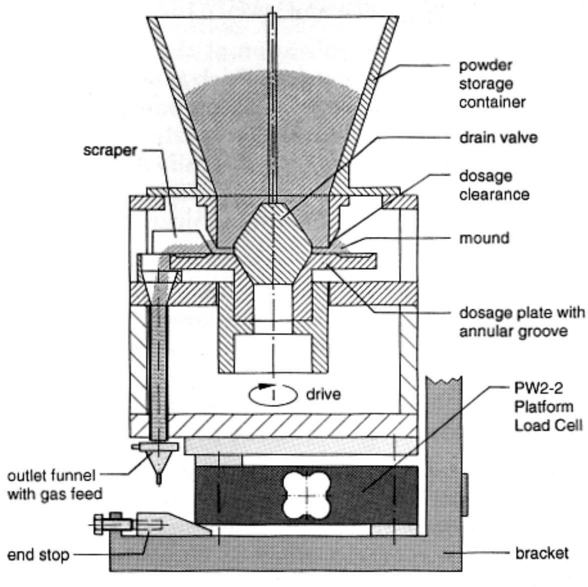

Fig. 5: Basic details of the feed-rate controller.

fed. In all cases, even with poorly flowing powders such as polygonal titanium carbide or fusible tungsten carbide, tolerances in the flow rate were measured at less than 3%.

The compact, light feeder construction (8 kg [17.6 lb] weight without powder) enables it to be positioned in the close vicinity of the optical focusing system and the point of processing. With the short pre-flow and residual-flow times for the powder flow of < 0.5 s, the feeder system has excellent time response characteristics.

Flow rate measurement

The powder flow measurement principle is based on the permanent measurement of the current weight of the powder feeder during feed operation using a weighing machine. When linked to a suitable PC program, the current powder flow rate can be determined and displayed as the loss of weight per unit time. This type of on-line flow rate measurement is made possible by the compact powder feeder construction that enables the complete feeder system to be placed on the load transfer point of a load cell and to be tared to zero. Due to the low weight of the feeder itself, an adequate resolution of the weight loss and therefore the feed rate can be realized even with low flow rates.

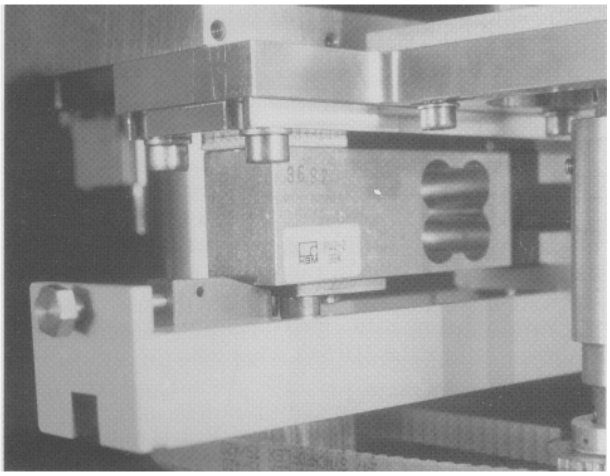

Fig. 6: Close-up photograph of the load cell built into the powder feeder.

A platform load cell of the type PW2-2/18kg from HBM and designed for use in top-loading weighing machines was employed as the weighing element. This load cell is designed as a double bending beam and is fitted with strain gages to form a measuring element. The load cell is shown in Fig. 5, fixed at one end to a strong bracket and at the other end it is carrying the complete feeder weight. The low mounting height of this platform load cell renders superfluous all the mechanical mounting parts that are usually necessary such as levers and bearings for the transfer of the force. To build a weighing machine the only mechanical components required apart from the load cell are a baseplate and a platform. A detailed view of the load cell mounted in the feeder is shown in **Fig. 6**. The load cell is corner-load compensated, i.e. off-center loads do not result in impermissible measurement deviations [8].

The load cell is connected to a carrier-frequency measuring amplifier of the type KWS 523.D which has its digital output signal connected on-line to a PC. The load-cell measurement signal resolution that can be achieved with the nominal load of 18 kg (40 lb) is in the range between 100 mg and 200 mg (0.0035 - 0.007 oz).

The powder feeder is mounted with a quick release clamp in the center at the free end of the load cell. In order to be able to measure the loss of weight in the complete system as quickly as possible, mechanical isolation in the form of a second outlet funnel is fitted between the powder feeder and the powder nozzle. The powder can then proceed unhindered to the nozzle, since the weighing machine at this point in time has alaready measured the loss in weight.

Flow rate control

The measurement signal from the load cell is evaluated and processed with the aid of a PC program (PUREG).

Initially, the type of powder and grain size is specified together with the limit quantity. The limit quantity is defined as the residual quantity of powder, due to the feeder design and the powder flow characteristics, which can no longer be fed. The demanded powder flow rate is specified by entering the set quantity in g/min. The feed time can also be defined depending on the work-piece geometry and feed rate. The number of measurements defines how many weight measurements per second are accepted from the load cell. The momentary flow rate is found from this quantity of data using linear regression. Finally, the regression period defines the duration during which the weight loss from the powder feeder is recorded.

Before use the system is calibrated for the type of powder to be coated. The new feed and evaluation system deals with this task almost exclusively automatically in contrast to the extensive calibration work necessary with traditional feeder systems. In this case, a data base is created to represent the basic parameters for the control of the flow rate.

The main control sequence for the powder flow-rate controller is shown in **Fig. 7**. After entering the set value, the calibration factor is selected from the data base according to the powder to be employed. Then the connection to the load cell in the feeder system is activated together with the current weight display. The system then checks the level with regard to the residual limit quantity that can no longer be fed. Then the feed process is started. Here, an initial value for the motor voltage is calculated from the loaded calibration factor and the entered set value. The voltage is passed to the motor via a D/A converter. This represents the real difference to traditional controllers. Due to the inertia in the system - the regression period can be freely selected and is normally in the range between 5 s and 15 s - a defined initial voltage is specified for

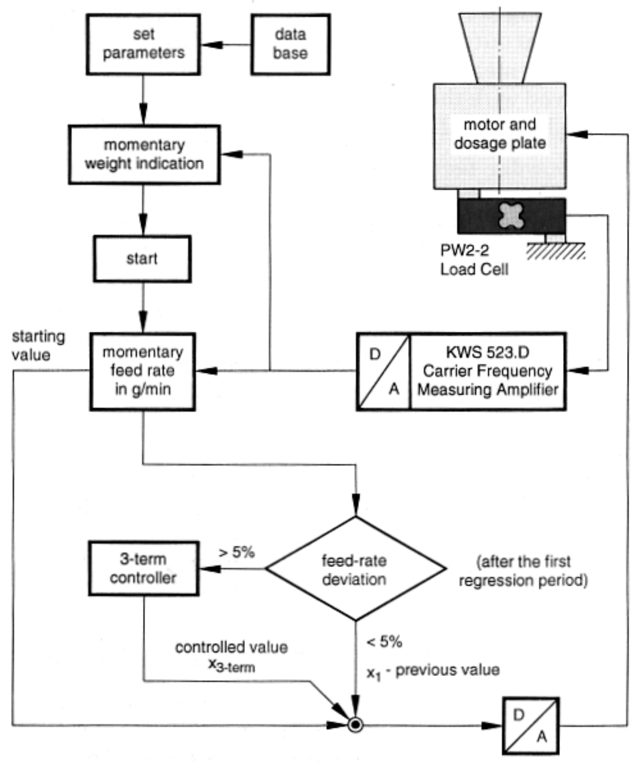

Fig. 7: Block diagram showing the control circuit.

the motor, avoiding a time consuming automatic regulating period. The integral three-term controller therefore has only the task of holding the current feed rate constant over longer time periods according to the specified set value. After the expiry of the set regression period the momentary feed rate is displayed. If the deviation of the momentary feed rate from the set

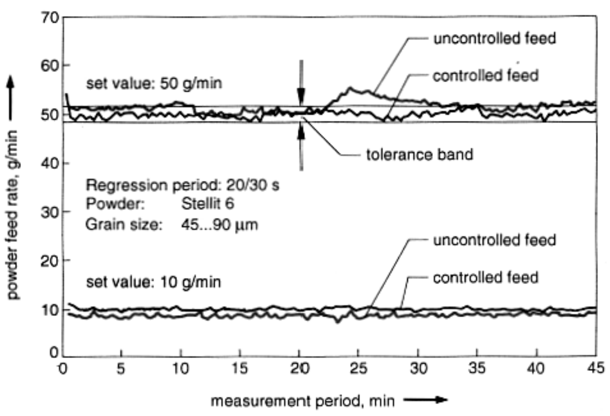

Fig. 8: Traces showing the effects of the controller: Uncontrolled and controlled powder feed for two set flow rates.

value is less than 5%, there is no intervention in the system, i.e. the motor voltage is not changed. The three-term controller only intervenes for deviations greater than 5%.

In **Fig. 8** traces of the uncontrolled and controlled feed rates for flow rates of 10 g/min and 50 g/min (0.35 and 1.76 oz) over a measurement period of 45 min. are shown. The effectiveness of the controller can be seen from the comparison. The powder flow rate remains within the set tolerance limits even over long periods of time. The diagram is based on a regression period of 15 s. Shorter measurement and regression intervals are possible but not required because the system short-term stability is guaranteed by the feeder mechanical system.

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