REAL-TIME KNOWLEDGE OF CO₂ c.w. LASER BEAM POWER AND SHOW-UP OF RETROACTION PHENOMENA DURING OPERATIONS ON METALLICAL MATERIALS

J.F. COUTOULY, F. EWELÉ, T. MANDERSCHIED*, J. MERLIN and J.J. SCHWARZ

INSA CALFETMAT, Bât. 403, 20 avenue A. Einstein, F-69621 Villeurbanne cedex, France

Abstract - The real-time knowledge of industrial laser power and energy profile distribution into beam gives important informations with the object of operation control like welding or thermal treatments, and even indispensable to control the system. With a view to show-up the feasibility of such an operation, we have executed some tests with different systems able to measure the beam global power and its energy spatial distribution on a 4000 watts CO₂ c.w. laser source (Cilas CI 4000)

1- Introduction.

The feasibility of surface treatments or welding by a laser beam is now easily proved, but the performances obtained are often underneath of the expected quality, because a lot of parameters can aleatorily fluctuate during an operation, for example, we have fluctuations of beam power, no-homogeneity of surfaces consequently of absorption, oxydation variation during the treatment. So, the material is not regularly treated or welded and the quality is sometimes insufficient.

Up to now, we accept the material and we analyse the material subsequently to treatment. Some researches are made with a view to improve the homogeneity of treatment so the quality: F.Bataille has studied an industrial laser optimization built around a infrared camera and a calculator changes the values of the exciting current and the speed of material under beam (1). B.Peuse has proved that it's possible to improve the power beam stability, he saw that the fine adjustment of the cavity mirror is very important on the beam power level and he studied an optimization of source based on a mirror position regulation (2).

In our research, we study a regulation of global power laser source which operate on exciting current, this optimization of source could give a stable global power level.

2- Measure of global power beam.**2.1- Measure device principle.**

The global power measure device we have chosen is based on a pyroelectric detection of modulated beam (Molelectron P300 detector, mechanic chopper), the output signal of detector is alternative and generally highly noisy, we have to transform it in a direct signal

and reduce the noise rate. We have chosen a lock-in amplifier (Scitec 500 MC) which realize the following operations:

- It compares a reference signal with the measure signal.
- It delivers a direct signal proportional to the beam power level.
- The noise superposed on signal dont contributes to output signal except if it has the frequency of reference signal.

The principle of device is shown on figure 1.

Fig.1- Diagram of the global power measure device.

2.2- Choice of a photodetector.

The control device is built around a lock-in amplifier, but we had to choose a photodetector. It exists various types of detectors able to work in the 10-11 micrometers wavelength zone. The two main detectors types are based on two physical principles:

- Pyroelectricity.
- Photoconductivity.

The pyroelectric detectors are able to work in a very large spectral zone, but they have a D^* detectivity rather feeble, on the other hand, they work at room temperature conditions, so they have a stable sensitiveness $\Delta I/\Delta F$, that last parameter is the important advantage of pyroelectric detectors.

The Hg Cd Te detectors are photoconductors, they have a better D^* detectivity than pyroelectrics if they are cooled (-196°C or -77°C) but some are able to work at 20°C and have a bad detectivity. Those detectors have the disadvantage to have a sensitiveness which vary with the illumination. Finally, we have chosen a pyroelectric detector because its sensitiveness is stable and known, and it doesn't need cooling device.

2.3- Conditions on the regulation imposed by the system.

In practice, the output signal of lock-in amplifier is usable if it is filtered to eliminate aleatory noise of high frequency, consequently the frequency band is limited, the rise time of the signal is limited at about 30 milliseconds. The regulation will have a minimum discrete period of 30 ms., so we can have 30 informations per second. The interaction time with the material to have some transformation is long by comparison with the regulation

period of 30 ms., so we can say that the lock-in amplifier output signal is suitable for a discrete regulation of beam global power.

2.4- Concise theoretical principles of regulation.

We can schematize the machine like a group of various functions: (see figure 2) with $E(t)$ = exciting current of laser source; $S(t)$ = instantaneous external global power (on the work table); $S'(t)$ = cavity internal power; $S''(t)$ = output signal of lock-in amplifier. $(G1.G2)(t)$ is the function that should be idealment used in the regulation calculation because it represents the relation between the laser exciting current and the external power; unfortunately, it's impossible to know the function of the only laser $G1(t)$ because we have no detector fast enough. $(G1.G3)(t)$ is the function chosen to the regulation calculation, it represents the relation between the current and the lock-in amplifier signal. We have calculated a discrete regulation with a feed back and the best performance and the stability are assured by a "proportional- integral" corrector.

Fig 2 - Transfer functions diagram.

3- Energy distribution of laser beam.

The informations about the energy distribution of laser beam are acquired by "laser beam analyser" (L.B.A) (3): As a needle crosses the beam, a fraction of the radiation is reflected on two pyroelectric detectors in such a way that it is obtained a signal proportional to the intensity distribution in two, to each other perpendicular strips across the beam.

Fig 3 - Schematic sketch of a working device

The outputs from the L.B.A are two voltage signals whose magnitudes correspond to the beam intensity profiles along the X and Y axes of the beam cross section. These outputs are sent in two ways of an acquisition board (Datel st-701) based on a computer (INTEL 320). Several processings can be program: for instance, acquisition and real-time visualization.

The visualization of digitalized datas gives two profile types according to the beam power level. We can observed "gaussian" mode for low power levels and "annular" mode for high power levels and more or less mode instabilities associated to power fluctuations.

4- Retroaction phenomena.

An important result obtained by means of pyroelectric device is the view of retroaction phenomena on cavity. As a matter of fact, in addition of the capacity to know the power characteristics evolution according to exciting current, internal pressure, cavity optical adjustments, it is possible to show-up retroaction phenomena during operations on high reflectivity materials and if it operates near focal point, it is possible to be in self collimation conditions, thus, a significant quantity of energy is reinjected in cavity and amplified again. So, global power measurement increase is observed (approximately 10% during surface's re-melting and 50% for welding), you can see on figure 4 the retroaction effect on global power.