Closed Loop Control of the Laser Welding Process through the Measurement of Plasma

Project objectives

Project CLET has three main objectives:

- To develop a sensor system: A sensor set able to gather the radiation emitted during laser welding process in the infrared, ultraviolet and visible spectrum ranges and to detect welding defects in real time. The sensors must satisfy some conditions regarding sampling speed in order to be useful for control. The optical system to be designed will be based on a fast spectrometer. Mathematical algorithms for defect detection will be also developed and integrate in the sensor system

- To develop a feedback controller: Once the sensor and defect detection system is available, the next objective is to develop a closed loop control system for laser welding. The system has to be robust enough for changes in equipment and material and it has to be operated in real industrial conditions as the ones present at the facilities of the SME partners. Moreover, it must be capable of rejecting perturbations. In case of deviations from the desired quality, it has to decide which changes to the process settings must be applied, e.g. by modifying the laser power and/or welding speed.

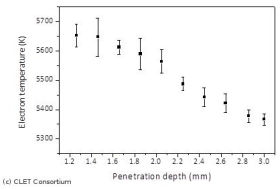
- To validate the system: To prove the capability of the system it will be tested and validated in a first stage at a pilot level in laboratories of RTD and at an industrial level in real applications in SMEs in a second stage.

The sensing system

During keyhole mode laser welding, plasma appears as a consequence of the metal-laser interaction. This radiation can be registered by means of a miniature spectrometer and the detected spectral lines can be used to compute the electron temperature.

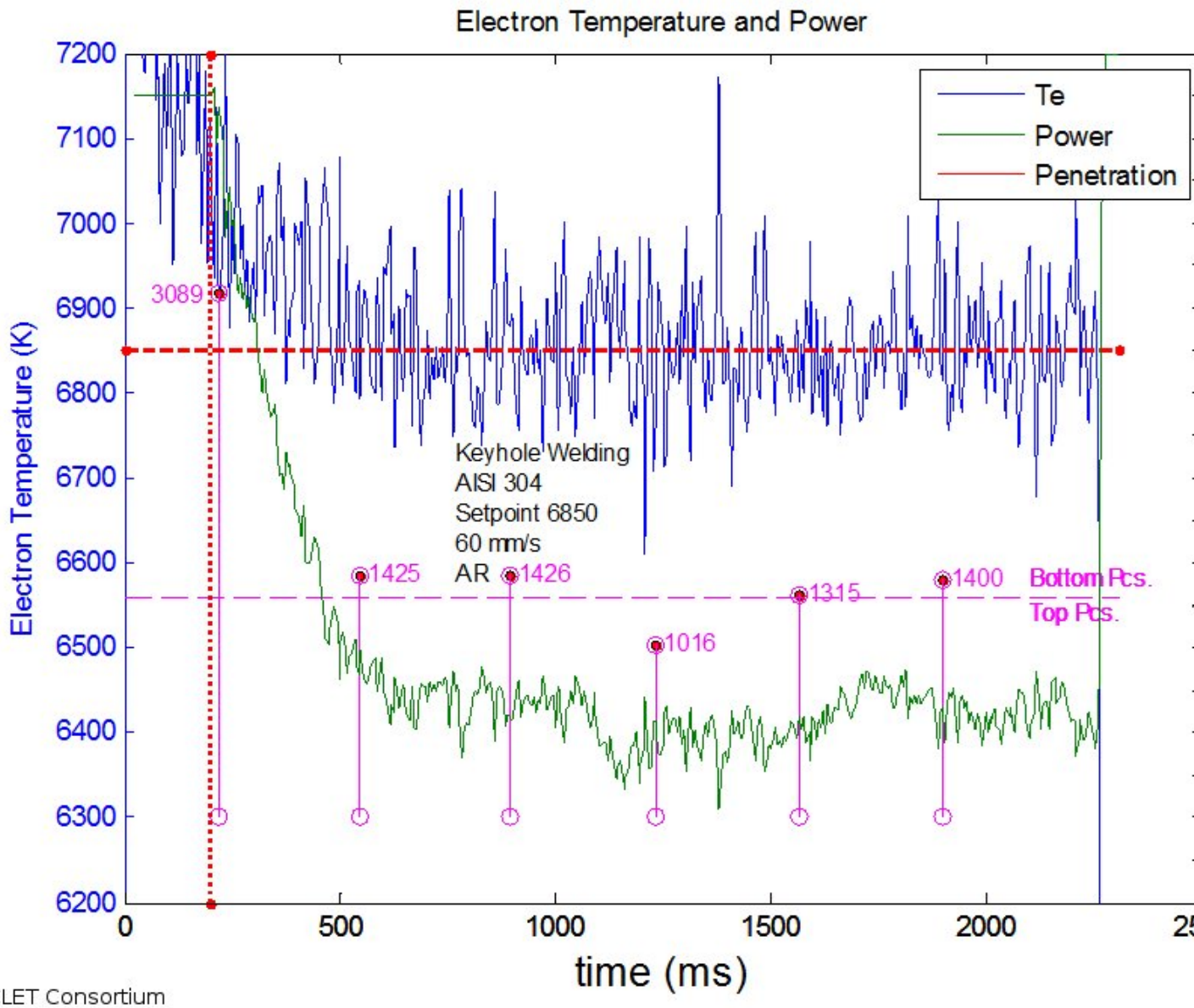
It has been found out that electron temperature has a characteristic value for a given welding conditions and that changes in electron temperature are related to quality deviations from the desired ones.

In particular, it has been learnt that when thin steel sheets are welded there is a clear relationship between electron temperature and penetration depth. This fact allows estimating the penetration depth on line, up to 500 times per second and in a non-destructive fashion. The relationship between electron temperature and penetration depth has been found in CO_2, continuous Nd:YAG and pulsed Nd:YAG laser welding.



The controller

Once the penetration depth can be measured on line, it is possible to control it by means of a closed-loop controller. The controller receives penetration depth values and, according to their deviations from the desired one, it adjusts the laser power in order to maintain the desired penetration depth. The well-known and common PID controller has proven its capability to achieve control objectives.



Workshop testing

The controller has been tested at Flexweld and Vatrans Zlín workshops. In the first case overlapping metal sheets welding was tried. In the second, pipe welding.

In both workshops, the controller successfully kept the penetration depth at the desired value. Moreover, in the case of pipe welding, the controller exhibited disturbance rejection capabilities.

For pipe welding they use a CO_2 laser. The beam is guided using mirrors and those are dirtiness prone. In this case, the energy density in the pipe decreases and penetration depth may be shallower than desired. The CLET controller was able to compensate the mirror dirtiness by increasing the laser power, so the penetration depth was the desired on at any time.

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