Laser welding of a titanium feed through

VIATGE Hélène
Mechanical Studies and Development

SORIN GROUP
AT THE HEART OF MEDICAL TECHNOLOGY

Abstract

Laser welding is increasingly used in many manufacturing processes, either with a moving laser or a stationary setup. This process might gradually replace conventional assembly methods for enhanced speed and precision. However, it is subject to a large number of parameters such as power of the laser, length of the pulse, ambiance in which it is performed... Being able to predict the influence of these parameters on the welded part temperature and internal residual stresses without an expensive and time-consuming experimental study could enable a more efficient optimization of the process. That is why numerical models for assessing thermal fields or thermo-induced mechanical stresses have been widely developed.

For SORIN, the laser welding process is used in particular to close the can and create a hermetic case. The components welded together are two half cans and a feed through.
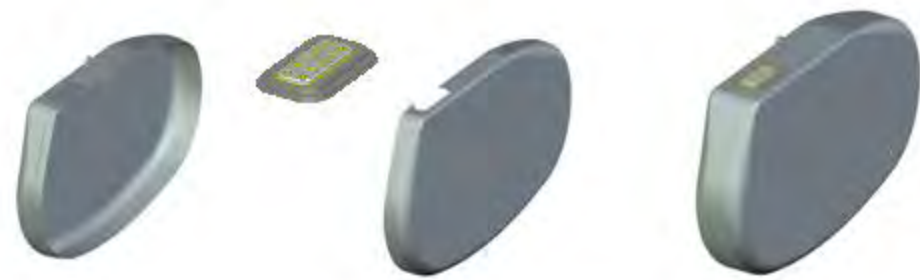
Objectives

The feed through is one of the most important components of the device, due to its function and price. Indeed, this component is responsible for the transmission of the electronic information from the inside of the can to the outside without affecting the hermiticity of the can.
It is made of four different materials: titanium, alumina, gold and platinum.
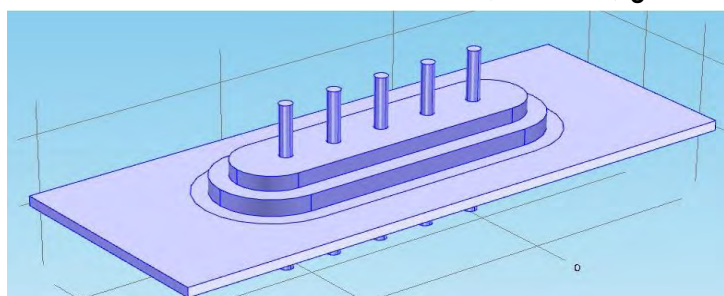
Using the traditional parameters of welding induces huge thermo mechanic stresses on the part due to among others different thermal expansion coefficient and thermal conductivity.
SORIN has developed a set of parameters for which the risk of having the alumina cracking itself and the hermeticity of the can lost is suppressed.
The objective is to be able in further studies and developments to better understand the heat transfer in the feed through and to optimize the process (lower the stress in the ceramic and minimize laser welding process duration).

The model to be developed needs to be as simple as possible, the idea being not really to have a very accurate description of the keyhole or the fusion bath but to have an average value of temperature and stresses undergone by both titanium and alumina.
As a result, we decided to begin with a thermal model and to add mechanical conditions in a second step. Described in this poster are the thermal description of the system, the way we assessed it and the way we envisaged to treat the mechanical aspect.

Methods

First point to deal with is the determination of thermal conditions.
The heat equation to solve on all volumes is

$$\rho C_p \frac{\partial T}{\partial t} - \nabla(k\nabla T) = Q$$

With C_p the heat capacity and ρ the density
We are using a spot laser welding. Considering the energy of the spot (0.9 J), the pulse duration (4 ms), and the frequency of the spot (70Hz), bibliography and discussions with experts have lead us to the conclusion that we shouldn't expect any vapor phase or plasma effect. As a result we will only consider a solid-liquid transition, which should simplify the model.
On surfaces, the boundary condition is the following:

$$n(k\nabla T) = q_0 + h(T_{inf} - T) + \sigma\varepsilon(T_{amb}^4 - T^4).$$

Different terms and values chosen are detailed below.
Conduction:
Values of material conductions are known as well as their temperature dependency. We have decided to consider them as constant to simplify the model.
Heat source:
The most difficult step of this work was to assess the laser heat source.
The surface source is most of the time represented as a Gaussian distribution of heat. Intend is to use thermal paper to have a more precise idea of the heat source shape.

$$q(x,y) = q(r) = \frac{3*Q_0}{\pi*R_z^2}*\exp\left(-3*\frac{r^2}{R_z^2}\right)$$
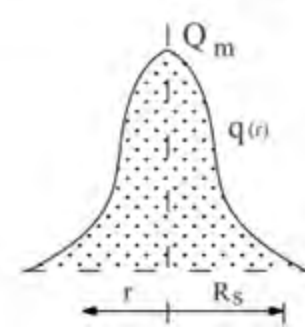
• Q_0 is the power of the laser. Although the laser beam welding is performed with a pulsed laser, the laser beam was considered as continuous with the power equal to the average power of the pulsed laser.
Moreover to model the fact that the entire power is not absorbed (there is some energy absorbed and some energy radiated), we add a coefficient, alpha (between 40-55% to be optimized).Therefore the power is defined as below:
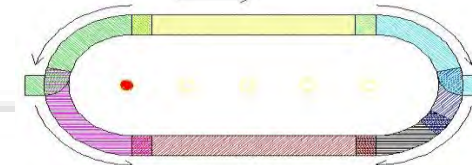
$$Q_0 = \alpha \times \frac{E}{\pi \times R_c^2} \times f$$

• r is the radius of the sphere affected by the laser spot.

$$r = \frac{(x - xc)^2 + (y - yc)^2}{Rc^2}$$

The center of the sphere (xc,yc) is moving around the feed through and is used to parameter the laser path on each section.
The heat source is equal to zero on all surfaces except on the path of the laser. The complete laser welding around the FT is composed by seven sectors.


Convection:
The laser welding process is done in an Argon-Helium ambiance.
To model the convection, we have decided not to consider any Navier-Stokes equations but to implement a loss of heat characterized by h, the heat transfer coefficient. This coefficient value was set to 20, with the use of other papers and of experimented people. We have moreover been able to see it has very limited influence in our model.
Radiation:
Radiation was not considered because the energy and pulse length of the laser we use are very low. As a result we have neglected this parameter.

We decided to have an accurate meshing around the laser beam path and to have a coarse meshing in areas of the feed through in which we do not need any data collection.
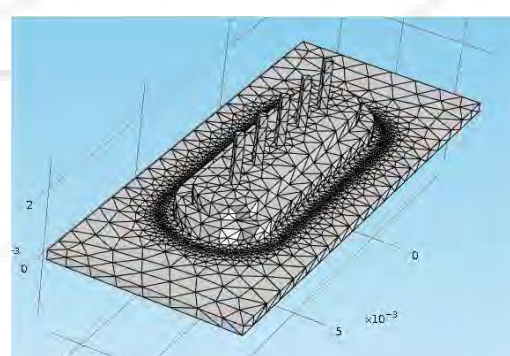
Experimental data acquisition

To be able to optimize the model and to validate it, objective is to compare the results of the simulation with the reality. This will be conducted in three different ways.
1) Spot dimensions
We have produced some experimental spots at different energies (close to the energy used currently) on a titanium sheet and measured the size of the welding areas (diameter of the welded surface and depth of the welded zone). These dimensions were compared to the theoretically modeled ones. The modeled ones correspond to the maximum dimensions reached by the isothermal melting front of titanium.
**2) Line dimensions**
To add the effect of heat accumulation during the entire laser welding, this experiment was also conducted for a line of spot. Same dimensions measurements were performed and compared to the simulation.
3) Temperature field
Last point is to check the temperature distribution the simulation gives is not too far from the reality. As a result, we will perform several experiments:

- Fix some thermocouples to the alumina of the feed through and monitor the acquisition of temperature, compare the temperature in time at a certain location in the model and in the reality
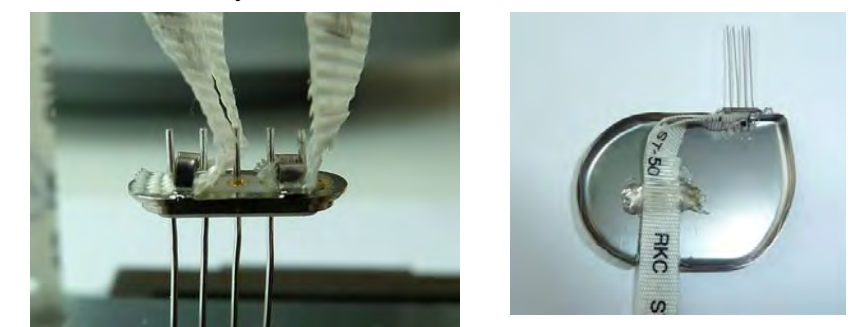
- Make a movie with an IR camera, knowing the emissivity of each material

Mechanical assessment

Mechanical description of the system could not be neglected as it has a huge important in the stresses field. Indeed the stresses are both induced by thermal dilatation and by the way the components are trapped. Two constrains need to be implemented:

-The entire device is trapped between two big clawing jaws. These jaws have an influence on both the thermal dissipation and the mechanical stresses.

- As long as the welding is performed, the titanium can traps the feed through without allowing any more stress release. This may have a bigger importance than initially anticipated. Indeed, it happens that the welding is performed twice and the stresses in the ceramic during the second welding is much more important than during the first.

These two mechanical aspects will be implemented in the model in the second step.

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