A THREE DIMENSIONAL MESHFREE-SIMULATION OF THE SELECTIVE LASER SINTERING PROCESS WITH CONSTANT THERMAL COEFFICIENTS APPLIED TO NYLON 12 POWDERS

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Abstract

3D printing is an interesting process in the context of creating original objects. Selective laser sintering printers use a laser to fuse polyamide particles together with specific resin and heat. The difference in temperature between the different areas in the process causes the appearance of deformations, the objective of this work is the modeling of the thermal SLS phenomena, by following the evolution of the temperature as a function of time. This model is based on the resolution of the heat conduction equation coupling with convection and radiation conditions with a distribution heat source and constant thermal coefficients by the meshless method based on radial basis function, the result of this study, will be presented and compared with other works.

Keywords: Meshfree method; radical basis function (RBF); thermal modeling; heat transfer; selective laser sintering (SLS).

1. Introduction

Recently, the use of 3D printing has moved from the development stage in research laboratories to the implementation stage on industrial production sites. Selective laser sintering enables manufacturing precise and durable plastic parts with low deformations, due to the better mechanical properties associated with the appearance quality. Numerical modeling is a suited tool for predicting certain characteristics of the final parts, and for the optimization of the laser process. Many numerical and analytical studies have been made to solve the transient problems of heat transfer of iridium objects by a source term [1-3]. In this study, a meshless method is applied using radial basis functions (RBFs) which results prove it’s efficient in solving radiative and conductive heat transfer coupled in the absorbing, emitting and diffusing media [4]. The MQ RBF approach created by kansah since 1990 has a successful history of numerical applications and its particularly attractive which is simple, accurate, and requires polygonalisation [5,6].

2. The SLS thermal process modelization

The main aim of the present work is to follow the evolution of temperature over time in the process of SLS, the transient conduction equations are written under the following assumptions:

- A complete model describes the thermal history shown in Fig.1 within the powder bed, taking into account a heat distribution and the convection in the SLS build chamber as a natural convection with radiation at the boundary.
- The polyamide powder bed was assumed to be homogeneous and continuous.
- The heat flux from the laser beam was modelled as Gaussian-distributed heat flux and was given directly on the top of the polyamide powder bed.
- Considering the constant coefficients thermal proprieties (no changing with temperature).

2.1 Linear Heat Transfer Equation In Meshless RBF

Thermal transfers are described by the following heat transfert equation as in [1,2] and [7-13]:

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The powder bed is initially at ambient temperature and we have imposed conditions of convective flux and radiation at the limits of the domain.

- **Initial condition**:
  For \( t = 0 \) s, \( T(x, y, z, 0) = 130 \) C° (Preheating temperature).

- **Boundary conditions**:
  For the simplification of the modeling, the radiation term was integrated into convection term, it’s can be expressed in \( Z \) direction, as follows [2]:

\[
\frac{\partial T}{\partial t} = \frac{T}{c_p \rho} \left( \frac{\partial T^2}{\partial x^2} + \frac{\partial T^2}{\partial y^2} + \frac{\partial T^2}{\partial z^2} \right) + Q_v
\]

(1)

where \( P \) and \( r \) are the parameters of the laser projection process, where their values are proposed and assembled in Table 2.

### Table 2: Mehless simulation parameters

| Process parameter | Full name                  | Value | Unit |
|-------------------|----------------------------|-------|------|
| \( P \)           | Mean laser power           | 1.8   | w    |
| \( r \)           | Laser beam radius          | 120   | Um   |

3. **Numerical results and discussion**

With a compture program writing by MATLAB software, using the RBF meshless method, the laser selective sintering of a first layer of nylon 12 powders is simulated in the case of rectangular layer cross section having the following physical dimensions 5mm*2mm*1mm. The temperature at the surface center of powder bed is calculated perpendicular to the projection of the spot laser.

![Fig.2: The position of point at the surface powder bed](image)

![Fig.3: Evolution of the temperature at top surface (z=0), at the middle(z=0.5mm), and bottom powder bed (z=-1 mm)).](image)

It can be noticed from the results obtained in the Fig. 3 that during the projection of the laser beam on the top surface of the powder bed, the temperature is rapidly increasing where the maximum temperature of PA12 is \( 171.5 \) C°, contrary to the case of the laser beam projected at the bottom surface, the temperature decreases rapidly and become constant at \( 100 \) C°, while the temperature remains constant \( 130 \) C° at the middle of powder bed.
In the Fig. 4 this model has been validated by comparing the results of the experimental work of the author Amado[1] (fig.4), which the evolution of the temperature at the surface powder bed $T_s$ was obtained from the measurements taken on the powder bed by the chamber infrared sensor.

**Conclusion**

In this study, three-dimensional meshfree method is developed for predicting the temperature fields within a first single polyamide layer based on the heat equation with polyamide melting and coupling with radiation and convection phenomena allowing to simulate the thermal history induced by the SLS process. The simulation of the evolution of the temperature at top surface ($z=0$), at the middle ($z=0.5mm$), and bottom powder bed ($z=-1mm$) have been done and a comparison of the result with experimental work allowed to validate a model proposed.

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