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Modeling of Heat Transfer for Calculation Temperature Profile in Drilling Process

Ehsan Ghaedi*, **Mohammad Gholamhossein Pour**

Department of Petroleum Engineering, Marvdasht Branch, Islamic Azad University, Marvdasht, Iran

Abstract

Drilling speed and drilling efficiency is studied by using the unsteady model of dynamic 1-D. The damage in the vapor and liquid leaving time is studied due to the material interaction of laser. The Interface places of liquid – solid and vapour are obtained by solving the formulas and energy conservation equations in the relations. The dependence of saturation temperature to the mutual pressure for the use of the Clausius–Clapeyron equation is considered. Transitive heat loss of solid is in this model and is solved by using an approximate total method. The results indicate that the fraction of heat which from the transfer through the solid is very small and its impact on evaporation is not important. In other words, the transitive heat loss greatly reduces the thickness of the liquid layer, which after drilling, a new layer is recast.

Keywords

Drilling, Heating Process, Laser, Heat Transfer, Liquid Layer, Solid

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1. Introduction

Considerable research has been conducted to develop a theoretical model of laser drilling, and most of the researches are described in detail in the present context. Detailed review of several hypotheses and briefing were discussed. Also, a theoretical solution to predict the temperature profile and the tangential distribution of laser drilling process pressure is proposed. Drilling speed and drilling efficiency is studied by using the unsteady model of dynamic 1-D. The damage in the vapor and liquid leaving time is studied due to the material interaction of laser. Both thermal transfers of mode changing and gas dynamics were considered in studies. Limitation of the above tasks is that the laser drilling process is sampling as the 1-D, but the actual processes of laser drilling are explicitly unsteady issues of 1-D or 2-D. In order to overcome the obstacles of the initial research work, researchers raised the problem of drilling 2-D metal based on the active heat balance method and they solved this issue by using the Crank – Fykvlsvn method. They also have done experimental investigations about the steel drilling by laser beam CO_2 and the experimental results were analyzed by the theoretical models of their selves. Other researchers proposed the unstable 1-D model to predict the laser-drilled holes by solving the energy conservation equation (the Stefan condition) in many places throughout the liquid - solid and liquid - vapor. However, the shape of the drilled laser hole, was assumed simply a combination of the parabola and the straight line on the bottom and the edge part respectively. The physical model due to multiple reflections inside the cavity and auxiliary gas effect is proposed. Energy loss due to the transition of work piece about laser drilling was not considered by researchers for some years. The effect of Conductive heat loss to work piece in the laser cutting process and the effect of transmission heat loss in the laser cutting process was investigated by other researchers. They found the effect of heat loss transmission in CW laser cut is important. About the Laser impact cut is not important. However, the change of state from solid to vapor in a step in single evaporation temperature was assumed, if the metal work piece is cut by laser this issue won't apply. the numerical studied about laser drilling on diamond plate was

* Corresponding author
E-mail address: ehsanghaedi0@gmail.com (E. Ghaedi), mohammad.gholamhosseinpour@gmail.com (M. G. Pour)

done and the results shows the strong priority in the performance of laser beats in CW laser due to more heat efficiency is generated. Also, numerical method with a lot of details and the physical model was developed for the laser drilling process using the free surface and simulation of state changing. The computer time relatively is high because 80 hours took on SAN SPARK station to generate 281 us laser drilling data. The analytical model of laser machine according to heat transfer in the melt and solid simultaneously was not found in the present context. In order to provide a simple and reliable model to predict the geometry of the drilling laser hole, the new model introduced with respect to the laser drilling process. Geometric constraints of the used hole in the industries, are eliminated. Dependence of saturation temperature to the mutual pressure will also be considered. Transmission heat loss to work piece is also in this model. In heat modeling of laser drilling process with the effect of transmission heat loss of workspace, the requirement of proper prototyping and solution of non-linear translational motion felt at both ends. The relationship between liquid - vapor and solid - liquid at research work, melting and evaporation, by transition to the work piece is solved analytically. The effect of many parameters on the laser drilling process will be discussed in this paper.

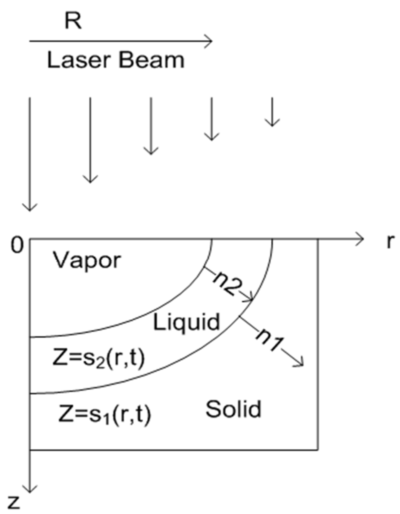

Figure 1. The physical model of laser drilling process.

2. Surface Energy Balance

In Figure 1, the physical model of laser drilling process is shown. Laser beam with the intensity of I (r, t) is generated and is directed to the solid target material in the initial temperature of the T<Tm, which absorbed the fraction of emitted light energy. The beam of laser produced very intense flux of heat in the solid which taking the solid temperature to the melting point and then it melts the solid and evaporate the obtained liquid. The following assumptions are required to analyse the laser drilling process. A – the target material is opaque, means the emitted laser energy is released instantly to target material surface and the laser beam does not penetrate to the target material. This hypothesis is true in good electrical conductors such as metal, because the laser energy attenuation occurring in areas of shallow depth of penetration increases, B - no plasma is produced in the laser drilled hole. This assumption is somewhat questionable in the material target of metals. Although the plasma effects can be waived which the time of the beat is much shorter than the time of silence beat due to the plasma between the beats becomes shelly. C - the stream of the liquid metal inside the hole is small and the temperature distribution in the liquid metal is assumed to be linear. To the heat to bring the temperature of the liquid layer to the mean value, the saturation temperature is required and the boiling point to the latent heat for consideration the effect of unstable state is added.

$$h'_{lv} = h_{lv} + \frac{1}{2} cp_l (T_{sat} - T_m) \quad (1)$$

D - liquid and solid properties are independent of temperature and intensity of liquid and solid are assumed equal d – the heat loss in the environment due to the superficial radiation is insignificant. These effects can simply be present during heating. However, the initial work on the laser cutting showed that heat loss due to radiation and advection in all cases, including the distension for donor acoustic is negligible ،a chemical interaction - Laser can be divided into three stages. During the first phase, the solid's temperature is below of the melting point and hence melt or evaporate not occur. The solid absorbs thermal energy and the solid's temperature increases with increase in time.

After the maximum temperature of the solid which is in the center of the laser beam, it reaches to the melting point of the material target, the laser beam irradiation causes melting the material target and the process is entering in its second phase. In the second stage, the surface temperature of the liquid is below of the saturation temperature and the required evaporation of thermodynamic equilibrium is negligible. When the maximum surface temperature of the liquid reaches the evaporation temperature, evaporation occurs in the surface of liquid and the third stage begins. During the third stage with the interface of solid - liquid and liquid – vapor places are unknown and needs to be identified. From the above description, it is evident that different locations under irradiation of the laser beam at different stages at the same time is different due to the intensity of the laser beam varies with the radius location. With assuming the evaporating started and liquid - vapor interface forms liquid interface the geometry of liquid-vapour interface and the solid – liquid interface, respectively, is expressed as follows.

$$f_1(z,r,t) = z - s_1(r,t) = 0.0 \quad (2)$$

$$f_2(z,r,t) = z - s_2(r,t) = 0.0 \quad (3)$$

Temperatures at the two interfaces are applying the following conditions.

$$T = T_{sat}, z = s_1(r,t) \quad (4)$$

$$T = T_m, z = s_2(r,t) \quad (5)$$

The energy balance equations for liquid - vapour can be written as follows:

$$\alpha_{abs} I(r,t) = \rho h_{lv} \frac{\partial s_2}{\partial t} - k_1 \frac{\partial T}{\partial n_1} \left|\nabla f_1\right| \quad (6)$$

It should be noted that the equation (6) may not be appropriate for identifying the location of the interface. The temperature gradient at the interface $\frac{\partial T}{\partial n_1}$ can be expressed as follows:

$$\frac{\partial T}{\partial n_1} = \frac{1}{\left|\nabla f_1\right|} \frac{\partial T}{\partial z}\left[1 + \left(\frac{\partial s_1}{\partial r}\right)^2\right] \quad (7)$$

3. Conclusions

Thermal models of the melting and evaporation phenomena in laser drilling process are introduced by decomposing the energy balance at the interface of solid - liquid and liquid - vapor. The dependence of saturation temperature on mutual pressure was calculated by Clausius – Clapeyron equation. Transmission heat loss to the work piece is also considered in this model and is solved by using the integral approximation.

The absorption rate of predicted materials from the qualitative is well matched with the experimental data.

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Biography

Mohammad Gholamhossein Pour studied reservoir engineering in Islamic Azad University, science and research in Fars province. He is interested in reservoir simulation, exploring and in - well facilities. He is now in Bachelor degree and works on well drilling, simulation and related fields.

Ehsan Ghaedi studied reservoir engineering in Islamic Azad University, science and research in Fars province. He is interested in reservoir simulation, drilling, exploring and in-well facilities. He is now in Bachelor degree and works on well drilling, simulation and related fields.