Experimental Study and Finite Element Simulation of Cutting Tool Temperature in Laser Assisted Machining

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ABSTRACT

The present paper has been dedicated to finite element simulation and experimental study of cutting tool temperature during laser assisted machining. To achieve this objective, a finite element model of the processes has been developed for Inconel 718 super alloy and the results have been verified by experimental measurements of cutting forces and cutting tool temperature. In this regard, first of all a finite element model of laser assisted turning process was developed and then experimental setup was designed and manufactured. Finally, a series of experimental tests were arranged to achieve proper range of process parameters and also to measure cutting forces and cutting tool temperatures during the machining process. Experimental results were then used to verify the results of finite element model. Using the developed model, the effect of laser source power, cutting speed and feed on cutting tool temperature were studied. According to the achieved results, using laser heat source, in the range without microstructural effects, will lead to 25% reduction in the average of main component of cutting force and 80% reduction in the average maximum temperature of cutting tool in comparison to conventional turning.

KEYWORDS

Laser Assisted Machining, Cutting Temperatures, Finite Element Simulation, Continuous Wave Laser.

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1. Introduction

Laser assisted machining is a process which uses a laser source, Fig. 1, to increase workpiece local temperature and thereby decrease the strength of material which is to be removed; therefore lower values of cutting forces and cutting temperatures are expected [1].

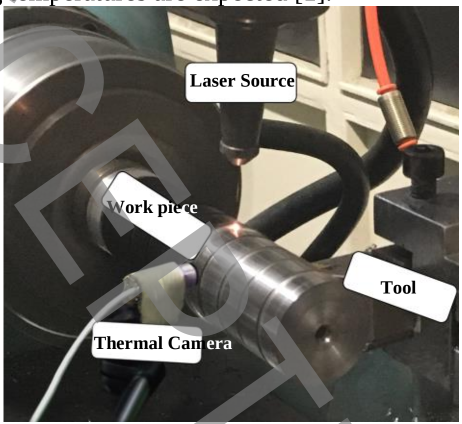


Fig.1.Experimental Setup of Laser Assisted Machining.

According to the previous studies [1-2], thermo-mechanical aspects of workpiece have been widely studied by numerical and experimental techniques, but limited works have considered theoretical and experimental aspects of cutting tool temperature in laser assisted machining processes. Therefore, in this research work, a finite element model have been developed to study the effects of laser power, cutting speed and feed on cutting tool temperature in laser assisted machining (LAM) of Inconel 718.

2. Methodology

In this research, using Deform 3D, a coupled thermo-mechanical finite element model have been developed to study cutting tool temperature, Fig. 2.

Because in LAM process, the laser beam is focused on the workpiece, it can be assumed that due to the laser heat flux entering the workpiece, the upper surface of the workpiece is preheated and is affected by a constant temperature (T_{Laser}), so according to the mathematical formulation introduced in Kashani et al. [2], to determine the temperature of different points on the workpiece being exposed to laser radiation, in proportion to the coexistence of laser power, cutting speed and feed, the surface temperature of the un-deformed chip is calculated and is considered as the boundary condition governing the surface of the workpiece in the FEM model according to Fig. 2.

In order to validate finite element model, the cutting tool temperature in the experimental and simulation modes is compared; for this purpose, a specific point with coordinates (0.97, 4.3) mm is considered on the cutting tool rake face and the thermocouple is embedded at mentioned point and the time history of temperature at this point is compared using the experimental method and finite element model.

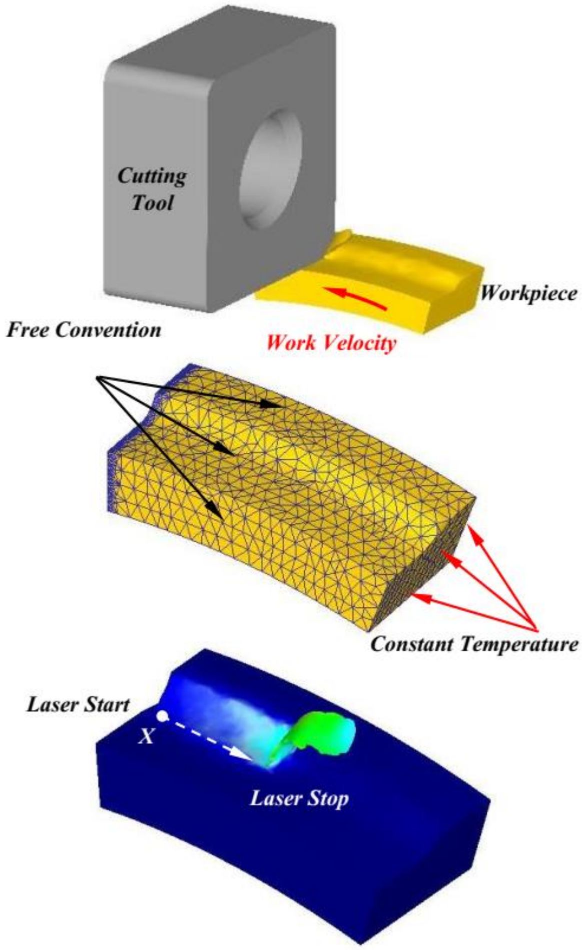


Fig.2.Applying of boundary conditions and laser heat source on the work piece in the finite element model.

In this research, Inconel 718 super alloy has been selected as workpiece material, Table 1; the elastic-plastic behavior of this material can be described by Johnson-Cook model. Therefore, Johnson-Cook parameters including A, B, C, m, and n are gathered in Table 2.

Table 1. Physical properties of Inconel 718 [3].

Elastic Module	Tensile Strength	Density
GPa	**MPa**	**Kg/m^3**
177	655	8220
Specific Heat	**Melting Point**	**Poison ratio**
520 J/kgK	1593 K	0.273

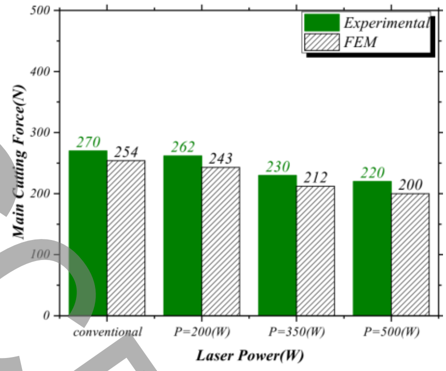
Table 2. Johson-Cook constants for Inconel 718 [3].

n	m	C	B (MPa)	A (MPa)
0.5189	1.2861	0.0085	699	1108

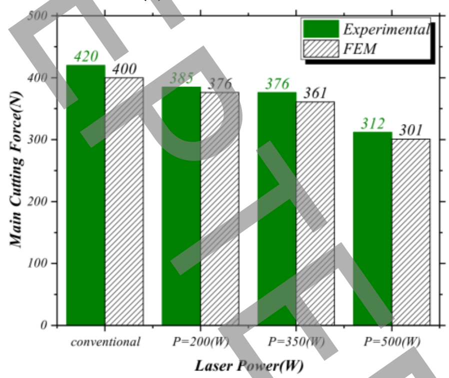
3. Results and discussion

3.1 Main Cutting Force

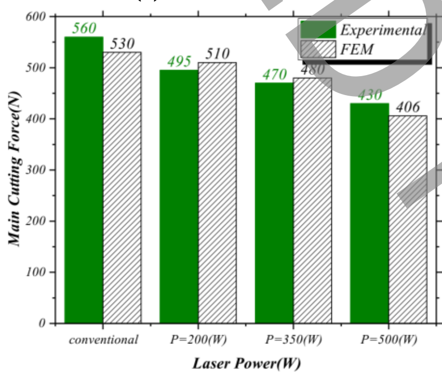
As shown in Fig. 3, the use of 350 and 500W laser powers have respectively reduced the cutting forces by 11.5 and 23% compared to the conventional turning. This decrease is justified by the decrease in material flow stress with increasing temperature.



(a) a_f=0.08 mm/rev



(b) a_f=0.14 mm/rev

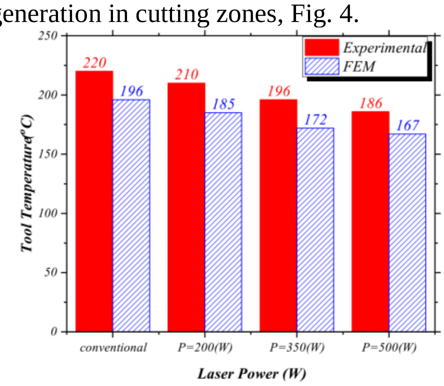


(c) a_f=0.20 mm/rev

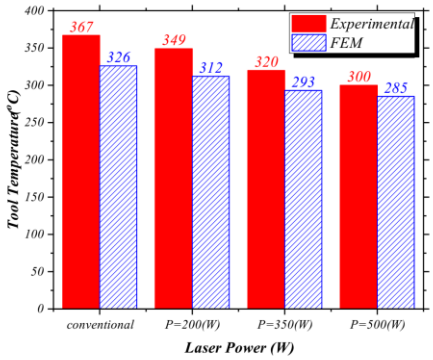
Fig. 3. FEM and Experimental Results on the effect of laser power and feed on Main Cutting Force (V_c=1.86 m/s).

3.2 Cutting Tool Temperature

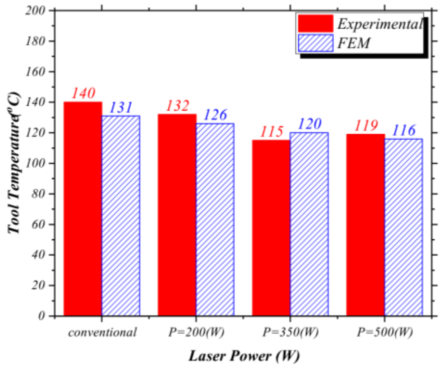
As a general trend, with increasing laser power, the cutting tool temperature decreases; this decrease is justified by the decrease in material flow stress with increasing temperature and finally decreasing temperature in the primary cutting zone. Therefore, the cutting tool temperature decreases due to lower amount of heat generation in cutting zones, Fig. 4.



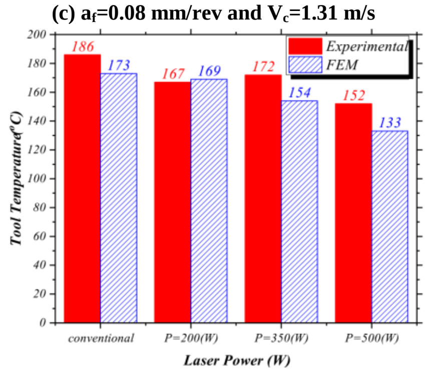
(a) a_f=0.14 mm/rev and V_c=1.31 m/s



(b) a_f=0.14 mm/rev and V_c=1.86 m/s



(c) a_f=0.08 mm/rev and V_c=1.31 m/s



(d) a_f=0.08 mm/rev and V_c=1.86 m/s

Fig. 4 Effects of power, speed and feed on Tool Temperature.

4. Conclusion

The following conclusions can be achieved:

1. A finite element model of laser assisted machining process developed and there is a good agreement between experimental results and finite element model.
2. By increasing laser power, the main component of cutting force decreases.
3. By increasing laser power, the cutting tool temperature decreases.

Reference

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