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Abstract

Grinding temperature spreads over the depth of the surface layer and in some cases causes the appearance of grinding burns and micro-cracks. These thermal grinding defects are located at a certain depth from the surface machined during grinding. In several cases, such defects are generally not permissible. In other cases, the possibility of the formation of such a defective surface layer must be provided for in the amount of the grinding stock, based on the obvious condition: the defective layer must be completely removed when the grinding stock is removed. In any case there is a need to determine the depth of the defective layer formed during grinding. The simplest way to solve this problem is the ability to determine the penetration depth of a certain critical temperature, which leads to thermal damage to the surface layer of the workpiece. To determine the depth of such a damaged layer, an approach based on modeling the temperature field in the surface layer is proposed. The possibility of determining in explicit form the depth of penetration of a fixed temperature exceeding a critical value is shown in the paper. A prerequisite for the analytical solution of such a temperature problem was the possibility of replacing the Jaeger fast-moving heat source with the action time of some unmoving heat source.

Keywords

Grinding temperature Peclet number Temperature penetration

In our previous studies, it was shown that it is possible to determine the grinding temperature by the traditional one-dimensional solution of the differential equation of heat conduction at the boundary conditions of the second kind and by the simplified equation if the Peclet number is more than 4, i.e. $H_H \geq 4$.

The traditional equation at the stages of heating (with the index “*H*”) and cooling (with the index “*C*”):

The simplified equation at the stages of heating and cooling:
In these equations H_H and H are the Peclet number and dimensionless action time of unmoving heat source, respectively.

From equations (1) and (3), we can find that the maximum dimensionless surface temperatures (at $X = 0$) according to these equations are the same, i.e. they are equal to each other. They correspond to the action time of the moving heat source of $\tau_H = 2h/V$ where $2h$ in m is the width of the moving heat source and V in m/s is its velocity. That is, the maximum grinding temperature at the heating stage in accordance with mentioned equations will be

The pairs of equations (1)-(2) as well as (3) and (4) fully correspond to the following pairs of equations which were obtained by prof. V.A. Sypailov in [20] for fast-moving heat source, i.e.
where H and Z are dimensionless half-width of moving heat source (Peclet number) and Cartesian coordinate in the direction of which the heat source moves with velocity V. By the other words, equations (6) and (7) allow you to find the grinding temperature on the surface during the heating and cooling stages for fast-moving heat source, i.e. when $H_H \geq 4$.

It is known that in order to optimize the grinding conditions according to the temperature criterion, the formulas are needed to calculate the temperature and depth of the defective layer during grinding. As a parameter to estimate the depth of the defective layer, the penetration depth of a fixed critical temperature is most often used, under the influence of which irreversible changes occur in the workpiece material being ground. Based on the analysis of the literature [18-20] and theoretical studies, new dependencies (1)-(4) were obtained to determine the dimensionless grinding temperature on the surface and along the depth of the surface layer both for the heating ($0 \leq H \leq H_H$) and cooling ($H_H \leq H \leq \infty$) stages, respectively.

References

1.

Christof, C., Schlattmeier, H.: Optimization of the gear profile grinding process utilizing an analogy process. Gear Technol. 34–40 (2006)

Google Scholar

2.

Klocke, F., Schlattmeier, H.: Surface damage caused by gear profile grinding and its effects on flank load carrying capacity. Gear Technol. 21, 44–53 (2004)

Google Scholar

3.

Jermolajev, S., Brinksmeier, E., Heinzel, C.: Surface layer modification charts for gear grinding. CIRP Ann. Manuf. Technol. 1, 1–4 (2018)

Google Scholar

4.

Jin, T., Jun, Y., Peng, S.: Determination of burn thresholds of precision gears in form grinding based on complex thermal modelling and Barkhausen noise measurements. Int. J. Adv. Manuf. Technol. 88(1–4), 789–800 (2017)

CrossRefGoogle Scholar

5.

Fergania, O., Shaoa, Y., Lazoglub, I.: Temperature effects on grinding residual stress. In: 6th CIRP International Conference on High Performance Cutting, HPC 2014, pp. 2–6 (2014)

Google Scholar

6.

Deivanathan, R., Vijayaraghavan, L.: Theoretical analysis of thermal profile and heat transfer in grinding. Int. J. Mech. Mater. Eng. (IJMME) 8(1), 21–31 (2013)

Google Scholar

7.

Yadav, R.K.: Analysis of grinding process by the use of finite element methods. ELK Asia Pacific J. Manuf. Sci. Eng. 1(1) (2014)

Google Scholar

8.

Foeckerer, T., Zaeh, M., Zhang, O.: A three-dimensional analytical model to predict the thermo-metallurgical effects within the surface layer during grinding and grind-hardening. Int. J. Heat Mass Transf. 56, 223–237 (2013)

CrossRefGoogle Scholar

9.

González-Santander, J.L.: Maximum temperature in dry surface grinding for high Peclet number and arbitrary heat flux profile. Math. Probl. Eng. 2016, 1–9 (2016)

MathSciNetzbMATHGoogle Scholar

10.

Guo, C., Malkin, S.: Analysis of transient temperatures in grinding. J. Eng. Ind. 117, 571–577 (1995)

CrossRefGoogle Scholar

11.

Heinzel, C., Sölter, J., Jermolajev, S.: A versatile method to determine thermal limits in grinding. In: 2nd CIRP Conference on Surface Integrity (CSI), Procedia CIRP, vol. 13, pp. 131–136 (2014)

Google Scholar

12.

Li, B., Zhu, D., Zhou, Z.: Research on workpiece surface temperature and surface quality in high-speed cylindrical grinding and its inspiration. Adv. Mater. Res. 325, 19–27 (2011)

CrossRefGoogle Scholar

13.

Li, H.N., Axinte, D.: On a stochastically grain-discretised model for 2D/3D temperature mapping prediction in grinding. Int. J. Mach. Tools Manuf. 1–27 (2017)

Google Scholar

14.

Tadeu, A., Simoes, N.: Three-dimensional fundamental solutions for transient heat transfer by conduction in an unbounded medium, half-space, slab and layered media. Eng. Anal. Bound. Elem. 30(5), 338–349 (2006)

CrossRefGoogle Scholar

15.

Chen, X., Öpöz, T.: Effect of different parameters on grinding efficiency and its monitoring by acoustic emission. Prod. Manuf. Res. Open Access J. 4(1), 190–208 (2016)

Google Scholar

16.

Malkin, S., Guo, C.: Thermal analysis of grinding. Ann. CIRP 56, 760–782 (2017)

CrossRefGoogle Scholar

17.

Malkin, S., Guo, C.: Grinding Technology: Theory and Application of Machining with Abrasives. Industrial Press Inc., New York (2008)

Google Scholar

18.

Jaeger, J.C.: Moving sources of heat and temperature at sliding contacts. Proc. Roy. Soc. New South Wales 76, 203–224 (1942)

Google Scholar

19.

Carslaw, H.S., Jaeger, J.C.: Conduction of Heat in Solids, 2nd edn. Oxford University Press, Oxford (1959)

zbMATHGoogle Scholar

20.

Sipaylov, V.A.: Thermal Processes During Grinding and Surface Quality Control. Mashinostroenie, Moscow (1978). (in Russian)

Google Scholar

21.

Lavine, A.S.: A simple model for convective cooling during the grinding process. J. Eng. Ind. 110(1), 1–6 (1988)

MathSciNetCrossRefGoogle Scholar

22.

Larshin, V.P., Kovalchuk, E.N., Yakimov, A.V.: Application of solutions of thermophysical problems to the calculation of the temperature and depth of the defective layer during grinding. In: Interuniversity Collection of Scientific Works, pp. 9–16. Perm (1986). (in Russian)

Google Scholar

23.

Kostyukov, K.M.: Automatic Infeed Devices. Mashinostroenie, Moscow (1980). (in Russian)

Google Scholar

24.

Larshin, V., Lishchenko, N.: Gear grinding system adapting to higher CNC grinder throughput. In: MATEC Web of Conferences, vol. 226, p. 04033 (2018)

Google Scholar

25.

Larshin, V., Lishchenko, N.: Adaptive profile gear grinding boosts productivity of this operation on the CNC machine tools. In: Ivanov, V., Rong, Y. (eds.) Advances in Design, Simulation and Manufacturing, DSMIE 2018. LNME, pp. 79–88. Springer, Cham (2019)

CrossRefGoogle Scholar

26.

Lishchenko, N., Larshin, V.: Temperature field analysis in grinding. In: Ivanov, V., Trojanowska, J. (eds.) Advances in Design, Simulation and Manufacturing II, DSMIE 2019. LNME. Springer, pp. 199–208. Springer, Cham (2020)

Google Scholar