

Heat generated in the process of abrasion

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Abstract: The heat released during the grinding process is directly proportional to the size of the forces developed in the cutting process, which depend on the nature and mechanical properties of the workpiece material, the geometric parameters of the cutting tool, the properties of cutting fluids used during the machining process.

Experimental research has confirmed the hypothesis that an increase in cutting speed leads to an increase in the amount of heat released and consequently to an increase in the temperature of the workpiece when using the same temperature control system. The paper presents the identification of heat sources in grinding process, as well as the distribution of heat to the elements which are part of the processing system.

Keywords: GRINDING PROCESS, HEAT GENERATION, HEAT DISTRIBUTION

1. Introduction

There is a consensus of specialists [1], [4], [6], on the fact that the mechanical cutting work is almost entirely transformed into heat. Only a small part of it (0.5-1%) remains stored as potential energy in the chips, as well as in the surface layer at the surface generated in the form of internal stresses [2].

With sufficient accuracy, one can calculate the amount of heat released in the cutting process with the relationship:

$$(1) \quad Q_{as} = \frac{(F_z \cdot v_{as} + F_x \cdot v_{av})}{E} \cdot \alpha_0 \cdot \tau [kcal]$$

where Q_{as} [kcal] is the amount of heat developed in the time interval, E - the mechanical equivalent of the calorie: $E = 427 \text{ daN} \cdot \text{m} / \text{kcal}$, τ - the time interval in which the cutting heat develops, α_0 - coefficient equal to 0.99 ... 0.995; F_z , F_x - cutting forces; v_{as} , v_{av} - cutting speed.

The heat released during the Q_{as} cutting process is directly proportional to the magnitude of the forces developed in the cutting process, which depends on:

- mechanical properties of the workpiece;
- parameters of the cutting tool;
- cutting speed and feed rate;
- properties of the grinding fluids used during the grinding process.

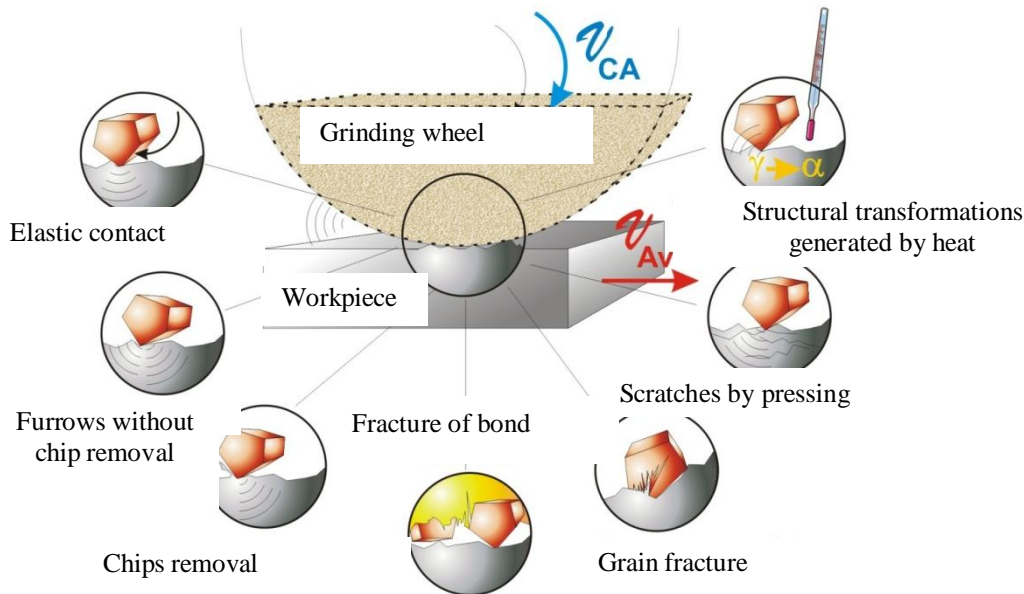


Fig.1 Phenomena that occur in the abrasive tool-workpiece contact area

2. Heat sources for grinding process

Grinding is a machining process with cutting tools with indefinite geometry. Some sources tell that grinding can be assimilated with a disc milling tool, considering that each abrasive grain behaves like a cutter tooth. This model has shortcomings in the fact that the

- If the considered abrasive grain is located at a distance that does not allow it to chip, it crawls on the surface of workpiece, which it deforms elastically or plastically (coulters without chip removal), or scratches it Fig.1), this representing a first source of heat, Q_{el-pl} .

abrasive grains have irregular shapes, rake angle of the grains is highly negative, and consequently grinding chips undergo much larger deformation than in other cutting processes.

Thus, in the case of grinding, the heat sources during the cutting process must be re-evaluated.

Next we will consider the simplifying case in which an elementary abrasive grain comes into contact with the material to be processed.

- In turn, the abrasive granule that does not detach the chips is subject to effort after contact with the workpiece. The bond can break, the abrasive grain can fracture, or it can be stuffed into the bond, which is a new heat source, Q_{detCA} - the heat released when the abrasive body is worn.

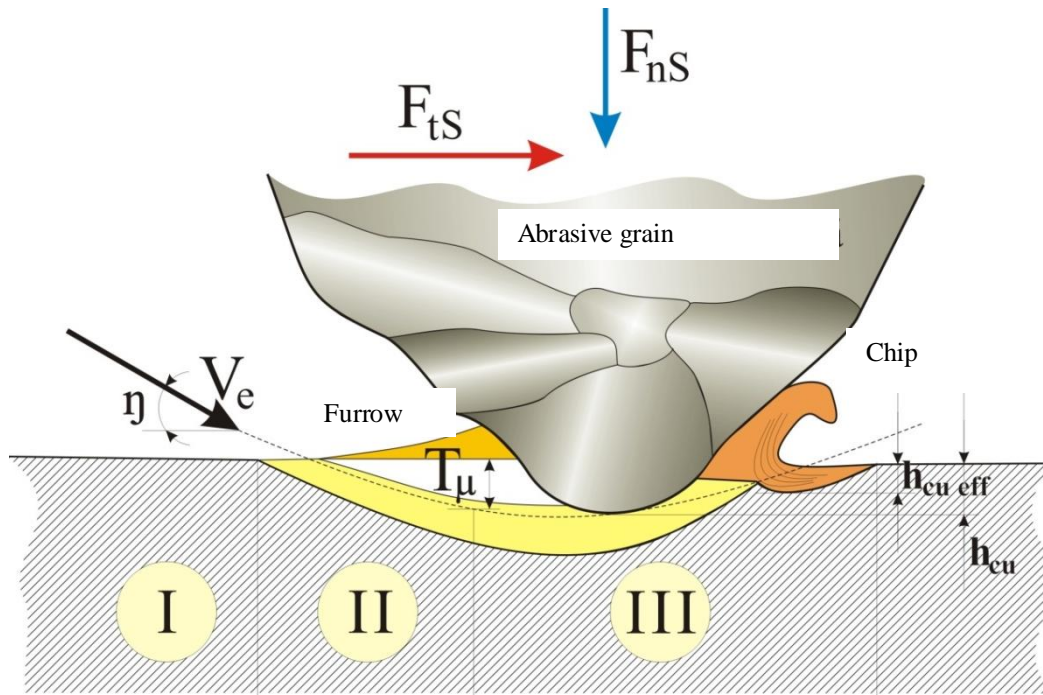


Fig.2 Chip removal during grinding process

During the grinding process at the abrasive grain-part contact area (Fig.2), 3 zones are distinguished, each representing a heat source.

Q_{zoneI} , the heat produced in zone I, zone of elastic deformation, in which the friction between the abrasive grain and workpiece takes place.

Q_{zoneII} , the heat developed in zone II, of elastic and plastic deformation, in which there is friction between the abrasive grain and the part but in which there are also internal frictions in the material of the part.

$Q_{zoneIII}$, the heat produced in zone III, in which the chip removal takes place.

When the chip is removed from the workpiece, the heat is generated by the cutting action from the next sources (Fig.3):

- shearing the cutting layer (Q_{ff});
- friction between abrasive grain and chip (Q_y);
- friction between abrasive grain and workpiece (Q_a);
- mechanical effort spent on chip removal (Q_{det});
- mechanical work from inside of chip (Q_{intas});

Due to the random position of the abrasive grains in the wheel abrasive body, at any time are non-cutting grains and grains that are cut or preparing to cut (zones I and II).

It can be stated that the sum of the heat released by the abrasive granules that cut and those that do not cut represents the total amount of heat released during grinding.

$$(2) \quad Q_{as} = \sum Q_{GA nu asch} + \sum Q_{GA asch}$$

$$(3) \quad \sum Q_{GA nu asch} = \sum Q_{el-pl} + \sum Q_{det CA}$$

$$(4) \quad \sum Q_{GA asch} = \sum Q_{zonal} + \sum Q_{zonalII} + \sum Q_{zonalIII}$$

$$(5) \quad \sum Q_{GA asch} = \sum Q_{zonal} + \sum Q_{zonalII} + \sum Q_{ff} + \sum Q_y + \sum Q_a + \sum Q_{det} + \sum Q_{intas}$$

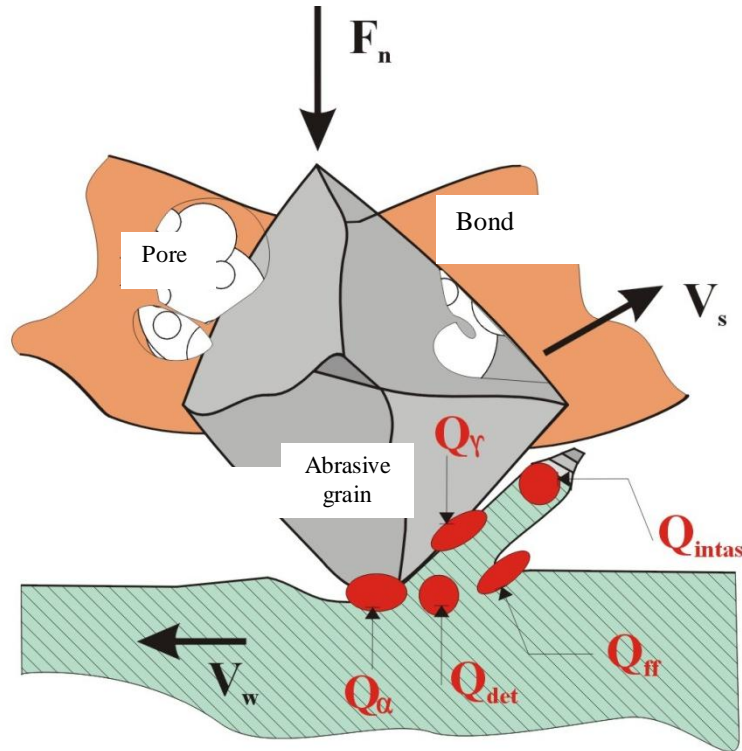


Fig.3 Heat sources when the chip is removed

where $Q_{GAnuasch}$ is the heat produced by a non-cutting abrasive grain, Q_{GAasch} - heat produced by an abrasive grain, Q_{el-pl} - heat released during the elastic-plastic deformation of the part by an abrasive grain that does not cut, Q_{detCA} - heat released during fracture of abrasive grains and bond, Q_{zonalI} - heat released in zone I, in which the elastic deformation of the material by an abrasive grain that cut, $Q_{zonalII}$ - heat released in zone II, in which the plastic

deformation of the material by an abrasive grain that cut, Q_{ff} - heat released during friction process, Q_v - heat released on the rake angle, Q_α - heat released on the relief angle, Q_{det} - heat released when the chip is removed from the part material, Q_{intas} - heat released by friction inside the chip.

3. Heat distribution in the chip, part, cutting tool and cutting fluid

The heat developed in the grinding process is propagated from the source to the nearest colder areas, being distributed in the cutting fluid, the chip, the cutting tool and the workpiece [5].

We will mark with Q_{LA} the heat taken up by the cutting fluid, Q_{piesa} the heat taken up by the part, Q_{CA} the heat taken up by the abrasive wheel, Q_{aschie} the heat taken up by the chip.

- Q_{LA} represents the heat taken up by the cutting fluid from Q_{el-pl} , Q_{uzCA} , Q_{zonalI} , $Q_{zonalII}$, Q_γ , Q_α , Q_{intas} .
- Q_{piesa} represents the heat taken over by the piece from Q_{el-pl} , Q_{zonalI} , $Q_{zonalII}$, Q_{ff} , Q_γ , Q_α , Q_{det} ;
- Q_{GA} represents the heat taken over by the abrasive grain from Q_{el-pl} , Q_{uzCA} , Q_{zonalI} , $Q_{zonalII}$, Q_γ , Q_α ;
- Q_{aschie} represents the heat taken up by the chip from Q_{ff} , Q_γ , Q_{det} and Q_{intas} .

The $Q_{zonalIII}$ heat is distributed in the part, the grinding wheel, the chip and the grinding fluid (Fig.4). It should be noted that if some of the heat from the process is initially taken up by the workpiece, the cutting tool or the chip, after a period of time, this heat also reaches the cutting fluid.

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- Q_{LA} represents the heat taken up by the cutting fluid from Q_{el-pl} , Q_{uzCA} , Q_{zonalI} , $Q_{zonalII}$, Q_γ , Q_α , Q_{intas} .
- Q_{piesa} represents the heat taken over by the piece from Q_{el-pl} , Q_{zonalI} , $Q_{zonalII}$, Q_{ff} , Q_γ , Q_α , Q_{det} ;
- Q_{GA} represents the heat taken over by the abrasive grain from Q_{el-pl} , Q_{uzCA} , Q_{zonalI} , $Q_{zonalII}$, Q_γ , Q_α ;
- Q_{aschie} represents the heat taken up by the chip from Q_{ff} , Q_γ , Q_{det} and Q_{intas} .

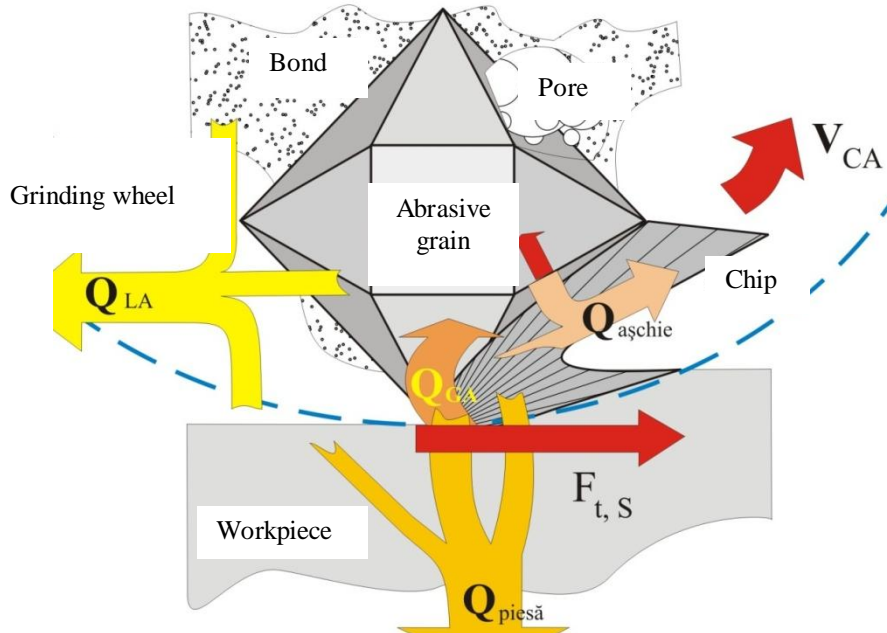


Fig.4 Thermal flux propagation directions, zone III

The general equation of the thermal balance at grinding is (6):

$$(6) \quad Q_{as} = Q_{piesa} + Q_{CA} + Q_{LA} + Q_{aschie}$$

where Q_{aschie} is the amount of heat taken up by the chip, Q_{piesa} - the amount of heat taken up by the piece, Q_{LA} - the amount of heat taken up by the grinding wheel, Q_{CA} - the amount of heat taken up by the grinding fluid.

From (5) and (6) we obtain the relation (7) which represents the equation of the thermal balance at grinding:

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$$(7) \quad Q_{as} = \sum Q_{el-pl} + \sum Q_{detCA} + \sum Q_{zonal} + \sum Q_{zonalII} + \sum Q_{zonalIII} = Q_{piesa} + Q_{LA} + Q_{CA} + Q_{aschie}$$

The analysis of relation (7) shows that the main ways of action in order to reduce the heat absorbed by the part and the abrasive body are: reducing the total amount of heat released and increasing the amount of heat taken up by the chip and the grinding fluid.

It is considered that the distribution of the heat developed during grinding process is done in the following proportions: $Q_{piesa} = 25-80\%$; $Q_{aschie} = 5-40\%$; $Q_{LA} = 5-50\%$; $Q_{CA} = 2-5\%$ [7].

4. Conclusions

1. There is a consensus of specialists that mechanical work is almost entirely transformed into heat.
2. The heat released in the grinding process increases with the increasing of cutting speeds.
3. Due to the uneven arrangement of the grains at the periphery of the abrasive wheel, not all grains participate in cutting, but also grains that do not participate in cutting process contribute to heat release by rubbing on the surfaces of the workpiece, by congestion in the bond and fracture of the abrasive grains.
4. Starting from these changes of the heat distribution, the heat sources for grinding process were re-evaluated and the equation of the thermal balance was reformulated.

5. References

- [1] Awiszus, B., Matthes, K.-J., Duerr, H., Bast, J. –Grundlagen der Fertigungstechnik, Seiten 125-130, EdituraHanser, 2006.
- [2] Bock, R. –Vorlesung Fertigungstechnik, Zeitspannvolumen, 2006.
- [3] Bushan, B. –Modern Tribology Handbook, Volumes I and II, CRC Press LLC, 2005.
- [4] Caglar M., Evans, R. –Grinding fluid performance and characterization of wheel wear in grinding using electroplated CBN wheels, in Abrasive Magazine, August/ September, 2002, Pages 8-14.
- [5] Duwell, E.J., Cosmano, R.J., Abrahamson, G. R. –Influence of chemically active water base grinding fluids on the dynamics of grinding at North American Manufacturing Research Conference Proceedings, May 19-22, 1985, pages 334- 340.
- [6] Ganesan, M., Malkin, S. –Analysis of hydrodynamic forces in grinding, in Abrasives Magazine, October/ December 2001, pages 6- 12.
- [7] Kruszynski, B., Togo, S., Wojcik, R. –Surface layer in cylindrical grinding, in International Journal for Manufacturing Science and Technology, vol. 7, No.1, pages 43-47.