ISSN 1509-5878
Nr 5
5/2011
AUTOBUSY
Technika, Eksploatacja, Systemy Transportowe

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SIMULATION OF THE PROCESS OF MACHINING WITH SINGLE ABRASIVE GRAIN IN THE ASPECT OF THE QUALITY OF SURFACE LAYER OF ENGINE PARTS

Abstract

In this paper the grinding process with single abrasive grain was developed. The effect of grinding process on the quality of the surface layer of engine parts was shown. Grinding process was conducted in ANSYS/LS-DYNA using the finite element method. Intensity of deformation maps at any time during the process time were obtained. Selected results of numerical analysis for the process of single abrasive grain grinding were presented.

ADMISSION

Grinding is a process based on removal of layer of the workpiece material by the tool. Its purpose is to receive the desired shape and dimensions of workpiece and surface layer properties. Abrasive machining is a kind of grinding where abrasive grains are used as machining cutting tools. Abrasive tools are most commonly used for surface treatment of engines and machine parts such as blocks, shafts, valves, valve seats, crankshafts, camshafts, holes in the block into the main pan (alignment), because the working surfaces of these elements after a long exploitation may be subjected to material consumption.

Abrasive material should have:
– resistance to abrasion,
– high hardness and bending strength and compressive strength,
– good cleavage and high thermal conductivity,
– resistance to high temperature.

The abrasive grain should have these properties because of the physical phenomena occurring during grinding process (fig. 1).

During the penetration of the abrasive grain in to the material, increasing strength and stresses cause the plastic deformations of material near to the contact surfaces of all grains in the material. It causes furrows, side fins, and swelling of the material in front of contact surface. Mechanical energy supplied to abrasive grain influence zone is used to overpower the forces of friction, swelling, crushing, shearing and machining of the workpiece material.

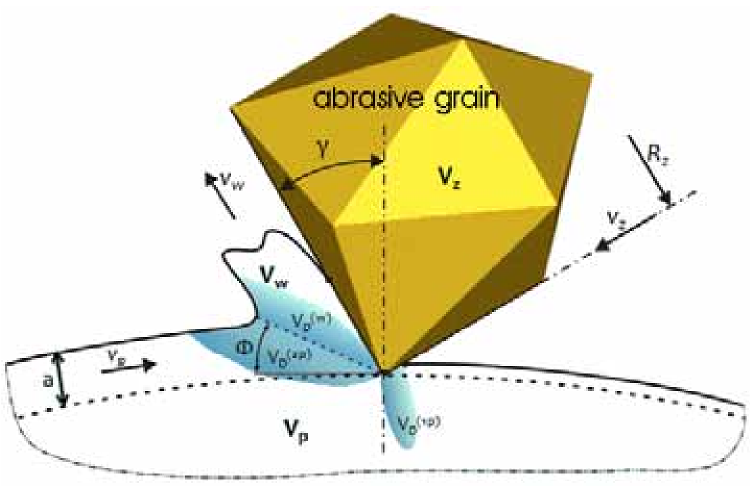

Fig. 1. Physical phenomena occurring during the cutting process
Source: own study.

Long-term researches performed by renowned companies confirmed that the durability and reliability of the machine can be increased, if the working area of one or more of the parts constituting the friction pairs have flat topped outline (fig. 2), so called „outline of the plateau". This outline is created by flattened tops inequalities separated by tips clearance.

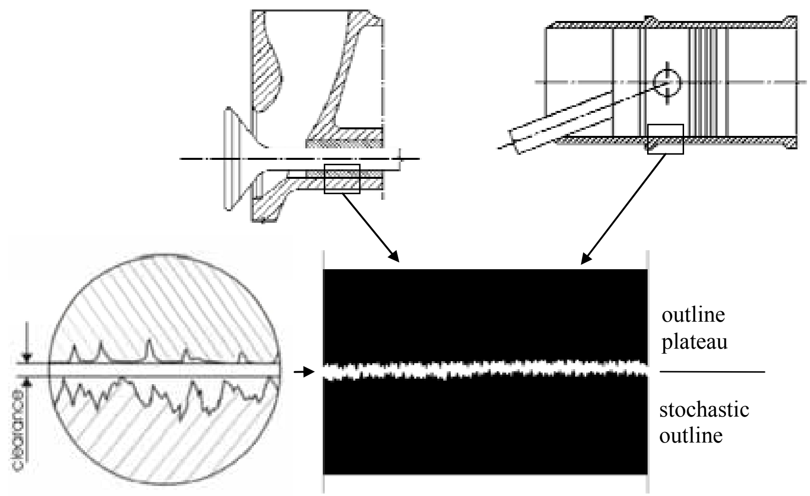

Fig. 2. Cutting pairs examples, required a special prepare of surface: valve-fence, piston-cylinder
Source: own study.

In grinding process the selection of technological parameters such as type of abrasive grains, machining speed, abrasive grain penetration is very important. Its affect the surface layer quality and the shape of the inequalities created by machining. Abrasive machining process is very complex but it can be simplified considering the single abrasive grain grinding example.

1. SIMULATION RESEARCH

Grinding process is strongly nonlinear boundary – initial problem with an unknown boundary conditions in the contact area of object surface and abrasive grain. Strong nonlinearity and ignorance of the boundary conditions in the contact area can be solved numerically using FEM (finite element method). Numerical simulations of grinding process with single abrasive grain were performed in Ansys/Ls-Dyna. In the numerical analysis the influence of machining speed on surface roughness of machine parts was examinated. The object surface layer had following dimensions (length of the sample l = 8 mm, thickness layer of cut g = 0,065 mm, cutting speed v = 160 ÷ 260 $m \cdot s^{-1}$). The object was divided by finite elements PLANE 164 type. The mesh has been concentrated in the area of contact between grain and object (fig. 3).

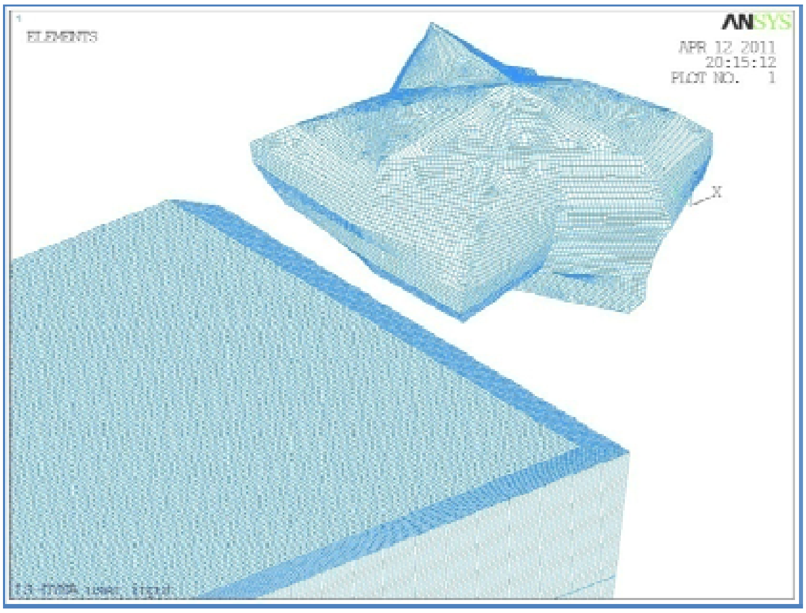

Fig. 3. Discreet model of the object
Source: own study.

In simulations it was assumed that the grain is perfect rigid body. Object surface layer was treated as elasto/visco-plastic body, using Cowper-Symonds'a material model, which mathematical form is:

$$\sigma_Y = (R_e + \beta \cdot E_{\tan} \cdot \varphi_i^{(p)})[1 + (\dot{\varphi}_i^{(p)} / C)]^m$$

where:
σ_Y – yeld stress [MPa],
R_e – initial limit of plasticity [MPa],
$\varphi_i^{(p)}$ [–], $\dot{\varphi}_i^{(p)}$ [s^{-1}] – the intensity of true strain and true strain rate, respectively
C [s^{-1}] – material parameter specifying the effect of the intensity of plastic of strain rate,
$m = 1 \cdot P^{-1}$ – material constant defining sensitivity of the material on speed of plastic deformation,
$E_{\tan} = E_T \cdot E \cdot (E - E_T)^{-1}$ – material parameter dependent on the strengthening of the module $E_T = \partial\sigma_Y \cdot (\partial\varphi_i^{(P)})^{-1}$ and Young's module E,
β – the parameter of plastic strain hardening, linear-isotropic (β = 1), kinematic (β = 0) or mixed (0< β <1) plastic strain hardening.

The density of the object material was ρ = 7830 $kg \cdot m^{-3}$, Young modulus E = 207 GPa, Poisson's ratio ν = 0.27, the initial yield stress R_e = 310 MPa, the work – hardening coefficient E_T = 763 MPa, the material parameter defining the effect of the intensity of plastic strain rate C = 40 s^{-1}, material constant defining sensitivity of the material on the speed of plastic strain rate P=5, failure strain ε_f = 1.

2. RESULTS OF NUMERICAL ANALISYS

The process of grinding is very important in the treatment of engines (fig. 4) and machine parts. Component parts have to be folded together well, because any inequality will cause damage of element. The numerical simulation researches of the grinding process with a single abrasive grain using Ansys/LS-Dyna computer program were mad. The range of input variables was: machining speed 60 ÷ 260 $m \cdot s^{-1}$ and the penetration of the abrasive grain 0,05÷1 mm. The influence of those variables on to the height of irregularity was tested. The physical properties of grain and material surface layer were constant in all cases. To show shape of surface formed during grinding in all simulations the screenshots for 40 step were made.

a) b)

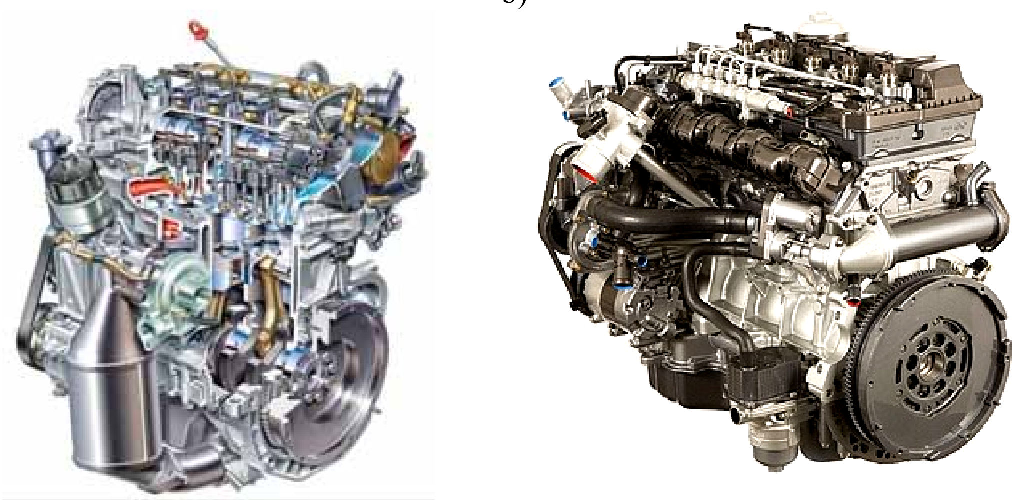

Fig. 4. Engines: a) diesel, b) combustion
Source: a) http://www.drewnozamiastbenzyny.pl/silnik-diesla/, b) http://www.4x4-shop.com/?silnik,84

The figures 5÷8 shows that grinding speed is related to the stresses and plastic strains occurring in the surface layer of the object. Increasing of the process speed is reducing the plastic properties of the material and also increasing its elastic properties. Irregularity occurring on the surface also depends of the abrasive grain geometry. At conventional grinding speed the irregularity on the surface of the material are much higher and are in the form of surface cracks, burrs or spalling of the material. Moreover with increasing of grinding speed the height of irregularity is decreasing.

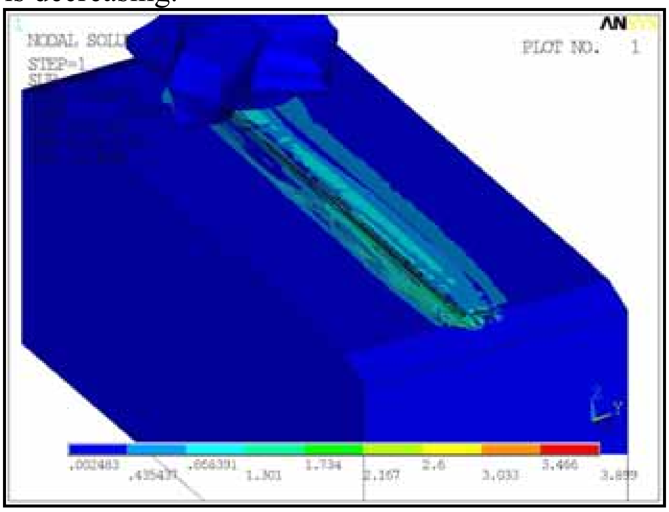

Fig. 5. Map of intensity stress σ_i [GPa] during process of tensions the cutting in surface layer of material
Source: own study.

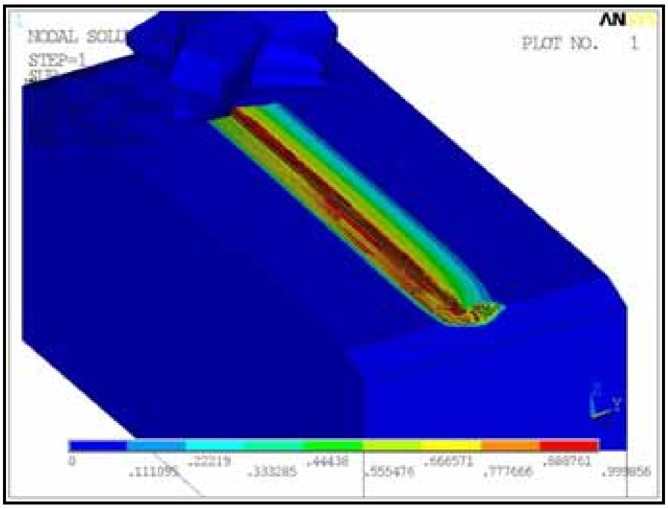

Fig. 6. Map of intensity plastic true strain during process of tensions the cutting in surface layer of material

Source: own study.

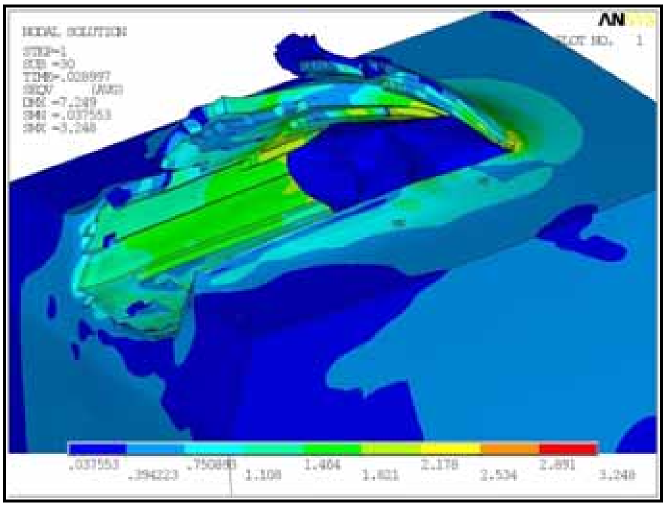

Fig. 7. Map of intensity stress σ_i [GPa] during process of tensions the cutting in surface layer of material

Source: own study.

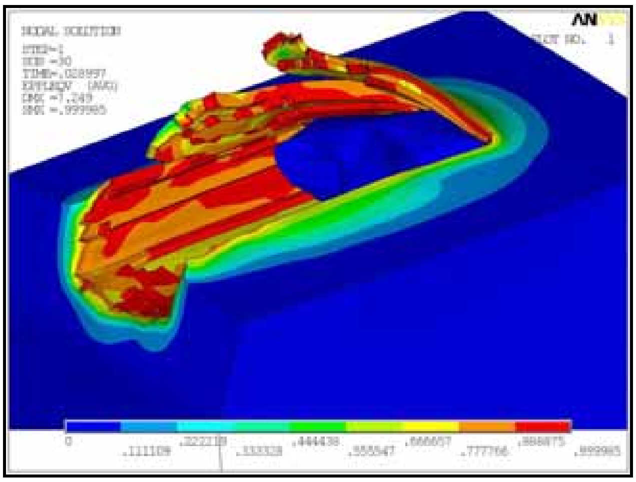

Fig. 8. Map of intensity plastic strain during process of tensions the cutting in top layer of material

Source: own study.

CONCLUSIONS

1. The simulations shows that the size of the abrasive grain, grinding penetration and grinding speed have got a significant influence on the quality of the surface layer during the grinding.
2. Reduction of irregularities occurring on the surface of the material can be obtained by the increasing the grinding speed.
3. The grinding speed with single abrasive grain significant impacts on plastic properties of the workpiece material. Increase of the speed causes a reduction of plastic properties and increase the impact of elasticity of material. Real surface asperities created after passing of the grain are larger than theoretical because of material elastic properties.
4. Using of high speeds machining will allow to reduce the irregularities created on the surface.

REFERENCES

1. Kaczmarek J.: *Podstawy obróbki wiórowej, ściernej i erozyjnej*, WNT, Warszawa 1970.
2. Kruszyński B.: *Wpływ obróbki na własności warstwy wierzchniej*, Przegląd Mechaniczny, 1994.
3. Miracki J.: *Poradnik Szlifierza*, WNT, 1973.
4. Oczoś K.E., Lubimow W.: *Nowe aspekty trójwymiarowej (3D) analizy chropowatości powierzchni obrobionej*, Mechanik, 1998.
5. Plichta S.: *Zmiany struktury warstwy wierzchniej przedmiotu podczas szlifowania*, XIII Naukowa Szkoła Obróbki Ściernej, Warszawa 1990.
6. Stępień P.: *Podstawy kształtowania regularnej struktury geometrycznej powierzchni w procesach szlifowania*, Monografia Wydziału Mechanicznego, Nr 125, Wydawnictwo Uczelniane Politechniki Koszalińskiej, Koszalin 2006.
7. Walasik A., Walasik S.: *Konstrukcja specjalnej beztrzpieniowej głowicy osełkowej*, XII Słupskie Forum Motoryzacji, Słupsk 2009.
8. http://skrawanie.nstrefa.pl/parametry_toczenia.php

SYMULACJA PROCESU SKRAWANIA POJEDYNCZYM ZIARNEM ŚCIERNYM W ASPEKCIE JAKOŚCI WARSTWY WIERZCHNIEJ CZĘŚCI SILNIKA

Streszczenie

Praca dotyczy symulacji procesu skrawania pojedynczym ziarnem ściernym. Przedstawiono wpływ procesu skrawania na jakość warstwy wierzchniej części silnika spalinowego. Proces skrawania przeprowadzono w programie Ansys/Ls-Dyna za pomocą metody elementów skończonych. Otrzymano mapy intensywności odkształceń w dowolnej chwili czasowej trwania procesu. Przedstawiono wybrane wyniki analizy numerycznej procesu skrawania pojedynczym ziarnem ściernym.

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