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Test stand for a complex investigation of the cylindrical traverse grinding processes

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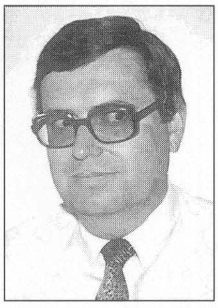

Pracownik naukowo-dydaktyczny Katedry Technik Wytwarzania i Automatyzacji Politechniki Rzeszowskiej. Studia wyższe o specjalności obrabiarki, narzędzia i technologia ogólna budowy maszyn ukończył w 1972 roku na Wydziale Mechanicznym Politechniki Krakowskiej. W tym samym roku podjął pracę w Zakładzie Obróbki Skrawaniem i Obrabiarek Wyższej Szkoły Inżynierskiej w Rzeszowie. Stopień doktora nauk technicznych uzyskał w 1977 roku w Instytucie Technologii Budowy Maszyn Politechniki Wrocławskiej. Obecnie zajmuje się tematyką związaną z budową, sterowaniem i programowaniem obrabiarek sterowanych numerycznie oraz badaniami procesów wytwarzania a w szczególności procesu szlifowania osiowego. Autor wielu publikacji krajowych i zagranicznych.

Abstract

A test stand carried out in the Department of Manufacturing Techniques and Automation, University of Technology, Rzeszow, and designed for the complex investigation of the cylindrical traverse grinding processes, is described in this paper. The modernized RUP 28 grinder with the CNC PRONUM 630T system was used in the process of building the test stand. The RUP 28 grinder is equipped with eight measuring systems, which during grinding measure the components of the grinding forces, the feeds rates and rotational speed of the workpiece, and, after grinding - the worksurface roughness, the shape of the cylindrical surface generating line and the topography of the grinding wheel. Examples of the recorded results of the traverse grinding process are also presented in this paper.

Key words: test stand, complex investigation, measuring systems, traverse grinding.

Streszczenie

W artykule przedstawiono wykonane w Katedrze Technik Wytwarzania i Automatyzacji Politechniki Rzeszowskiej stanowisko badawcze przeznaczone do kompleksowych badań procesów szlifowania osiowego zewnętrznych powierzchni walcowych. Do budowy stanowiska badawczego wykorzystano zmodernizowaną szlifierkę RUP 28 z układem CNC PRONUM 630T. Szlifierka RUP 28 wyposażona jest w osiem układów pomiarowych umożliwiających pomiar składowych siły szlifowania oraz prędkości posuwów i pręd-kości obrotowej przedmiotu - w czasie szlifowania, jak również, chropowatości powierz-chni obrobionej, kształtu tworzącej powierzchni walcowej i topografii ściernicy - po szlifowaniu. W artykule pokazano również przykłady rejestrowanych wyników badań procesu szlifowania osiowego.

Słowa kluczowe: stanowisko badawcze, badania kompleksowe, układy pomiarowe, szlifowanie osiowe zewnętrznych powierzchni walcowych.

1. Introduction

Grinding as one of the methods of abrasive machining has been known for thousands of years [1] and is continually being developed as a result of increasing demands as to the quality and durability of the products made from even more upgraded constructional materials. Grinding of the cylindrical surfaces may be conducted in various ways [1, 2] but its basic grinding actions are (Fig.1) plunge grinding and traverse grinding. The plunge grinding is a process kinematically simpler because the machining of the surface, which has a smaller width, than the width of the wheel is only conducted in one controlled axis (the X-axis). Therefore, the majority of the published papers, both theoretical and empirical, concern this type of grinding. Traverse grinding is a more complex process which is a result of the occurrence of the traverse feed rate v_{fa} and the variable of the system MWT (machine-workpiece-tool) stiffness along the Z-axis - this would explain the relatively small amount of the published papers concerning the research of this type of grinding [3]. However, on the other hand, the traverse grinding is widely applied to the grinding of cylindrical surfaces with the diameters ranging from a few millimeter decimals to few meters and the lengths reaching even a few meters. Therefore, conducting successive research, both empirical and theoretical, whose aim is to explore the traverse grinding more thoroughly is more than justified and it will always be beneficial, especially with regards to more efficient ways of conducting the process of traverse grinding. The investigation of traverse grinding should be carried out on a properly prepared NC grinder because such a machine will provide much better technological possibilities and a greater stability of the adjustable parameters in comparison to conventional machine tool.

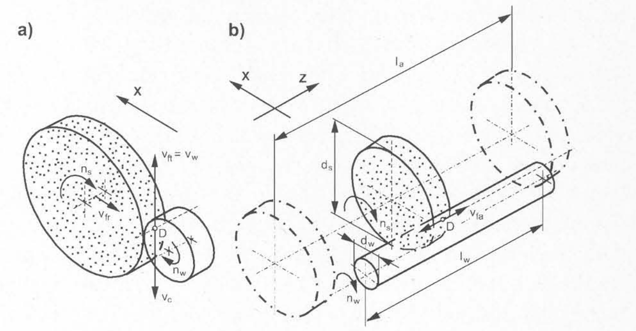

Fig.1. Grinding of the cylindrical surfaces: a) plunge grinding, b) traverse grinding [1, 2]

2. Test stand

In order to conduct a more complex research of the traverse grinding, the test stand was carried out in the Department of Manufacturing Techniques and Automation, University of Technology, Rzeszow - with the use of a modernized grinder RUP 28. In order to control the machine tool, the CNC PRONUM 630T system was applied (the lathe version), which enables the use of its system programme in the cylindrical traverse grinding. Certain constructional changes in the power transmission system of the traverse feed rate and in the drive of the workpiece's spindle [4] were a result of the application of the computer controlling system. The general diagram of the grinder is presented in Fig. 2.

The RUP 28 grinder is designed for the cylindrical traverse

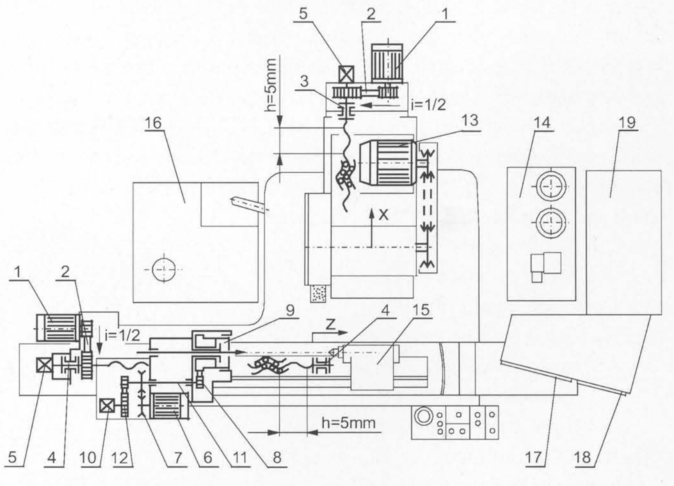

Fig. 2. The diagram of the RUP 28 grinder with the CNC PRONUM 630T system

grinding. The workpieces may be fixed in the grinder centres or in the handle. The grinder is adapted to grind with the speed of 45m/s. The machine tool consists of two controlled axes, the X-axis, along which the movement of the headstock of the grinding wheel occurs, and the Z-axis for the traverse movement of the table, together with the headstock of the workpiece and the tailstock. The feed in both axes is propelled by the direct current servo-mechanism motors 1 with permanent magnets, by the belt toothed gear 2 and by the ball screw. The transmission ratios of the belt toothed gears and the leads of ball screws are identical in both axes. The ball screw of the X-axis is mounted on a bearing on one-side with the help of the radial and axial bearing system 3. In the case of the Z-axis, where the screw is much longer, bearings on both sides were applied, using the same bearing systems 4 with a possibility of straining the screw. The ball screws have double nuts, which allow deleting the axial clearance. Both axes are equipped with rotary encoders 5 propelled directly by the screws. The used encoders, which are the same for both axes, send 2500 impulses per revolution - this connected with the lead of screws h=5mm leads to the resolution of the measurement for both axes as being equal to 0.5 μm. The practical resolution of the axis when cooperating with the CNC system equals 1 μm. The workpiece is propelled by the direct current servo-mechanism motor 6 with permanent magnets, from which the drive is transposed by the gear 7 with the wedge belt, and then by the belt toothed gear 8 onto the catch plate 9. The workpiece's spindle might be still in the case of machining the workpiece fixed in the centres or might be propelled by the catch plate when the workpiece is fixed in the handle. The workpiece's headstock has an encoder 10, which enables the measurement of the angular position of the workpiece. The encoder is propelled by the motion shaft 11 with the help of the belt toothed gear 12. The transmission ratios of the 8 and 12 gears are identical, which makes the transmission ratio between the catch plate or the workpiece's spindle and the encoder equal to 1. Due to that, it is possible to use the software of the CNC system in machining of the screw surfaces on cylinders, cones or frontal surfaces, including the cams with the Archimedes coil design. Moreover, the encoder in the power transmission system of the workpiece together with the software of the CNC system enables the angular positioning of the workpiece. This encoder sends 1024 impulses per revolution - due to that, the resolution of the angular positioning is equal to 1/4096 of a rotation, that is ~5.3'. The grinder has the wheel's drive with a constant rotational speed of the asynchronous motor 13 due to the gear with wedge belts. The spindle of the grinding wheel is on the hydrostatically lubricated bearings supplied by the hydraulic system 14. Both controlled axes have open hydrostatically lubricated slides, which are also supplied by the hydraulic system. Besides, the hydraulic system is applied to supply the spindle of the tailstock 15, as well as additional mechanisms e.g. a device, which actively controls the size of the grinded cylindrical surfaces. System 16, which consists of a container, a pump, a magnetic filter and a system of conduits and valves is used for cooling and lubricating during the grinding. The CNC system 17 and the measuring instrument of the active control 18 are placed on the bracket, which is attached to the board of the electrical system 19. The basic technical data of this machine:

- the grinding wheel -
  - max. diameter 400mm,
  - max. speed 45m/s,
- the workpiece
  - max. diameter 280mm,
  - max. length 500mm,
  - rotational speed 1-500rev/min,
- the range of the feeds 1-5000mm/min.

The diagram of the test stand with the use of the RUP 28 CNC grinder is presented in Fig. 3. The RUP 28 CNC grinder is equipped with eight measuring systems, which during the grinding measure the components of the grinding force, the feeds rates and rotational speed of the workpiece, and, after the grinding - the worksurface roughness, the shape of cylindrical surface generating line and the topography of the wheel. The data from all measuring systems is then, transmitted into the IBM PC with a standard RS 232 connection and an 8-canal DAS 1602 card together with a 12 bit A/C converter. In order to record the results of the measurement, the *Talyprofile* program, produced by Rank Taylor Hobson, has been used for recording the worksurface roughness, while the *Testpoint* program enabled the configuration of the other measuring systems with regards to collecting, filtering and recording the data.

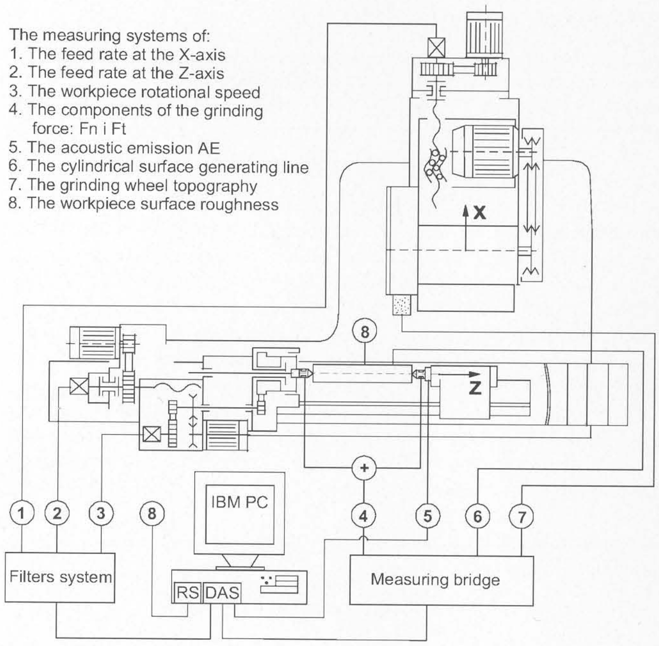

Fig. 3. The test stand diagram

In the measuring systems 1, 2 and 3, which are identical, the measuring signals are obtained from the tachometers (servodrives elements) and transmitted through the lowpass filters into the inputs of the DAS card.

System 4 is used to measure the components of the grinding force: the normal grinding force F_n and the tangential grinding force F_t. Attached to the grinder centres are the semi-conductor strain gauges (produced by Veb Rft) whose signals are transmitted through a 6-canal measuring bridge (produced by Hottinger) to the DAS card.

In order to measure the acoustic emission EA (measuring system 5) the 8152 A1 probe (produced by Kistler) of a frequency of 50-400 kHz has been installed on the tailstock centre.

The GT 21 inductive probes (produced by Tesa) with the chisel endings made of sintered carbides, were used in the measuring systems 6 and 7. In order to record the topography of the grinding wheel, the probe is installed at the grinder's table, after the workpiece has been removed. The inductive probe that records the shape of the cylindrical surface generating line is installed in the device on the wheel's headstock. Moreover, the radial grinding wheel wear is defined by recording of the replica profile of the active grinder's surface, gained by grinding a thin metal strip. The recording is carried out with the use of measuring system 6.

The worksurface roughness is measured by a Surtronic 3+ device (produced by the Rank Taylor Hobson), which is connected with an IBM PC by the RS 232 (measuring system 8). The Surtronic 3+ device is installed in the same device on the wheel's headstock as the probe of the measuring system 6.

3. Examples of the recorded investigation results

3.1. Grinding wheel wear

The character of the form and the course of the grinding wheel wear in the traverse grinding process is very much different from that of the plunge grinding. The grinding wheel wear in this process occurs in the step (sectional) - way, with the width of the step (section) being equal to the value of the feed per revolution of the workpiece. It is a result of the occurrence of the traverse feed rate, either one-directional or two-directional (pendulum). The grinding wheel wear can be defined basing on the recorded topography of the grinding wheel (Fig.4) with the help of measuring systems 6 and 7 (Fig.3) with the chisel endings and the top angle of 50° and the radius of the curve ~0.04 mm and the length of 6mm.

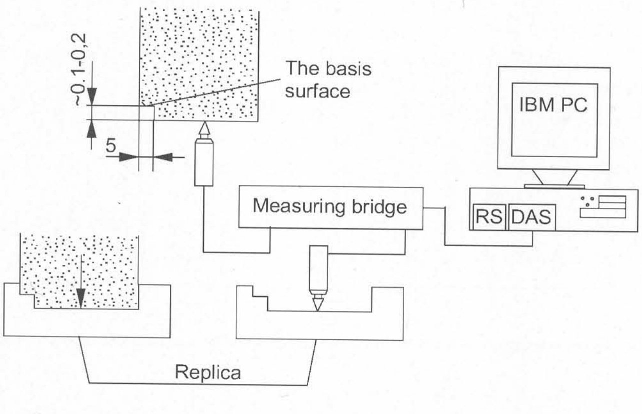

Fig.4. The diagram of the measurement grinding wheel topography

The typical course of the outline of the active grinding wheel surface recorded during the measurement by using the measurement system 7 (Fig.3), is presented in Fig.5. The x-axis represents the width of the wheel (in mm) and the y-axis - the radial grinding wheel wear in μm. During the tests, it was concluded that the direct measurement of the topography is more reliable than the measurement of the replica (the measuring systems 6 - Fig.3 and 4). The grinding wheel wear at its different steps was defined as an arithmetical average of the height of the grain tops with regards to the basis surface of the wheel (Fig.4) which did not participate in the grinding.

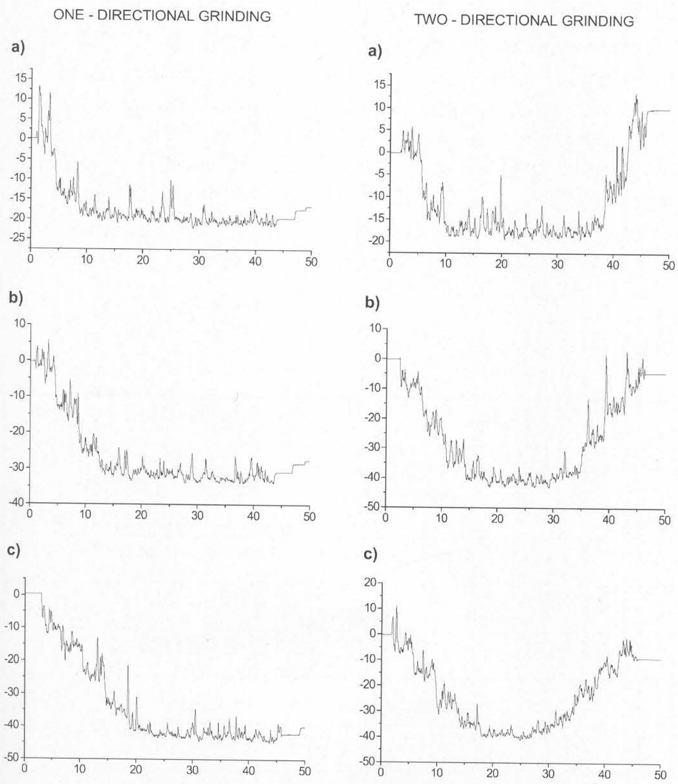

Fig.5. The radial grinding wheel wear in the cylindrical traverse grinding for the depth of cut 40μm and the time of the grinding: a) 0.9 min b) 2.7 min c) 3.6

3.2. Components of the grinding force

The basic meaning in the analysis of the grinding processes is attributed to the components of the grinding force, which highly influence various quantities characteristic for this type of processing. The possibility of defining the components of the grinding force analytically (according to the dependence received on the basis of empirical research) allows to estimate the course of machining at the stage of its designing, which in turn enables to define the correct parameters of the grinding process.

Fig.6 contains examples of the courses of the components of the grinding force: the normal F_n and the tangential F_t measured with the measuring system 4 and the signal of the acoustic emission AE from the measuring system 5 (Fig.3).

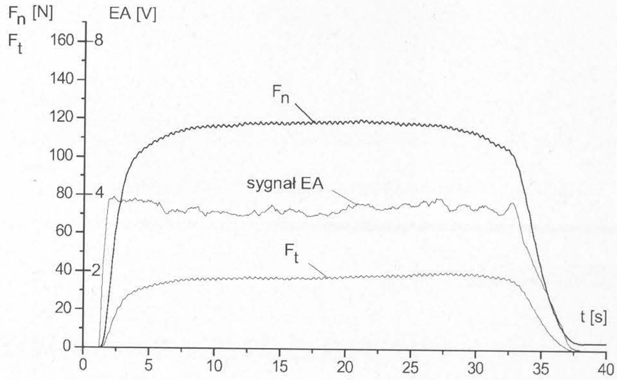

Fig.6. Components of the grinding force

3.3. Cylindrical surface generating line

Grinding is a part of the finish machining, therefore, the precision of the workpieces is one of the distinguishing features

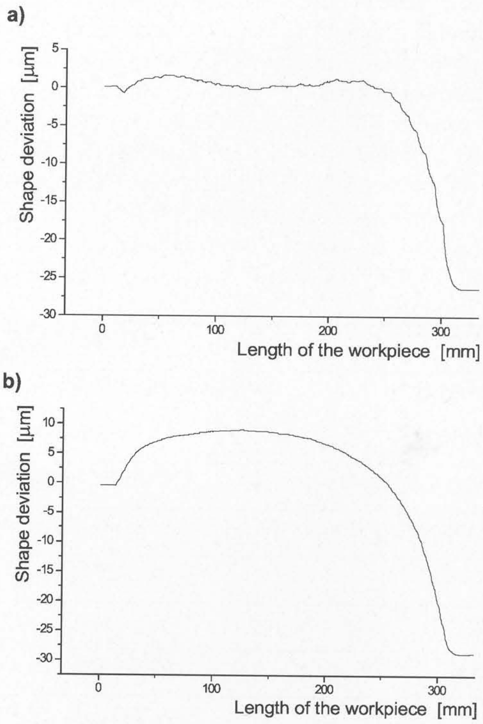

Fig.7. Examples of shapes of the machined cylindrical surfaces generating lines: a) workpiece with great stiffness b) workpiece with little stiffness

defining the efficiency of this process. The deviations of the shape of the machined surface, including the shape of the cylindrical surface generating line, are a clear evidence of the precision. With the help of the measuring system 6 (Fig.3) the shape of this line can be recorded just after grinding.

Fig.7a presents a typical shape of the cylindrical surface generating line, gained after grinding with a complete coasting of the grinding wheel out of the workpiece with a great stiffness, and Fig.7b presents the shape of the generating line of the workpiece with little stiffness.

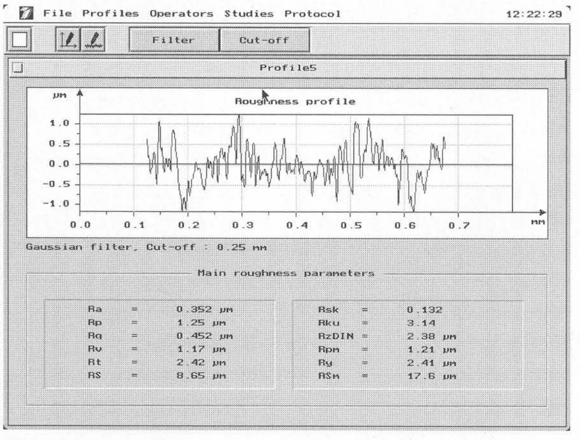

Fig.8. The profile of the worksurface roughness and its main parameters

3.4. Worksurface roughness

The measuring system 8 (Fig.3), which can measure the worksurface roughness allows not only the registration of the profilogram but also enables recording on a disk of a PC computer parameters characterizing the measured roughness. The data are presented in Fig.8.

4. Conclusion

The described test stand, thanks to its measuring possibilities, enables complex research on cylindrical traverse grinding. Using in the investigation NC machine tool provides more stable conditions of grinding in comparison to the conventional machine tool, which in turn causes the greater recurrence of the research results.

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Tytuł: Stanowisko badawcze do kompleksowych badań procesów szlifowania osiowego zewnętrznych powierzchni walcowych

Artykuł recenzowany

INFORMACJE

Firma National Instruments przedstawia nowy Compact Vision System

System NI CVS-1455 posiada czterokrotnie większą pamięć w stosunku do zaprezentowanego w lipcu 2003 System Compact Vision NI CVS-1454.

Zapewniając wydajność na poziomie 1,436 miliona instrukcji na sekundę (MIPS), System NI CVS-1455 zapewnia ponad trzykrotnie większą moc obliczeniową niż typowe inteligentne kamery. To powoduje przyspieszenie nadzorowania wizji dając inżynierom możliwość budowania aplikacji obsługujących wiele kamer, bez konieczności zapewniania im osobnych procesorów. Inżynierowie mogą wybierać z pośród 50 kamer kompatybilnych z IEEE 1394. System zawiera również 128 MB nieulotnej pamięci Flash - 8 razy więcej niż w typowych inteligentnych kamerach, więc inżynierowie mogą zapisać więcej obrazów do późniejszej kontroli i analizy. Dodatkowo NI CVS-1455 zawiera 29 cyfrowych linii I/O do kontroli komunikacji z modułami PLC, przekaźnikami, modułami Compact FieldPoint oraz innymi urządzeniami automatyki przemysłowej.

Inżynierowie mogą tworzyć swoje aplikacje do NI CVS-1455 używając albo NI Vision Builder do automatycznej kontroli albo NI LabVIEW - graficznego środowiska programowania. Vision Builder oferuje intuicyjny interfejs - wskaż i kliknij - do szybkiego tworzenia aplikacji. Dla bardzo złożonych i wyrafinowanych aplikacji, LabVIEW dostarcza otwarte i w pełni wyposażone środowisko programowania. Kod LabVIEW generowany w Vision Builder umożliwia programistom łatwe przeniesienie swoich aplikacji do środowiska LabVIEW.

*MIPS: milion operacji na sekundę

	NI CVS-1455	**NI CVS-1454**	**typowa inteligentna kamera**
oprogramowanie konfiguracyjne	Vision Builder for Automated Inspection	Vision Builder for Automated Inspection	dostępne
programowalny system	LabVIEW Real-Time	LabVIEW Real-Time	nie dostępny
typowa wydajność procesora	1436 MIPS*	883 MIPS*	60-360 MIPS*
linie cyfrowe I/O	29 DIO	29 DIO	2-20 DIO
liczba kamer	do 3	do 3	1
rozdzielczość	do 2,000 x 2,000	do 2,000 x 2,000	640x480
liczba klatek	do 100 fps	do 100 fps	30 fps
wielkość pamięci	128 MB	32MB	4-16 MB