Journal of Industrial Technology 17 (1), 2008, 73-80

EVALUATION OF DIFFERENT CUTTING TOOLS WHEN MILLING VANADIS 10

[1]*Habeeb Hattab Al-Ani*. [2]Bashir Mohamad, [2]Kumaran Kadirgama, [3]Khaled Abou El- Hossein

College of Engineering
Universiti Tenaga Nasional
(1-2)Km7, Jalan Kajang-Puchong, 43009, Kajang, Selangor Darul Ehsan, MALAYSIA

(3)Mechanical Engineering, Curtin University of Technology, Miri, Sarawak, MALAYSIA

(*Habeeb@uniten.edu.my)

RINGKASAN : *Artikel ini menerangkan kesan kekerasan logam kerja, kadar pemotongan, kelajuan pemotongan dan kedalaman axial terhadap jangka hayat pemotong dan kekasaran permukaan logam semasa pemesinan Vanadis 10 dengan menggunakan mata pemotong Kennametal KC850 dan K313. Logam Vanadis 10 biasanya digunakan di dalam kilang membuat die dan mould. Methodology sambutan permukaan telah digunakan dalam menjalankan eksperimen. Keputusan jangka hayat dan kekasaran permukaan amat memuaskan. Kekerasan logam kerja dan faktor-faktor lain memainkan peranan yang penting dalam menghasilkan keputusan eksperimen.*

ABSTRACT : This paper describes a study on the effects of work piece hardness, feed rate, cutting speed, and axial depth on the output parameters of tool life and surface roughness finishing when machining raw material of Vanadis 10 using KC850 and K313 Kennametal inserts. The Vanadis 10 is widely applied in manufacturing of dies and moulds especially in applications where tooling made from cemented carbide tends to chip off or crack. Statistical analysis method utilizing response surface methodology (RSM) is applied and shows that the effects on tool life and surface finish roughness are statistically significant. The workpiece hardness and other factors played significant roles.

KEYWORDS : Workpiece, surface roughness, hardening, Vanadis 10, response surface methodology

INTRODUCTION

In manufacturing of dies and moulds, many different cutting tools are involved from deep hole drills to the smallest ball nose end mills. The selection of a die and mould material is often made at the design stage in order to have the material ready to be machined when the design is completed. This is not always a simple task. In many cases, the choice of the material grade is a compromise between the wishes of the mould maker and the molders (Sandvic Coromant, 2000). Therefore the researchers of die and mould and manufacturing companies are looking forward to improve the aspects of die and mould machining especially in term of cutting tools materials which relate to machining cost and surface roughness finishing. Some studies deal with the performance of cutting tools like Inconel 718 using turning operations (American N. C. M., 2005). Recent study used milling operation in order to carry out the experiment using Vanadis 10 plate.

Machining of raw material for making dies and moulds can be enhanced by the use of advanced cutting tool materials such as KC850 and K313 with improved physical and mechanical properties (Kennametal, 2004).

Recent study also observed and evaluated the performance of cutting tool materials when machining Vanadis 10 in terms of tool life, surface finish roughness as well as wear mechanisms under various finishing conditions. The tools failed mainly due to the wear on the cutting edges which interacted with work piece. The hardness of the workpiece played a significant role in this failure. High abrasion wear, plastic deformation, and cratering wear were observed on cutting tools especially for KC850. Through observation on the tool wear, factors involved include characteristics of the workpiece; the extremely high abrasive wear resistance, high compressive strength, as well as high hardness create difficulties in machinability and generated high wear values leading to short tool life for cutting tools (Sandvic Coromant. 2000). The cold work tool steel such as Vanadis 10 can be hardened to obtain higher hardness for making cutting tools. As the alloy content and hardness goes up, the machinability goes down. Machining cost needs to be considered as it reached 65% of the total production cost for a die and mould. This meant that machinability is an important factor for economical production of dies and moulds. The relationship between the machining cost and tool life are highly correlative.

METHOD

Machining of Vanadis 10 is carried out using a CNC vertical milling machine with speeds ranging from 800 rpm to 3000 rpm. Workpiece dimensions are 170mm length, 100mm width, and 20mm thickness. One millimeter thickness of the top surface of workpiece was removed prior to actual machining in order to eliminate any surface defects that can adversely affect machining results. Coated carbide KC850 and uncoated carbide K313 inserts were used for machining (American N. C. M. 2005, Kennametal, 2004). The chemical compositions and physical properties of Vanadis 10 are given in Table 1 and Table 2 respectively.

Table 1. Chemical composition of Vanadis 10

C	Cr	Mo	V
2.90%	8.00%	1.50%	9.80%

Table 2. Physical properties of Vanadis 10

Temperature	$20^{\circ}C$	$200^{\circ}C$	$400^{\circ}C$
Density kg/m3	7400	–	–
Modulus of elasticity N/mm2	220 000	210 000	220 000
Coefficient of thermal expansion per $^{\circ}C$ from $20^{\circ}C$	–	10.7x106	11.4x106
Thermal conductivity W/m. $^{\circ}C$	–	20	22
Specific heat J/kg$^{\circ}C$	460	–	–

The following coating layers for insert KC850 are specified by the insert manufacturer :

- TiN (outer layer) : 3.0 micron
- TiCN: 3.5 micron
- Tic (inner layer) : 4.5 micron
- Total 11 micron

In this study, the cutting conditions employed during the end milling of Vanadis 10 are shown in Table 3.

Table 3. Cutting parameters

Speed (m/min)	80, 190, 300
Feed rate (mm/rev.)	0.025 – 0.05
Axial depth (mm)	0.05, 0.1, 0.15
Radial depth (mm)	3.5

Cutting conditions, cutting speeds, feed rate, and axial depth as shown in Table 3 can be applied for finish machining of Vanadis 10 in the manufacturing processes. Cutting forces generated during the machining trials were measured using dynamometer. Tool wear was measured with a microscope connected to a digital readout at a magnification of 5x. Surface roughness was measured using a hand held roughness tester TR200. Statistical method using RMS can assist to obtain and create predicted values for cutting speed, feed rate, and axial depth. The RSM is able to determine and quantify the relationship between the values of one or more measurable response variables and set up a group of experimental factors presumed to affect the responses, in order to find the experimental factors that produce the best value or best set of values of the response. This experiment applied three variable factors of the experimental machining data shown in Table 4. The cutting tools of KC850 and K313 are used and recommended by Montgomery, D. C. (1997) and Khuri *et. al.* (1996).

Table 4. Experimental machining data

C1	C2	C3	C4	C5 (m/min)	C6 (mm/rev)	C7 (mm)
3	1	2	1	80	0.0500	0.10
12	2	2	1	190	0.0500	0.15
14	3	0	1	190	0.0375	0.10
7	4	2	1	80	0.0375	0.15
17	5	0	1	190	0.0375	0.10
2	6	2	1	300	0.0250	0.10
5	7	2	1	80	0.0375	0.05
4	8	2	1	300	0.0500	0.10
11	9	2	1	190	0.0250	0.15
6	10	2	1	300	0.0375	0.05
10	11	2	1	190	0.0500	0.05
13	12	0	1	190	0.0375	0.10
9	13	2	1	190	0.0250	0.05
15	14	0	1	190	0.0375	0.10
1	15	2	1	80	0.0250	0.10
8	16	2	1	300	0.0375	0.15
16	17	0	1	190	0.0375	0.10

[C1 = Standard order, C2 = Run order No., C3 = Stores the point type, C4 = Block No., C5 = Cutting speed m/min, C6 = Feed rate mm/rev, C7 = Axial depth mm].

RESULTS AND DISCUSSION

Figures 1, 2, and 3 described the tool life generated when machining Vanadis 10 with KC850 and K313 tools at various cutting conditions. The K313 uncoated cutting tool produced the best overall performance in terms of tool life whereas, wear crater, plastic deformation and abrasive flank wear compared to KC850 coated cutting tool. The KC850 and K313 have different chemical compositions, physical properties, and percentage of tungsten carbide, cobalt, and hardness of cutting edge of cutting tools. The K313 should theoretically perform better than KC850 because of its higher hardness, higher tungsten carbide and cobalt. Experimental results confirmed the theoretical performance of K313. The KC850 is subjected to machining conditions of cutting speed 300m/min, feed rate 0.05mm/rev., and axial depth 0.1mm. A crater wear, abrasive flank wear, and plastic deformation appeared on cutting edge as shown in Figure 4. This consequently resulted in accelerated short tool life Serope (1995). Tool K313 is subjected to machining conditions of cutting speed 300 m/min, feed rate 0.05mm/rev., and axial depth 0.1mm as shown in Figure 5. Abrasive flank wear, chipping and crater wear were obtained without plastic deformation. The wear observed on tool K313 is the same as for KC850 at the same machining conditions. Tool life decreased rapidly with increasing temperature. This depends on the energy generated per unit time and the cutting speed and hardness of the workpiece material. Therefore when machining of any raw material, cutting speeds and feed rate will automatically decrease with increasing hardness (Kennametal cutting tools, 2004, Schey, 2002, Beitzand & Kuttner, 1994).

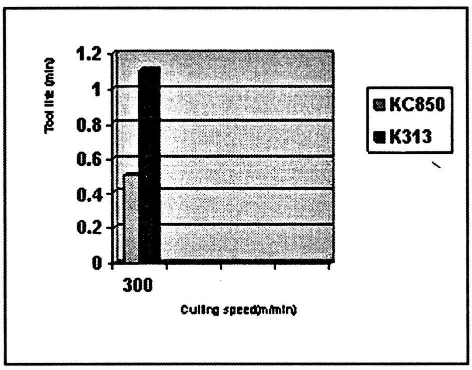

Figure 1. *Lower tool life obtained for K313 when machining Vanadis10 at feed rate 0.05 mm/rev and cutting speed 300m/min*

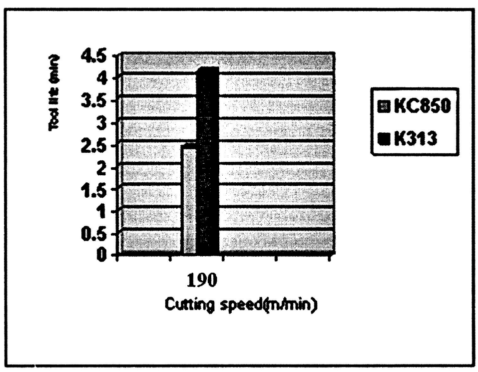

Figure 2. *Moderate tool life obtained for K313 when machining Vanadis10 at feed rate 0.05 mm/rev and cutting speed 190m/min*

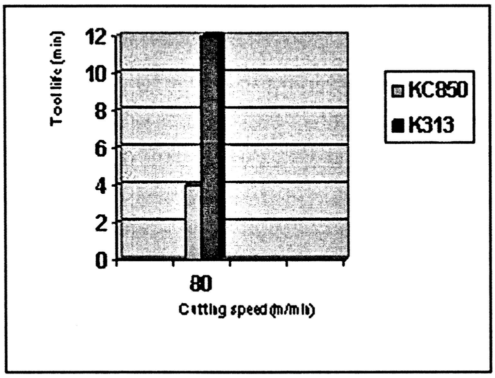

Figure 3. *Higher tool life obtained for K313 when machining Vanadis 10 at feed rate 0.05 mm/rev and cutting speed 80 m/min*

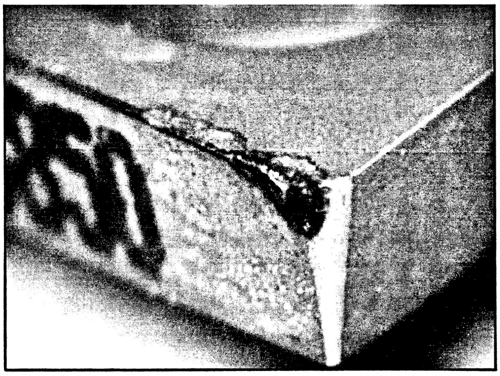

Figure 4. *Wear generated after machining Vanadis 10 with KC850 at feed rate 0.05 mm/rev and cutting speed 300m/min and axial depth 0.1mm*

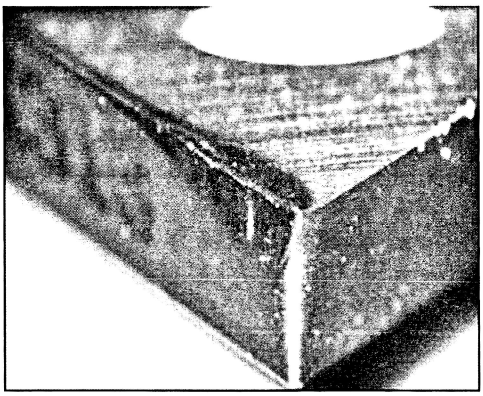

Figure 5. *Wear generated after machining Vanadis 10 with KC313 at feed rate 0.05 mm/rev, cutting speed 300m/min and axial depth 0.1mm*

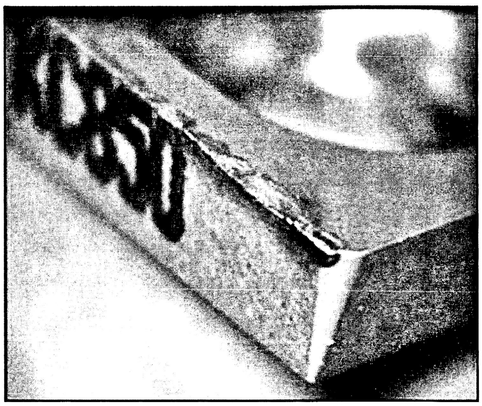

Figure 6. *Wear generated after machining Vanadis 10 with KC850 at feed rate 0.05 mm/rev, cutting speed 80m/min, and axial depth 0.1mm*

The flank wear, plastic deformation, and crater wear for cutting tool as shown in Figures 6 and 7 are similar to the cutting tool in Figures 4 and 5.

In terms of surface roughness, values recorded for all the cutting conditions especially at a speed of 80 m/min for KC850 and K313 tools shows there is a large variation between these tools as shown in Figure 8. The large variation is because the type of cutting tools and cutting depth played a significant role to generate this variation.

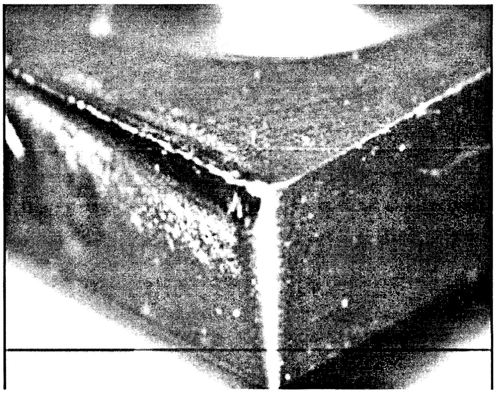

Figure 7. *Wear generated after machining Vanadis 10 with K313 tool at cutting speed 80m/min, feed rate 0.05mm/rev, and axial depth 0.1mm*

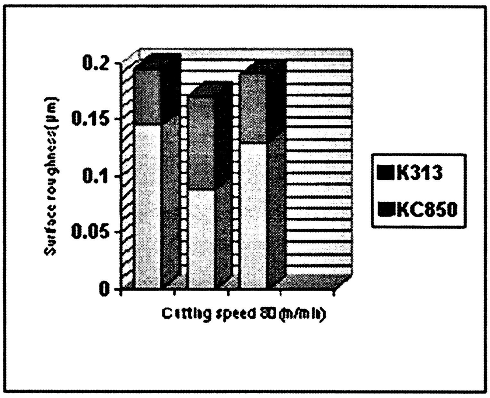

Figure 8. *Surface recorded when machining at cutting speed 80m/min.*

CONCLUSIONS

The K313 tool gives better performance in terms of tool life and surface roughness compared to KC850 tool. The higher wear rate appeared when machining Vanadis 10 with KC850. The life of K313 and KC850 tools is significantly increased at lower cutting speeds. Increase in cutting speed generally led to increase in wear rate. Surface roughness increased when machining Vanadis 10 using K313 compared to KC850.

ACKNOWLEDGEMENT

The research grant (IRPA: 003-99-03-0041-EA001) from MOSTI, used to carry out the work reported in this paper is gratefully acknowledged.

REFERENCES

American National Carbide Milling, Drilling and Boring Inserts Catalog and Technical Information, USA. (2005).

Beitzand, W. K., Kuttner H (1994) HB. mechanical engineering. Springer-verllag London limited.

Kennametal cutting tools- Catalog. (2004).

Khuri, *et. al,* (1996). Response surfaces, University of Florida, Markel Dekker, Inc, New York. (1996).

Monlgomery, D. C. (1997). Design and Analysis of Experiments, John Wiley and Sons, Inc. USA.

Sandvic Coromant, Die and Mould introduction, Sweden (2000).

Schey, J. A. (2002). Introduction to manufacturing processes, MC Graw-Hill, USA.

Serope K. (1995) Manufacturing engineering and technology, Wesley publishing company, Inc. USA.