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A Comparison of Tool Life of Two Coated Carbide Inserts Under Identical Conditions and at Different Cycle Times

Garold Zander
University of Northern Iowa

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Abstract

Coated hardmetals have brought tremendous increases in productivity since 1969, when they were first applied to cutting materials. These coatings are extremely hard and are very abrasion resistant. Typical coatings are alumina oxide, silicon nitride with metal oxides, titanium carbonnitrides with metal carbides, titanium nitride, titanium carbonitride, and zirconium oxide. This study examined two different coated cutting inserts to determine which would maximize performance for lathe operators.

The two chemical vapor deposition (CVD) coated indexible inserts examined were Carboloy CMNA 543 TP 100, and Carboloy CNMA 543 TP 10. Both cutting inserts were multi-coated with alumina (Al2O3), titanium nitride (TiN), titanium carbide (TiC), and titanium carbonitride (TiCN). CNMA 543 TP 10 had more TiN in its top coat. A comparison was made to determine ways to make it easier for lathe machine processors and operators to choose cutting inserts that maximize performance when cutting gray cast iron on high speed CNC lathe machines under specific manufacturing conditions at John Deere Drive Train, Waterloo, Iowa.

This study was conducted under actual production conditions during regular scheduled production shifts, using two CNC lathes. Lathe spindle speed parameters were set at 800 surface feet per minute with a feed rate of .012 inches per revolution. CNMA 543 TP 10 and CNMA 543 TP 100 cutting inserts were used to rough cut gray cast iron. A comparison was made between a 100 % cycle time and a 120 % cycle time. This study concluded that under specific conditions, the CNMA 543 TP 10 cutting insert showed better performance than the CNMA 543 TP 100 cutting insert.

A COMPARISON OF TOOL LIFE OF TWO COATED CARBIDE INSERTS UNDER IDENTICAL CONDITIONS AND AT DIFFERENT CYCLE TIMES

A Research Paper

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Garold Zander

University of Northern Iowa

Spring 1996

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(Name) Advising Professor of Research Paper   Date Approved

_______________________________ 5-6-96

(Name) Graduate Faculty Member   Date Approved
Second Reader of Research Paper/Course
Professor

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CHAPTER 1

INTRODUCTION

Tool life as Kalpakjian (1995) described included tool wear and tool failure. Tool wear is a gradual process associated with normal wear during a machining cycle and can be likened to wear on the tip of an ordinary pencil. The rate of wear depends on the pressure applied to the tip and the speed in which the tip makes contact with the material. The rate of tool wear in turning machines depends on the cutting tool shape, the workpiece, and cutting fluid used. Some other factors include cutting speed, cutting depth, cutting feed, and machine characteristics. Two general areas of wear on cutting tools described by Boothroyd and Knight (1989) include flank wear, and crater wear.

Edwards (1993) cited research done at the Institute of Materials in London which indicated that advancements in indexible coated inserts had resulted in greater productivity. Cutting insert grades have been developed in a systematic way allowing the CNC lathe operator to cover a wide range of applications with fewer inserts (Carboloy, 1994). Using existing CNC lathes, productivity can be increased when tool life is maximized, reducing the time spent in replacing tooling.

This study was to help make cutting tool selection easier for CNC lathe operators who cut cast iron at high speeds, but who find it difficult to choose a grade of carbide-coated insert. These inserts, used as roughing tools in the machining process, have different grades ranging from maximum wear resistance to maximum toughness. In this study, two carbide-coated indexible inserts manufactured by Carboloy, Inc. were examined. They were CNMA 543 TP 100 and CNMA 543 TP 10. These coated inserts had been used for high speed cutting of gray cast iron at John Deere Drive Train in

Waterloo, Iowa. Tool life of these coated inserts were compared under similar conditions at two different lathe spindle surface feet per minute (s.f.p.m.) rates and feed rates.

Statement of the Problem

Process development people at John Deere Drive Train were faced with increased production demands, without specific definitions describing how production should be increased. The traditional method used at John Deere Drive Train , according to Roger Klingfus, of that facility, included increasing lathe surface feet per minute (s.f.p.m.) rate and feed rate, and then find the correct cutting tool that would withstand the increased forces. Heizer and Render (1991) suggested a similar managed approach when making production plans. The problem process development people at John Deere Drive Train faced were increased production demands but not given the resources to purchase new machine tools and hire machine operators. Therefore, old machine tools, and machine operators were expected to meet increasing production demands by finding the correct cutting tools needed to withstand greater forces for increased production. Problem areas undertaken by this study involved comparing two different chemical vaporized deposition (CVD) coated carbide inserts and then choosing one that would be suitable for increasing production. However, little comparative information was available on finding the correct CVD tool that would provide the longest tool life.

Machine operators and processors know how to operate CNC lathes but find it difficult to choose cutting inserts when choosing specific lathe cycle times. This study examined two different cutting inserts to determine which one should be used for decreasing cycle times under a specific production situation at John Deere Drive Train. The independent variables in this study were grades of chemical vapor deposition (CVD) carbide inserts, and the machine parameters; which included lathe spindle surface feet per minute rates, and feed rates. The dependent variable were the number of parts cut per insert corner.

Significance of the study

The significance of comparing two similar coated inserts, and then determining which coated insert best meets specific production conditions at John Deere Drive, would benefit manufacturing processors and machine operators at John Deere Drive Train who were operating under a specific lathe spindle surface feet per minute rate and feed rates. The problem of choosing which insert would best meet manufacturing and production demands under these conditions would be decided.

Delimitation / Limitations of the Study

This research involved two CNC lathes used for cutting gray cast iron. The first lathe cut one side of a rough cast iron workpiece and the second lathe cut the other side of the cast iron workpiece. During this research, normal production included three shifts per day, 5 days a week, for 12 weeks in which an average of 150 parts were produced per day. For this study, data was collected from only one production shift, third shift. Cutting tools used in this investigation were provided by Roger Klingfus, John Deere Drive Train.

Assumptions of the Study

It was assumed for this study that all lathe operations had similar and comparable operating conditions and parameters. Assumptions made regarding lathes included: (a) the two CNC lathes were in good condition, (b) the variability in the execution of machine cycles were not significant for purposes of this study, (c) no mechanical or electrical problems existed in these lathes, (d) the speed and feed rates were not a significant factor during each comparison evaluation.

It was further assumed that: (a) the same coolant was used to cool the tools and workpiece materials; (b) the characteristic of the coolant did not change; (c) cutting parameters were similar for cutting speed, cutting feed, approach angle, depth of cut, nose radius, end cutting angle, rake angle, clearance angle, and wedge angle; (d) cutting tools were all sharpened and coated; and (e) all inserts used were of uniform size and could be interchanged with each other. It was further assumed that: (a) the workpieces being machined had the same part number, (b) similar hardness, and (c) no other variables affected tool life.

Research Question

How does tool life of two differently coated CVD coated carbide inserts compare when used under similar controlled machining conditions; except for the introduction of two different lathe spindle surface feet per minute rates, and feed rates? Which CVD insert would achieve optimal tool life under increased spindle feet per minute rate and feed rate?

Definition of Terms

Chatter: The rapid elastic vibrations that sometimes appears between tool and workpiece and is easily detected by marks on the work surface and by the sound that gives it the name "chatter" (Society of Manufacturing Engineers, 1991).

Chuck: A lathe component which is a workpiece holding device.

Computer Numerical Control (CNC). Is a system in which a microcomputer or a microprocessor is an integral part of the control of a machine or equipment (Kalpakajian, 1995).

Cutting Speed: Cutting velocities which result in high cutting temperatures (Society of Manufacturing Engineers, 1991).

Cutting Tool: The material used to make contact with the workpiece and makes the chip.

Depth of Cut: The distance the cutting tool penetrates the workpiece.

Feed Rate: The relative movement of the cutting tool in the direction of the workpiece, expressed as inches per revolution (Warner & Swassey, 1991).

Force: The actual pressure of the cut against the cutting tool measured in pounds per square inch and generated by the spindle drive (Warner & Swasey, 1991).

Horsepower: The effort in turning the spindle measured in foot pounds of torque times the revolutions per-minute. This result is divided by 33,000 to convert to horsepower. One horsepower equals 33,000 ft. lb. per minute (Warner & Swasey, 1991).

Roughing Tool: The first tool used when cutting a workpiece that removes the most material from the workpiece (Carbaloy, 1994).

Tool Coating: A layer of special material applied to the cutting tool. Common coatings are aluminum oxide and titanium nitride (Carbaloy, 1994).

Tool Failure: Failure of the cutting tool has occurred when it no longer produces the required specifications to the workpiece.

cutting edge. Tool wear is normally gradual and predictable. Wear can take place

Tool Wear: Tool failure is associated with tool wear which involves breaking down the cutting edge. Tool wear is normally gradual and predictable. Wear can take place on cutting tool face and flank. (Society of Manufacturing Engineers, 1991).

Torque: A force that produces or tends to produce rotation or torsion and or causes to twist (Warner & Swasey, 1991).

CHAPTER 2

REVIEW OF THE RELATED LITERATURE

It has been proposed that recent advances in cutting materials have led to higher production rates. Improvements in CNC turning machines have led to better tool monitoring and greater production capabilities. Some CNC machines (Warner & Swasey, 1991) have better rigidity to allow for greater tool pressures and higher spindle speeds. Important factors in recent developments for increasing production (The Society of Manufacturing Engineers, 1991) included a balanced mix of tool materials, tool design, and machine tool improvements. Use of improved cutting tools, machines with greater rigidity, and improved cutting fluids have led to high speed production processes. Mills (1994) suggested that customer demand for products is an important factor concerning why production was continuously improved and increased.

Much research and development work has been done on high speed machining. Kalpakajian (1995) identified high speed machining as a result of increased demands for higher productivity at lower production costs. Considerable data have been collected on the effects of high speed machining. Some characteristics of high speed machining, (Edwards, 1993a), included: (a) increased cutting forces, (b) increased temperatures generated on tool tip, (c) increased flank and nose wear, and (d) increased crater wear. Some other categories explaining tool wear are increased notching, thermal cracking, built up edge wear, plastic deformation, chipping, and fracture.

Cutting tools used in high speed machining must have characteristics of hardness, wear resistance, and chemical stability for the material being machined. Some cutting tool materials considered for high speed machining of gray cast iron must have characteristics that can resist vibration, abrasion, chemical diffusion, plastic deformation, and thermal shock. Katbi (1995) suggested that in some cases carbides, titanium-coated carbides, and silicon nitride-based ceramics are suitable for high speed machining of cast iron.

Understanding cutting processes well enough to suggest improvements and predict the results is fundamental when dealing with high speed machining. D'Erricco (1995) suggested that understanding new cermet materials and their behavior can lead to increased productivity. At John Deere Drive Train , coated carbide and ceramic tooling were used because these tools can tolerate higher lathe spindle feet per minute rates, and feed rates.

The physics of metal cutting and workpiece material and hardness must be considered when selecting cutting tools. Trial and error was the normal way for selecting cutting tools, but today, this method is too expensive. Tool manufacturers have developed data to determine tool selection. The Society of Mechanical Engineers (1991) suggested criteria for evaluating tool life: (a) change in quality of the machined surface, (b) change in the magnitude of the cutting forces and cutting tool needed to cause workpiece dimensions to change, (c) change in cutting temperatures, and (d) costs involved in machining, including labor costs.

Tool material is also important to sustain high speed velocities. For example, sintered carbide tools and ceramic tools made with different chemical compositions behave differently under similar cutting conditions. Flat-faced inserts cutting gray cast iron form discontinuous chips. Without a chip groove pressed in, these stronger, flat top inserts are more economical and last longer, particularly when applied to machining cast iron. Many grades of inserts are available. Carboloy (1994) claim that their inserts range from those that are more wear resistant to those that are tougher but less wear resistant. Cutting forces are usually greater when increasing spindle feet per minute rates and feed rates.

The Society of Mechanical Engineers (1995) suggested that tool materials selected should match the following criteria: (a) rigidity of the setup, (b) strength of the setup, (c) weak links of the structures, (d) force limitations, (e) spindle surface feet per minute rates, feed rate, and size of machine tools used, (e) chip disposal, and (f) chatter or vibration. Tool selection should relate to temperatures created during machining. Some types of tool wear during machining processes should reflect the type of cutting materials used. The tool selection should have acceptable face wear, flank wear, and nose wear.

Mills (1994) suggested that the cutting tool relationship between fracture, toughness, strength, wear rate, and contact pressure, depended on the application of hard ceramic coatings. Two methods were used for coating machining tool inserts. The first was Chemical Vapor Depositions (CVD), a method of coating a carbide tool at high temperatures of about 900 ° C. The second method, Physical Vapor Deposition (PVD), were a method of coating carbide inserts at reduced temperatures of about 500 ° C. PVD allowed high speed steel to retain hardness, and is a very popular way to coat high speed drills, (Carboloy Inc. 1991). CVD coatings applied to carbide cutting tools in this study were titanium nitride, kappa-aluminum oxide, alpha-aluminum oxide, titanium carbide, and titanium carbonitride.

Many factors influence tool wear. Although tool wear causes are not fully understood, Mills (1994) suggested that researchers have made great strides in their understanding of tool wear.

Some differences do exist regarding the true mechanisms by which tool wear actually takes place. Mills (1983) described at least five basic causes of wear: (a) abrasive action of hard particles contained in the work material, (b) plastic deformation of the cutting edge, (c) chemical decomposition of the cutting tool contact surfaces, (d) diffusion between work and tool material, and (e) welding of asperities between work and tool. Trent (1991) described two important factors influencing tool wear: (a) cutting temperature and, (b) material hardness. Most tool materials show rapid loss of strength, hardness, and resistance to abrasion above some critical temperature. The rate of diffusion between work and tool materials rises very rapidly as the temperature increases past the critical point. Edwards (1994a) observed that peak temperatures occurred at the tool-chip interface near the point where the chip leaves the tool surface. Crater wear appeared at this point. Edwards (1994b) suggested that cutting tool properties should include hardness, toughness, and hot strength, to overcome the heat involved. Kyocera (1992) suggested that tool wear categories should include: (a) normal flank and nose wear, (b) notching, (c) crater wear, (d) thermal cracking, (e) built-up edge wear, (f) chipping, (g) plastic deformation, and (h) fracture.

Another factor influencing tool life is use of cutting coolants. In CNC lathes, advancements in cutting coolants allowed greater spindle surface feet per minute rates, and feed rates due to greater thermal capabilities. Cutting oils provide good lubrication but have less conductivity than water soluble coolants. Kuhn (1992), suggested water-based coolants are 2.2 times more conductive than cutting oils. The coolant removes the heat generated during the cutting process from the tool tip and work material. Water-based coolants used at John Deere Drive Train in lathes were Castrol 9904 mixed with ionized water. Kuhn (1992) suggested that between a 10% and 100% increase in tool life could be achieved by switching from oil-based coolants to water-based coolants.

However, there are disadvantages to using water-based coolants. Some disadvantages include decreased useful life of machine tools due to leaks in places where coolant does not belong. Water-based coolants can cause more rust and corrosion. Some seal materials do not stand up well to water-based coolants. By changing seal materials for specific coolants and by adding rust preventative properties to the coolants, the benefits of using water-based coolants far outweigh the problems associated with oil-based coolants.

CHAPTER 3

METHODOLOGY

An in-depth review of the literature was conducted on the topic of cutting tools with particular interest in extending tool life. This literature search was delimited to literature available at the University of Northern Iowa library and its resources which included, but were not limited to, LEXUS/NEXUS and inter-library loan. Other resources were taken from private collections of professors at the Industrial Technology Center, University of Northern Iowa, but were not limited to Dr. Ahmed Elsawy, a University of Northern Iowa Professor; John Deere Westfield Avenue resource files; and The University of Iowa Library. In addition, personal interviews were conducted with Roger Klingfus and Rick Wanase, who were employees at John Deere Drive Train, Department 310, Waterloo, Iowa.

From a synthesis of various theories, opinions, and studies concerning cutting tools, a comparative study was conducted regarding insert tool life on specific CNC lathes to determine which insert should be used at John Deere Drive Train. As discussed in the review of literature, minimization of the machining cycle time was generally considered after part quality and finish had been established.

Sample

In this study, two coated indexible inserts manufactured by Carboloy, Inc. were examined. They were CNMA 543 TP 100 (TP 100) and CNMA 543 TP 10 (TP 10). These coated inserts have been used as roughing tools in high speed cutting of gray cast iron at John Deere Drive Train in Waterloo, Iowa. Both TP 100 and TP 10 were coated with Multi Al_2O_3 and TiC and TiC using the CVD method. TP 10 had more gold TiN in the top coat than TP 100. Both inserts have excellent wear resistance with good toughness for medium to rough turning of cast iron. The TP 100 had enhanced edge strength over TP 10. Both inserts rough cut gray cast iron 3/8 inches deep with constant surface feet per minute of 800 feet per minute, and at a .012 inches per revolution (i.p.r.) feed rate at the centerline of the lathe spindle. These inserts were expected to leave approximately .020 inch stock for the finish insert. The TP 100 had a cost of $5.73 per insert while the TP 10 had a cost of $7.60 per insert.

The parts being cut were 11.6 inches in diameter. This meant that as the cutting tool moved towards the centerline of the part, spindle surface feet per minute rate would be constant at a 800 (s.f.p.m) rate while the r.p.m. rate increased. The feed rate remained constant at .012 inch per revolution (i.p.r). This process of machining produced an even surface finish that were free of defects.

Cutting speed is determined by this simple formula. Revolutions per minute (r.p.m.) equals (=) surface feet per minute (s.f.p.m.) divided (÷) (.262 × Diameter) (Carboloy 1991). Cutting speed is limited chiefly by heat produced at the cutting edge, which shortens tool life and affects the finished size of the piece. Other factors include cutter type and shape, shape of the work piece, and rigidity of machine and tool holder.

Procedures

This study took place using production schedules designed for particular production quotas for tractor production and manufacturing at John Deere Drive Train, Waterloo, Iowa. A CNC program had been designed and was implemented to meet production quotas. To achieve a shorter cycle time, trial and error approach to determining desired machine cycle time is sometimes necessary. Shortening cycle time by increasing s.f.p.m. rates and feed rates often results in shortened cutting tool life.

This method of first determining the desired cycle time, and then finding cutting tools to match the cycle time were typical at John Deere Drive Train. Rick Wanase, who is an industrial engineer at John Deere Drive Train, Waterloo, Iowa, explained this method is useful because production quotas usually have been set before machine capabilities are studied. Theoretical machine capabilities are determined by using tool manufacturing data and CNC lathe data to develop a cycle time to meet a specific production goal.

In most cases, selecting desired lathe spindle surface feet per minute and feed rates, and then selecting the correct cutting tool, using trial and error methods, were used at John Deere Drive Train. Tool manufacturing representatives were helpful in producing experimental tools and data about their tools. Roger Klingfus, process engineer at John Deere Drive Train Waterloo, Iowa, described this method as the best way to determine which cutting tool should be used under specific lathe spindle surface feet per minute rate, and feed rate situations.

Due to a 20% increased demand for production, processors needed to decrease the machining process time. In this study, the quota was one finished part every 7.8 minutes, or a total of 39 completed parts per shift, for a standard of 100%. Production processors and lathe operators needed to select cutting tools to meet the production demand to meet increased quotas. To reach increased quotas two roughing tool inserts were tested and compared to determine which had best tool life. Both inserts were manufactured by Carboloy, Inc. Tool life of these inserts were compared under similar conditions; two different spindle surface feet per minute rates and feed rates. In this study, it took 7.8 minutes to cycle one part through two CNC lathes, which operated simultaneously.

First, data was collected using TP 100 cutting insert tools making rough cuts in gray cast iron at the 7.8 minute cycle time. A tally was made to determine the life of the TP 100 cutting insert. This was done because TP 100 insert corners were being replaced much sooner than anticipated. Changing insert corners involved two problems: (a) changing the insert took time away from cutting time, and (b) frequent changing of the insert corner created added costs because fresh insert corners were needed. Then TP 10 cutting insert was tested in a similar manner TP 100 was tested by simply replacing TP 100 with TP 10 and getting a workpiece count.

The next step was to decrease the lathe cycle time by 20%, simply by turning the feed rate and spindle surface feet per minute toggle switch to 120%. The cycle times were decreased by 20% to 6.08 minutes. The original cutting tool (TP 100) was tested and data was collected at the 120% rate. The second cutting tool (TP 10) was then tested and data was collected at the 120% feed rate. Surface finish was inspected by a pocket surf at the machine inspection table, to maintain a surface finish of less than 1.6 micrometers.

Two CNC lathes were used to turn cast iron parts. The workpieces were held in a three jaw hydraulic 15 inch chuck. Two turrets were used in each lathe. There were eight cutting tool stations per turret on each lathe. The CNC lathe programs were set at 800 constant s.f.p.m. rate with a .012 feed rate. Insert holders used were qualified to industry standards of plus or minus .003 inch from the tool locating surfaces (Warner & Swasey, 1991). These qualified dimensions were taken using a master insert gauge, with a nose radius that varied with the size of the inscribed circle of the insert. For example, a rough turning tool with a 3/4 inch inscribed circle insert had a qualified dimension taken over a 3/64 (.047) inch nose radius. These qualified dimensions using a master gauge were basic dimensions used in calculating X and Z dimensions. The lathe chucks were turning in a clockwise rotation. (See Appendix B for machine specifications.)

Qualified tool holders were used to hold both TP 100 and TP 10 rouging tools. The CNC turning machine was operated with G96 condition, which means that spindle surface feet per minute rate and feed rates were similar.

Water-based coolants used for each test were Castrol SYNTILO 9904. Coolants were directed at the workpiece, where the cutting tool met the workpiece, under medium pressure; approximately 25 pounds per square inch, and at a constant rate of flow.

Analysis of the Data

This study was conducted during an 12 week period using regular production schedules. The inserts being tested were used for cutting gray cast iron workpieces that had been molded at John Deere 8000 Foundry, Waterloo, Iowa. During each shift a numerical workpiece count was made for the rough cutting insert corners being tested. In this manner it was determined how long an insert corner would stand up to cutting gray cast iron. For example, a TP 100 roughing insert corner in Station Number 1 would cut six workpieces before it was replaced. Criteria for replacing the insert corner depended on the tool nose and flank wear which was determined by the CNC lathe operator. In some cases, the sound made when the insert was cutting was enough for the operator to change the insert corner. If the lathe was allowed to destroy the insert corner, labor-costs would be enormous to replace the tool holders and realign the lathe. Tool nose and flank wear on the worn cutting tool were examined using a magnified scale. During this 12 week period, 200 inserts were investigated. These included 100 TP 10 inserts and 100 TP 100 inserts. Each insert had four cutting corners.

CHAPTER 4

RESULTS

Findings

Rough cuts were done by Station Number 1 on each lathe, and were approximately 3/8 inches deep. During the 7.6 minute cycle time, the TP 100 cutting tool cut six workpieces, on the average, before it needed to be replaced by a new cutting corner. In this study, cutting tools were either indexed to a new cutting corner or removed and replaced by a new cutting insert. The TP 10 insert corner could cut up to 25 workpieces, on the average, under similar conditions before it needed to be replaced. In some cases, the TP 10 insert would cut 30 workpieces before being replaced. The TP 100 insert had a black coating but had essentially the same layers of coating of the TP 10 insert. However the TP 10 had a titanium top coat that was gold in color and contained more titanium than the TP 100 contained in its' top coat..

With the lathes speed decreased to 120% rate, the TP 100 insert failed at 6.0 workpieces, on the average. The TP 10 roughing insert often failed, on the average, at 25 workpieces. When excess cast iron stock was left by the roughing tool, the tool life of the finish tool was decreased due to excess stock left by the roughing tool.

Table 1 compared tool life during this investigation. A total of 2898 cast iron parts were machined during this comparison study. Inserts used in this comparison study were 100 Carboloy TP 10 inserts and 100 TP 10 inserts at predetermined programmed lathe cycle setting called 100 % machine cycle times, and 120 % machine cycle times. At 100% machine cycle times 50 TP 100, and 50 TP 10 inserts were compared The cycle time was then decreased by 20% and 50 TP 100 and 50 TP 100 inserts were compared.

Table 1.

Tool Life Comparison Between Carboloy CNMA 543 TP 10 and Carboloy CNMA 543 TP 100 Machine Tool Cutting Insert

	Workpieces Cut at 100% Cycle Times	Workpieces Cut at 120 % Cycle Times
TP 10	1260	936
TP 100	420	282

Table 2.

Variability in Workpieces Machined Per Insert Corner (Range)

	Workpieces Cut at 100% Cycle Times						Workpieces Cut at 120% Cycle Times					
	high	-	low	=	Range		high	-	low	=	Range	
TP 10	30	-	16	=	14		30	-	11	=	19	
TP 100	16	-	1	=	15		10	-	1	=	9	

Table 3.

Mean Parts Turned Per Insert Corner Listed As Whole Numbers

	Workpieces Cut at 100% Cycle Times	Workpieces Cut at 120% Cycle Times
TP 10	25	18
TP 100	8	6

Table 4.

Median Parts Turned Per Insert Corner Listed As Whole Numbers

	Workpieces Cut at 100% Cycle Times	Workpieces Cut at 120% Cycle Times
TP 10	24	20
TP 100	9	6

Discussion

It was observed that the tool nose radius lost its coating before its substrate would wear, or erode, and then fail. The tool nose lasted longer when machine cycle times had longer spindle surface feet per minute rates, and feed rates. TP 10 inserts studied had longer tool life than TP 100 inserts using similar spindle surface feet per minute rate, and feed rates. When the machine cycle times were decreased to 6.08 minutes, or to 120%, the roughing tool failed earlier. TP 10 gold-coated cutting inserts lasted longer than TP 100 black-coated cutting inserts. TP 100 black-coated inserts appeared to be more brittle and could not withstand chipping caused by vibration or intermittent shock when cutting gray cast iron at higher spindle surface feet per minute rates, and feed rates. Carboloy (1994) described the black-coated TP 100 as having an enhanced edge strength over TP 10. Contrary to this, this study found that when cutting gray cast iron, the gold-colored TP 10 stood up to tool wear better than the TP 100. The cutting edge of the TP 100 appeared to have been more brittle and chipped more easily, exposing the carbide core of the cutting insert. Choudry and ElBaradie (1995) suggested that thermal softening of the cutting tool resulted in plastic deformation of the cutting tool, and subsequent deformation of the cutting edge. Increased heat generated by increased machine speed may be a factor in tool life. Horgan (1993) suggested that ceramic materials were more desirable because ceramics could withstand heat better than carbide cutting tools.

CHAPTER 5

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

Two chemical vapor deposition coated inserts examined in this study were Carboloy CNMA 543 TP 10 and Carboloy CNMA 543 TP 100. These coated inserts were similar, except that Carboloy CNMA 543 TP 10 had more titanium in its top coat. Under similar production conditions, at John Deere Drive Train, Waterloo, Iowa, Carboloy CNMA 543 TP 10 insert out performed Carboloy CNMA 543 TP 100 insert.

This study was conducted under similar production conditions at John Deere Drive Train. Carboloy CNMA 543 TP 10 had a longer life than Carboloy CNMA 543 TP 100. When lathe cycle times were decreased by 20% both inserts had decreased cutting life.

The study concluded that Carboloy CNMA 543 TP 10 showed better tool wear characteristics than did Carboloy CNMA 543 TP 100 under similar production conditions at John Deere Drive Train, Waterloo, Iowa.

Conclusions

This study showed some limits to increasing spindle surface feet per minute rate, and feed rate, decreasing cycle times.

1. Life of cutting tools CNMA 543 TP 10 and CNMA 543 TP 100 was shortened with increased spindle surface feet per minute rate, and feed rates.
2. Too much spindle surface feet per minute caused vibrations (chatter).
3. Cutting tool Carboloy CMNA 543 TP 10 with a Titanium top coat cut more workpieces than Carboloy CNMA 543 TP 100 under similar conditions.

Recommendations

1. It is recommended that further research be conducted into Carboloy CNMA 543 TP 10 and Carboloy CNMA 543 TP 100 cutting insert having slower spindle surface feet per minute rate, and feed rates.
2. It is recommended that further research be conducted into Carboloy CNMA 543 TP 10 and Carboloy CNMA TP 100 following manufacturer's other suggested spindle surface feet per minute rates, and feed rates.
3. It is recommended that further research into Carboloy CNMA 543 TP 10 and Carboloy CNMA 543 TP 100 cutting insert be conducted using other coolants which may help produce a better surface finish on the workpiece and increase tool life.
4. It is recommended that further research into Carboloy CNMA 543 TP 10 and Carboloy CNMA 543 TP 100 be conducted using different tool holders having different thickness and clamping systems to ensure correct positioning and maximum rigidity during machining.
5. It is recommended that further research into Carboloy CNMA 543 TP 10 and Carboloy CNMA 543 TP 100 be conducted regarding depth of cut during other spindle surface feet per minute rate, and feed rates.
6. It is recommended that further research into Carboloy CNMA 543 TP 10 and Carboloy CNMA TP 100 be conducted under dry machining (no coolant) conditions to determine the effect on tool life.

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APPENDIX A

Advanced Tool Steel Properties and Applications

High Speed Steels: These have the lowest hardness and the highest toughness of the cutting materials. Their major disadvantage is that their hardness is brought about by a heat treatment process so they are not naturally hard. If their cutting edge rises to 600 degrees C, they soften and the edge will fail. Their primary application is for drilling.

Stellite: Stellite is the trade name for cobalt-based alloy which is naturally hard and does not require heat treatment to attain cutting properties. Stellite will perform on heavy cutting operations at medium to low speeds.

Hardmetals: This family of alloys is the hard core of all cutting materials in use today. Hardmetals cover a very wide band of machining applications. It is estimated that 70% of turning tasks are done by hardmetals. They are made of a combination of tungsten carbide, cobalt, titanium, and tantalum carbide. Some are then coated with titanium.

Ceremet: Ceremet are carbonitride-based materials. They have titanium carbonitride as the major base which is held together by a softer binder alloy of cobalt and/or nickel.

Ceremet-Sialons: The properties of sialons make them suitable for machining heat resistant alloys. They perform well on cast irons at high cutting speeds but are not suitable for general steel machining. Hardness runs approximately 1700 VDH.

Ceramics: Aluminum oxide-based ceramics. The alumina-based ceramics have a higher hot hardness, and therefore, can operate at higher speeds without plastic deformation of the cutting edge occurring. Their higher hardness makes them more sensitive to shock and, therefore, their range of application is generally confined to clean cutting, semi-finishing, and finishing operations. On hard metals, alumina-based ceramics can produce surface finishes normally obtainable only by grinding. Its hardness is 2000 VDH.

Ceramics: Silicon nitride. Silicon nitride is a ceramic used as a cutting material. It is made into shapes by powder metallurgy processes, but does not sinter readily to full density. Its hardness is approximately 1800 VDH. It has toughness which permits rough turning of gray iron with interrupted cuts at higher speeds. It should not be used for machining steels.

Cubic Boron Nitride: With the exception of diamond, this is the hardest of cutting materials at 4000 VDH. It cuts hardmetals very well, but shows no advantage when cutting soft materials. It is made synthetically with techniques similar to making synthetic diamond.

Titanium Nitride: This is widely used as coatings on cutting tools. It improves tool life by its low frictional characteristics. This coating is good for high flank wear resistance in machining abrasive materials.

Polycrystalline Diamond (PCD): PCD is suited for machining soft abrasive non-ferrous materials at a very high cutting speed. It has a hardness approaching diamond. It should not be used on steels and cast iron as it chips easily if subjected to impact. Under the right conditions, it could be used for machining hardmetals.

Diamond: The hardest substance of all known materials. Diamond has low friction, high-wear resistance, and the ability to maintain a sharp cutting edge. It is used when a good surface finish and dimensional accuracy are required. It works well for machining soft nonferrous alloys and abrasive nonmetallic materials, such as optical mirrors. Because diamond is so brittle, tool shapes and angles are used to reduce microchipping caused by stress and oxidation, and transformation to carbon, caused by heat generated during cutting. Diamond is suitable for light uninterrupted finishing cuts. It has a hardness of approximately 7000 to 8000 VDH.

Whiskered reinforced alumina ceramics: An improvement in ceramic tools, fibers or whiskers made of silicon carbide, reinforced with alumina have improved mechanical properties, fracture toughness, thermal conductivity, and thermal shock. These ceramics have a hardness of approximately 2000 HVD.

APPENDIX B

Warner & Swasey M-6167 Titan Medium Slant Bed Turning Machine

Chuck Size	3 jaw Hydraulic Hi-Low	15 inch
Motor	DC Variable Speed, SCR controlled	60 HP
Spindle Speeds	Direct Drive	3416 rpm
	Constant HP Range	272-3148 rpm
Gear Box Drive	Low range	8- 937 rpm
	High Range	36-4026 rpm
Rapid Rates	Cross	600 i.p.i.
	Longitudinal	600 i.p.i.
Feed Rates	Cross	0-350 i.p.i.
	Longitudinal	0-350 i.p.i.
Turret (2)	Tool Stations	8
	Swing over Waycover	29 in.
Cutter Size		1 1/4 sq. 6
Cross Stroke	Upper Turret	9.449 in.
	Lower Turret	6.496 in.

APPENDIX C

Formulas for Determining Constant Surface Spindle Speed and Feed Rate for the Warner & Swasey M-6167 Titan Medium Slant Bed Turning Machine

Cutting Speed, feet/min	$V_c = .262 \times D_t \times RPM$
Revolutions Per Minute	$RPM = 3.82 \times V_c/D_t$
Feed Rate, inches/min (IPM)	$f_m = f_r \times RPM$
Cutting Time, minute	$t = L/f_m$
Rate of Metal Removal cu. In/min	$Q = 12 \times d \times f_r \times V_c$
Horsepower Required at Spindle	$Hp_s = Q \times P$
Horsepower required at Motor	$Hp_m \times Q \times P/ E$
Torque at Spindle	$T_s = 63030\ Hp_s/ RPM$

Symbols

D_t = Diameter of workpiece in turning inches

d = Depth of cut, inches

E = Efficiency of spindle drive

f_m = Feed rate, inches per minute

f_r = Feed rate, inches per revolution

Hp_m = Horsepower at motor, hp

Hp_s = Horsepower at spindle, hp

L = Length of cut, inches

P = Unit power factor, horsepower per cubic inches per minute

Q = Rate of metal removed, cubic inches per minute

RPM = Revolutions per minute of work or cutter

T_s = Torque at spindle. Inch pounds

t = cutting time, minutes

V_c = Cutting speed, feet per minute