焼結鉄材切削における工具摩耗

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Tool Wear in Cutting of Sintered Iron Material

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パワーステアリング用ヨーク，ステッピングモータ用ローター部品など良好な磁性特性が要求される部品には焼結鉄材が使用される．複雑形状部品を高精度に大量生産するには粉末冶金が有効な製造技術であるが，成形の制約から最終製品形状を得るために焼結後の機械加工が避けられない場合も数多くある(1)．この場合，切削による機械加工が多く，大量加工のため，工具材種，工具形状および治具を工夫し能率を上げる必要がある(2)．焼結材料切削における工具摩耗は，同一組成の溶製材切削に比べ工具摩耗が一般的に大きくなりやすいとされている．この理由として，焼結材料内部に存在する気孔部で切削の状態が不連続になること，気孔による被削材の熱伝導率の低下による切削温度の上昇が主な理由と考えられている．現在，焼結材料としてよく使用される焼結鋼を切削した場合の工具摩耗を調べた研究は多い(3)−(5)．これに対し，焼結鉄材を切削した場合の工具摩耗を調べた研究は見あたらなく，焼結鋼切削における研究結果を，焼結鋼と異なる化学成分・機械的性質を持つ焼結鉄材の切削にそのままあてはめるのは有効でないと考えられる．

そこで本研究では，焼結鉄材の切削に適した工具材種を明らかにするために，超硬合金工具，コーテッド超硬工具，サーメット工具，セラミックス工具の摩耗進行を調べた．さらに，焼結鉄材の切削における工具の摩耗機構を調べるために，工具摩耗面のSEM観察などを行い考察を加えた．

得られた主な結果は，次の通りである．

(1) コーテッド超硬工具の摩耗面のSEM観察より，いずれのコーテッド工具のコーティング層にも，微細な条こんが顕著に見られた．

(2) セラミックス工具の中では，Si_3N_4セラミックス工具の摩耗進行が最も遅く，しかもTiVNコーテッド超硬工具の摩耗進行よりも遅かった．

(3) セラミックス工具の摩耗面のSEM観察より，工具摩耗面には微細な条こんが顕著に見られた．さらに，EDXによりFe，Pの元素分析を行った結果，工具摩耗面におけるFe，Pの存在は，ほとんど認められなかった．これらのことから，セラミックス工具の主な摩耗形態は，アブレシブ摩耗である．

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WARM TEMPER CUTTING OF HARDENED STEELS

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In the automotive industry, the flexible production system has been already introduced, and the energy saving in the manufacturing processes is now strongly requested.

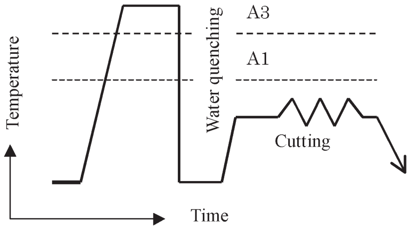
A high strength forged material such as a crank shaft or a gear is considered as an example of products, here. The actual manufacturing processes for the product consist of a hot forging, turning, heat treatments and grinding. However, the grinding process is recently replaced on the cutting process with the cutting tool material having both the heat-resistance and high-hardness, such as C-BN tools. Such new machining methods may be available for the shortage of working process, but there are still difficult problems on the tool life and the surface accuracy of products.

In this study, a new cutting method, "warm temper cutting", is being developed. The warm temper cutting seems to be effective for improving the efficiency of cutting for harden steels. In the process, a work-piece is first quenched, and then heated up to a warm temperature. Subsequently, the quenched work-piece is turned in its tempering process. Useful ranges of cutting temperature are investigated from view points of cutting force, surface roughness, resultant hardness and tool wear. The optimum temperature range is found to be around 250℃ for a carbon steel (0.45%C).

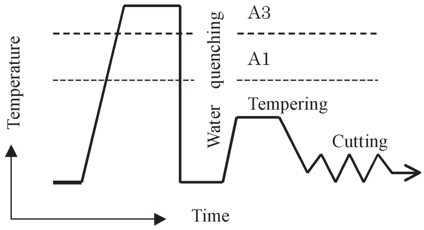
Fig. 1 shows the difference between the warm temper cutting method and the conventional cutting method. In the case of the conventional cutting shown in Fig. 1(b), a work-piece is first quenched and tempered , and then is cut at room temperature. On the other hand, in the case of the warm temper cutting shown in Fig. 1(a), a work-piece is first quenched, and then is cut at a warm temperature after the tempering or in the process of tempering. For the warm temper cutting, experiments are conducted at different heating temperatures, and the tempering temperatures of quenched steels are changed in the conventional cutting method

The effects expected in the warm temper cutting is shown as follows;

(1) the working process and the heat-treatment process can be combined,
(2) the surface hardness of work-pieces can be changed by the selecting of heating temperature,
(3) because the work-piece is softened by the heating, it is possible to cut even a quenched steel using by cemented carbide or cermet tools. As a result, the cutting condition, such as depth of cut or feed rate, can be selected in wide ranges,
(4) the cutting force is decreased by the softening of work-piece surface,
(5) good surface roughness is obtained, and
(6) dry cutting, i.e. cutting without any coolant, can be possible.



(a) Warm temper cutting



(b) Conventional cutting

Fig.1 Warm temper cutting and conventional cutting.

The main results obtained are as follows:

(1) In warm temper cutting, the good machined surface can be obtained at the working/tempering temperature above 200℃.
(2) In warm temper cutting, the wear of tool is very small at the temperatures above 250℃.
(3) In warm temper cutting, it is not necessary to use any coolant during cutting; dry cutting may be possible.
(4) The process can reduce the total cost and working time, because it is a duplex process of heat-treatment and machining.

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TOOL WEAR OF PVD COATED CEMENTED CARBIDE TOOL IN TURNING OF FORGED SINTERED MATERIAL

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A machine part having the complicated shape can be mass-produced accurately by the technology of powder metallurgy. A sintered material can be produced because it has the large degree of freedom on the material-design. However, the sintered material is slightly poor impact-resistance as compared with the melted steel. After the sintering, the sintered material is forged to this defect. By being forged, the mechanical properties are improved because of the increase of the sintered density (1).

The forged sintered material begins to use as the machine parts which are demanded for both the impact-resistance and the wear resistance. However, it is often necessary for the forged sintered materials to be machined. In this case, the cutting is generally used as the means of the machining. However, there are few report about the tool wear in the cutting of the forged sintered material. Recently the demand of the forged sintered material is increasing. Moreover the high speed cutting is used for the improvement of the productivity. However, in the high speed cutting of the forged sintered material, the tool wear increases rapidly with the increase of the cutting speed.

In this study, in order to find out the effective tool materials for the high speed turning of the forged sintered material, the forged sintered material was turned with the various tool materials at the cutting speed from 5.0m/s, the feed rate 0.2mm/rev and the depth of cut 0.1mm. And the tool wear etc. were investigated.

Table 1 Chemical compositions(mass%) and mechanical properties of forged sintered material

C	Ni	Mo	others	Fe
0.4～0.6	1.75～2.25	0.3～0.6	<1	Bal.
Mechanical properties		Tensile strength		650MPa
		Brinell hardness		HB197
		Elongation		18%

The chemical compositions and the mechanical properties of the forged sintered material are shown in Table 1, and the cutting tools used are shown in Table 2.

The main results obtained are as follows:

(1) The abrasive wear was remarkably found on the worn surface of the coating layer in all PVD coated cemented carbide tools.

(2) The wear progress of TiVN (Ti/V 75/25) PVD coated tool was slowest, because the TiVN (Ti/V 75/25) coating layer had high micro-hardness and high critical load measured by the scratch test.

(3) In the Al_2O_3-TiC ceramics tool, the tool wear decreased with the increase of the TiC contents. The wear progress of the 30% Al_2O_3-70%TiC ceramics tool was slowest among four ceramics tools. However, the wear progress of the 30% Al_2O_3-70%TiC ceramics tool was faster than that of the TiVN (Ti/V 75/25) PVD coated tool. The wear progress of both Al_2O_3 ceramics tool and Si_3N_4 ceramics tool was rapid.

Table 2 Cutting tools

Tool	Substrate	Coating layer
Coated A	K10	TiVN (Ti75V25)
Coated B	K10	TiVN (Ti50V50)
Coated C	K10	TiN
Coated D	K10	TiAlN
Ceramics W	Al_2O_3	
Ceramics B	Al_2O_3-TiC (70% Al_2O_3-30%TiC)	
Ceramics T	Al_2O_3-TiC (30% Al_2O_3-70%TiC)	
Ceramics S	Si_3N_4	

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電磁力による回転液層中の溶融合金ジェット流の能動制御と短繊維材の製作

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Active Control of Molten Alloy Jet in Rotating Liquid Layer by Electromagnetic Force and Production of Short Fiber

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本論文は，回転液中紡糸法によって製作される連続細線の断面の円形度や寸法の均一性を向上させるために，また，短繊維材を製作するために，本紡糸法へ電磁力を適用し，溶融合金ジェット流を能動的に制御することを試みたものである．

電磁力は，Fig.1に示すように，二つのNd－Fe－B永久磁石を対向設置して形成した静磁場中を通過する溶融合金ジェットに，直流を通電することによって発生させた．Fig.2はFig.1（a）の磁石設置形態で連続的に電磁力を付与した場合のSn－Pb合金ジェットの軌跡で，ジェット軌跡をシミュレートできる計算手法も呈示している．溶融アルミニウムジェットは，回転液層表面を流れる傾向にあるが，このような方法で電磁力を作用させることによって冷却液体中に沈ませることができた．

また，周期的かつ衝撃的に電磁力を作用させることによって，ジェット流を容易に短繊維に分断することができた．Fig.3に示すように，細線の最短長さは，Sn－Pb－Bi合金の場合で約40mmであった．

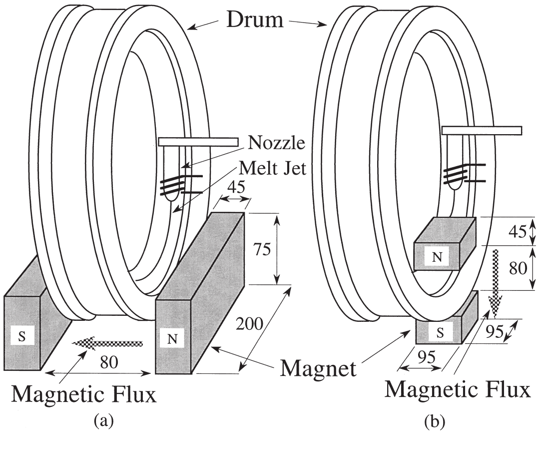

fig. 1　Formation of magnetic field with Nd-Fe-B magnets.

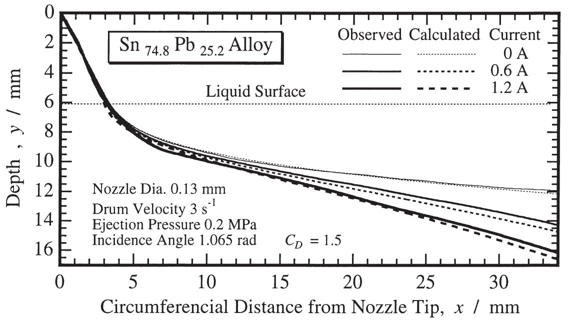

Fig. 2　Observed and calculated Jet orbits.

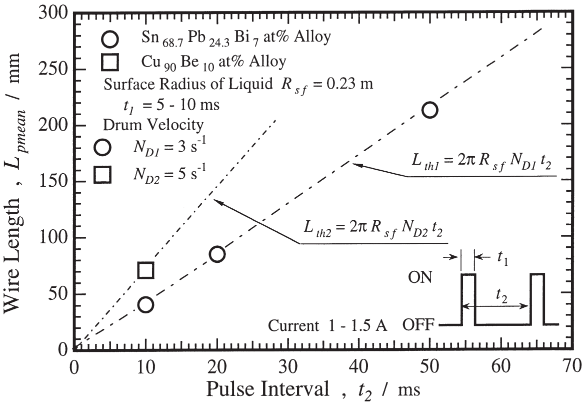

Fig. 3　Relation between the mean wire length and pulse interval.

一方，Fig.1（b）の磁石設置形態で，Sn－Pb溶融合金ジェットに電磁力をドラム軸方向に作用させたところ，細線の断面の円形度はおよそ0.3から0.6に増大した．なお，磁気変態点以下で磁性を有するCo－Cu－Be合金の場合，溶融合金ジェット流が磁場を通過中に磁力によって短繊維に分断された．得られた細線の平均長さはノズル先端から磁石までの距離によって変化した．

回転液中紡糸法によってより優れた均一性を有する連続細線や短繊維材を製作するにあたって，電磁力の適用がきわめて有効であることを示した．

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