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NEW MATERIALS AND TOOLS

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ABSTRACT: The purpose of this paper is to present a general survey of the tool material situation with a view to briefing the industrial user about the current trends and to clarify his thinking in the quest for alternative tool materials. It is intended to create a general awareness of the 'real' requirements of a cutting tool in the light of the overall production situation.

Specific tool material types are discussed and new developments taking place are highlighted.

INTRODUCTION

With automation, reliability in the performance of materials has become more and more important the cutting tool used in a machining operation is a good example of this. If the tool fails frequently or prematurely the machine capabilities cannot be fully exploited. Most modern machining systems are capable of cutting metals and non-metallics at high material removal rates. When cutting extremely hard materials at high speeds their productivity is limited by cutting tool edge wear.

As cutting edge wears off, control over part size becomes difficult and the surface finish deteriorates. There are courses of action to be taken in this situation. The most common solution is simply to change or regrind the tool. Down time for tool change decreases machine output. A second solution is to reduce machining speeds to control the rates of tool wear. This too lowers machine output. A third solution that improves machine productivity is to use a more wear resistant, better performance cutting tool. This is where a knowledge of tool structure and properties, tool design, heat treatment procedure etc. becomes useful.

The ultimate aim of a machining centre is to provide the most efficient and cost - effective method of work peice - cutting tool interaction. Therefore these two components have to be considered essentially as a system and never in isolation. The term ' machinability ' therefore has a much broader meaning in a production situation than simply denoting the rate at or the ease with which material is removed. Machinability may then be taken to imply the number of components produced per hour, the cost of machining the component and the quality of surface finish achieved together with dimensional accuracy.

Tool Material Requirements

Tools used in manufacturing industry can be broadly classified into two groups, viz. cutting tools and forming tools. The former is of primary importance in the present context.

The 'perfect' tool material for cutting high strength materials at high removal rates requires the following characteristics:

a High hardness , abrasion resistance and strength-impact resistance combination, all at the tool operating temperature.

b High resistance to oxidation and to chemical attack by the workpeice materials.

c Reasonable ease of fabrication into the variety of forms required by the industry.

d Wide availability at a price which makes the tool cost- effective.

Year by year 'better' tool materials are inovated and put to use by industry. However, obviously, no one tool material can meet the diversity of industrial conditions. Most tool materials used by industry today combine a satisfactory compromise of the above characteristics and have increased productivity in a wide range of materials. However the real problems in machining are encountered when dealing with those work materials identified as 'difficult-to-machine materials', for example the nickel-based super alloys used in the aerospace industry. These are mostly machining situations unlikely to be encountered by the local manufacturing industry in the near future, but an awareness of these problem situatations is nevertheless useful.

What is expected of a cutting tool material by the local industry, probably even after moving towards automation, are:

a Adequate tool life and reliability.

b Reproducibility of cuting performance.

c Adaptability to a variety of machining situations.

d Ability to be brazed (indexable insert types apart).

Tool Material Types and Selection

Increased productivity is sought by the industrial user primarily through higher cutting speeds. This has led to a continued demand for tool material more resistant to higher temperature. The development of cutting tool materials has kept pace with the advances in machine tool technology. The full potential of new machine tools cannot be exploited without improved materials and vice-versa. Development in cutting technology during the last two centuries or so has meant more than a hundred-fold increase in the maximum speed available to the user, realised primarily through much improved temperature capability.

The tool materials used in industry fall basically into four groups:

1 High speed steels HSS

2 Cemented carbides

3 Ceramic materials

4 Ultra-hard materials

Within these four specialised groups, hundreds of different compositions are currently available, posing problems of selection to the user. The use of the latter groups is very limited in the local scene.

There is considerable area of overlap where different materials are in competition, particularly in the speed range 100-300 m/min for stee Thus there is no unique choice as such available to the user. HSS and cemented carbides can cater for more than 90 % of all machining, the ceramics and ultra-hard materials being reserved for special applications. This reflects the fact that routine cutting of cast irons, low carbon steels and low alloy steels make up the majority of component machining. These work materials pose relatively few technical problems and HSS and the carbides possess the correct balance od properties coupled with economy for such situations.

Choice between the HSS and carbides depend upon application. The greater toughness and edge retention capability of HSS have tended to give it a wider range of applications than the carbides. HSS very nearly monopolise the tool material field for products such as saw blades and drills. They also have a very large share of the market for turning, boring and milling tools where the nature of the operation restricts cutting speeds practicable or the work is of a jobbing nature. It is also still the most favoured material for making complex shaped tools. The carbides, however, are prefered where very rapid metal removal is to be carried out on rigid and well controlled machines. Thus carbides are primarily the tools for mass production.

High Speed Steels

The high cost and scarcity of Tungsten have led to increased use of Molybdenum grades of HSS (M-seried) for economy in prference to T-series HSS. High Cobalt/Molybdenum grades are particularly prefered for increased wear resistance and toughness.

The widely used conventional casting route for production of HSS which often poses problems of carbide segregation, is now being substituted to some extent by powder metallurgy processes. Sintered parts produced directly to shape would bring about reductions in HSS price in the long run. Application of surface coating technique to HSS tips/inserts has not proved much successful.

The only type which shows a significant improvement in cutting speed is a Ti N coating , but the use of coated HSS is still very limited.

Cemented Carbides

Developments in carbide technology have provided the user with harder, tougher and more wear resistant varieties. Again due to the escalating price of tungsten and cobalt, there is now a greater interest shown in TiC grades bonded with nickel deviating from the more established WC-Co types. Clearly the economy will primarily determine the pattern of development.

Undoubtedly the greatest improvements in the performance of carbide tools have come from the introduction of vapour deposited coatings, initially of TiN or TiN/TiC but more recently covering a variety of compositions. These give very substantial increases in tool life over the uncoated carbides, and by benefitting from the 'throw-away tip' (indexable insert) concept, have made significant in roads into the carbide market. This unfortunately has resulted in a problematic situation confronting the user as far as selection is concerned since a wide variety of coating types are now proliferating the market.

Ceramics

The development of Alumina tool materials was at one time considered a major break through in the tool material field but the original expectations were not quite realised. The ceramics require very rigid machines operating at high speeds and the maintenance of good machining practice generally. Perhaps the user application of ceramics to unsuitable operations has been responsible for some of the mistrust now placed on ceramics. Despite this, sufficiently reliable varieties of ceramics (and cermets) are now available for specialised applications.

Oxides have dominated the ceramic tool market up to now with Alumina taking a lead role, but Sialon materials (Si-Al-O-N) represent a recent potential addition. A particular advantage, inspite of high price, is in continuous cutting of cast iron at extremely high speeds. Its applicability also to interrupted cutting situations makes sintered Sialon a prospective future tool material.

Ultra-Hard Materials

These are tool materials used for dealing with hard and abrasive workpiece materials.
For example compact polycrystalline diamond (generally on a tungsten carbide substrate) is successfully applied for machining high silicon containing aluminium alloys used as piston materials and also for mchining plastics and fibre glass. Inspite of being 20-30 times as expensive as its carbide equivalent, diamond tools still have the potential for claiming overall economic superiority. They are,however, not suitable at all for machining steels. Cubic boron nitride, which is even more expensive, is the other established material in this group. It is used in machining aerospace materials, hardened steels and cast irons, which would otherwise need grinding.

Present Trends

The emphasis in tool material development has so far been mainly directed at improving their temperature capability, the ultimate aim being to achieve a higher cutting speed. Obviously there must be a limit to the economy that can be achieved through increased cutting speed alone. The trend in development is now clearly shifting towards tool reliabilty. The really significant costs are the tool changing costs and the losses due to lost production time. In this light, the actual cost of the tool material may be relatively insignificant,

On the other hand no machine tool will be cutting the whole of the time it is running, and therefore increased cutting speed alone does not really mean much unless machine loading time, chip removal etc. can be speeded up to match. Thus the modern machining centre capabilities will ultimately decide the realistic tool requirements in the automated production situation.