THE IMPORTANCE OF TOOL, DIE AND MOULD WELDING

(Continued from June, 1985 issue)

by Leon D. Richardson

"Tipping" Tools and Dies with Sintered Tungsten Carbide

Sintered tungsten carbide is formed by exposing powdered tungsten, heated to high temperatures, to carbon monoxide, or other hydrocarbon gases and forming with pressure and a bonding agent (generally cobalt). It has exceptional resistance to wear and abrasion even at high temperatures. Due to its brittle characteristics with no toughness, it is not considered as a suitable material for the making of dies and moulds. Drill bits and masonry drills are usually tungsten carbide tipped and, in this writer's opinion, there are hundreds of other applications where "tipping" tool steel with tungsten carbide should be adopted. Tungsten carbide is the hardest of all commercial materials except for diamonds. It is approximately Rockwell A 90 in hardness. It's main advantage is it's "shapeability" and low cost compared to diamonds.

Tungsten carbide can be used to reinforce wear areas of tools, dies and moulds and increase the life of the tool very significantly. Tungsten carbide is extremely brittle and successful tipping of tools require careful preparation and application to ensure proper results.

Following is the suggested procedure for effective joining of tungsten carbide inserts to steel shanks. This procedure avoids "flip-offs" of tungsten carbide particles, poor wetting and stress cracking.

1. Use good quality solvent on steel to remove any grease. (Do not use dangerous petroleum solvents such as carbon tetrachloride).
2. Insert the work piece (shank) in a vice for easy accessibility.
3. Flux the tipping area with a suitable flux that will protect the carbides from oxidation. Then flux the tungsten carbide insert.
4. A process to protect the weld's integrity pioneered by this writer, is to "shim" the tool before welding with a thin piece of silver alloy solder.
5. Heat the assembly to be worked with an excess acetylene flame (the outer cone of the flame should be 2-½ times the length of the inner cone). Use a reasonably large tip to spread the torch's heat evenly. Heat from the underside of the piece (the tungsten carbide should not be heated directly but instead get all its heat indirectly from the work piece).
6. After welding, the carbide tool should be allowed to cool slowly to prevent stresses caused by uneven cooling. This can be done by packing in lime or mica. (Do not use asbestos due to its unsafe handling properties).
7. When brazing large tools, a cushion is recommended. This is accomplished with a 0.08-0.13 mm (0.003-0.005 inch) copper or constantin shim inserted between the carbide and the steel. The soft shim inserted between the tungsten carbide and the steel will allow the carbide to take some shock and absorb stress, and especially not crack during

cooling or during service.

Case Hardening Tool Steels

Case hardening provides tool steels with a high surface hardness up to a depth of between 0.005 inch and 0.015 inch, depending on the period of heating.

What actually happens is that tool steel is heated to a high temperature and a carbonaceous material is used to surround the piece. Continued heating causes some of the carbon to migrate into the piece of steel. The case hardening process is completed by rapidly cooling the tool steel piece in water or brine.

In the good old days, blacksmiths used to case-harden horseshoes by wrapping the shoe in leather and keeping the shoe at high temperature for a day. This gave the horseshoe an increased superficial hardness and therefore slightly improved wearing characteristics. The carbon from the leather penetrated the steels surface and hardened it.

A rapid and modern method of case hardening is to heat a steel piece to cherry red heat and sprinkling the piece with "instant hardening powder" composed of various salts, which provides the piece with immediate extra hardness. These are proprietary products engineered for this purpose. Most contain cyanide which is highly toxic and should be avoided. There are non-cyanide hardening powders available.

Tools, dies and moulds are often case hardened and repairing these case hardened tool steels only requires that the die be annealed prior to welding.

Fabricating Composite Dies by Welding

The one fabricating technique of welding composite die sections together to form the final manufacturing die is not new. The practice, however, has mostly fallen out of favour with most tool-and die-makers for reasons that will be covered in my final conclusion.

In this writer's opinion, however, the savings made possible by fabricating final dies from composite dies are significant and can probably save industries millions of dollars annually when properly exploited.

Die-making Today

Most dies are today made using time-consuming and wasteful machining of tough tool steel blanks to final desired dimensions.

The tool-and die-maker of today has much to gain in using welding techniques to produce dies. He avoids spending days and weeks patiently grinding, cutting, boring, drilling and finishing the hard-to-machine tool steel die.

If the die is as large as your office desk, without welding, the die-maker will have to machine the die section by section, taking perhaps a month or two of patient, meticulous (and hopefully!) fault-free work.

The end result is an extremely expensive die. If the die maker had spent a little time studying composite die welding techniques, he could have saved his company thousands of dollars and weeks of production delay.

Composite Die Construction

There are two types of composite dies. The first are dies or die sections made from common steels with the "work areas" made from weld deposits of "super metal". This provides a tough resilient shock absorbing support material and a hard non-wearing or non-deforming work area. Figure 3 explains this type of structure.

The tool-and die-maker may use welding

to join segments of a bulky or irregular shaped die together and thus avoid several problems. To make a complicated die, such as one with several punches protruding is an exceedingly slow, difficult and costly procedure.

He must machine, for example, four punches and a base plate from a huge piece of steel. Michelangelo hardly had it so difficult with marble. The whole piece now has to be carefully heat treated to avoid distortion and stress cracking.

By using the composite die fabrication technique, he could have used a low-cost and easy-to-machine base plate to hold the four punches (which he can make separately). After heat treating, the four punches only need to be welded to the low-cost base plate with the newly-developed "high elongation" tough steel welding electrodes which resist hot cracking. He then quickly and economically obtains a high integrity composite die at a fraction of the cost of sculpturing the complex assembly from one block as Michelangelo had to do.

Another method our tool and die maker could have used is to fabricate the die base from common and inexpensive

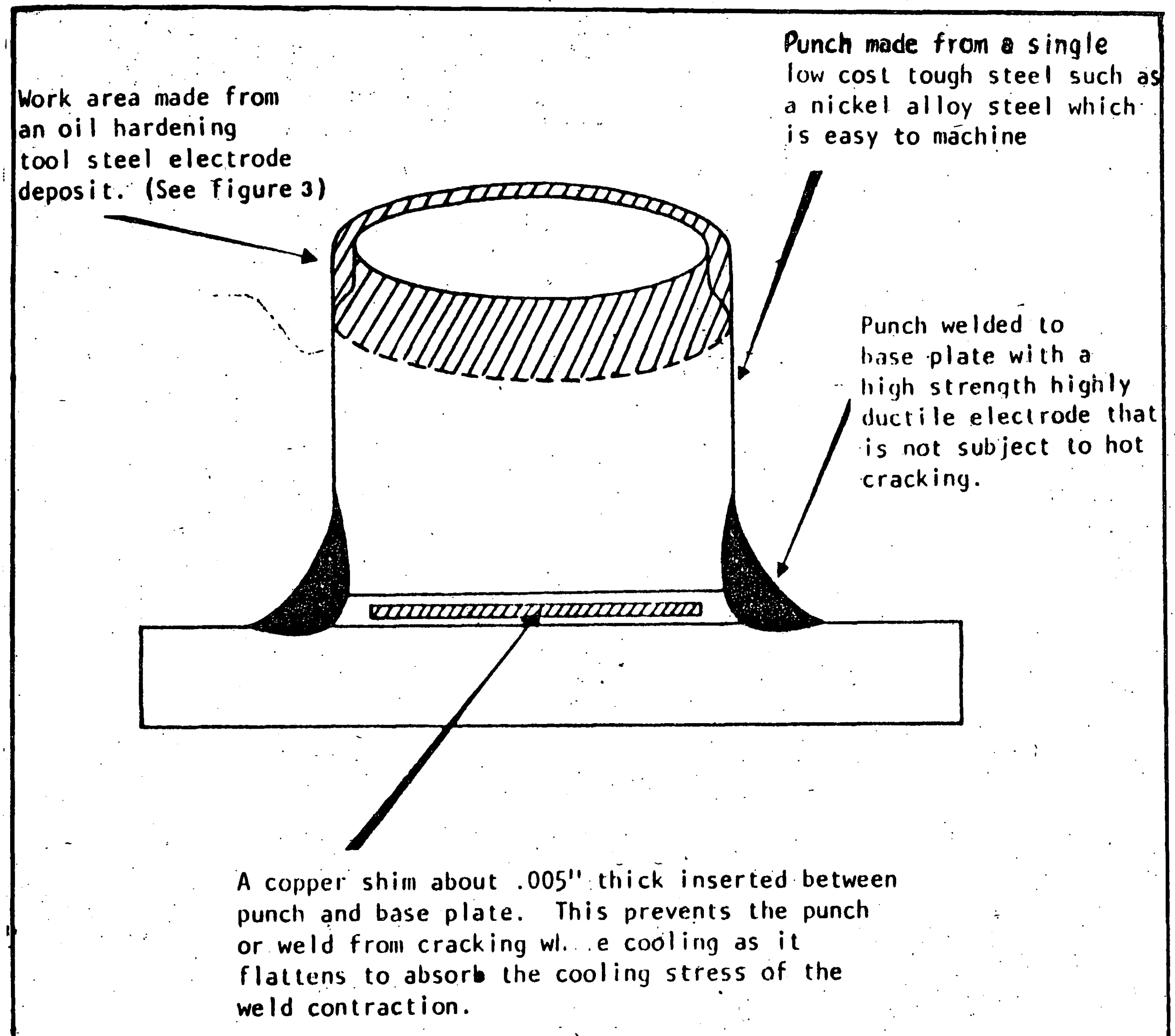
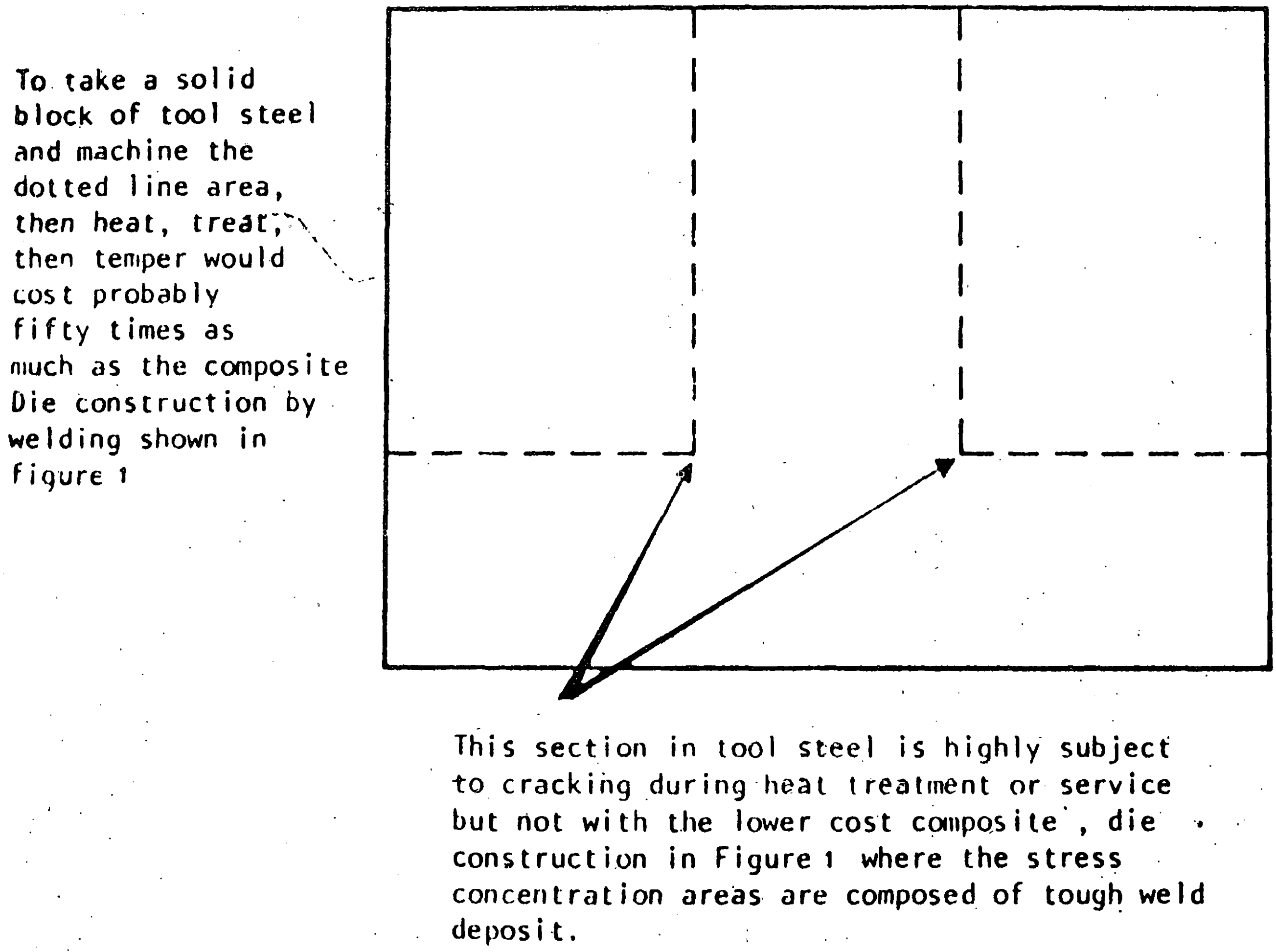


FIGURE 1

FIGURE 2



steel. He then would weld the four punch profile with a high quality weld metal and overlays the punch surface areas only with a high wearing overlay material. The procedure is explained in Figure 3.

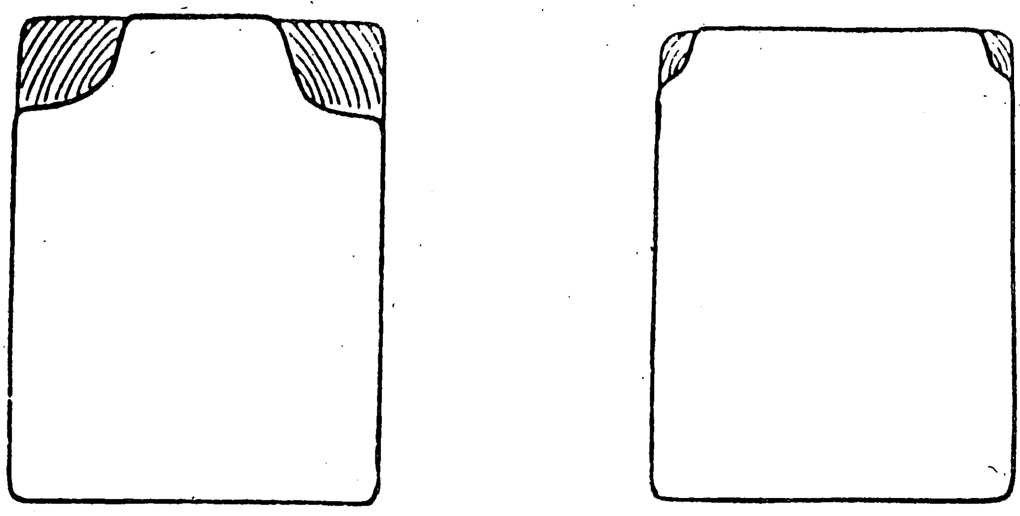
The result of using welding almost exclusively is that he has now obtained a fabricated composite die constructed entirely of inexpensive steel. The welding and finishing may take only hours. He can save his organisation thousands of dollars and hundreds of manhours.

The die shown in Figure 1 can be completely manufactured in a period of perhaps 2 to 3 hours and the cost is so small it is non-important. If the weld is properly made, heat treatment of the die is avoided. Only a simple tempering of the weld deposit is suggested.

Compare this to the cost and time consumption of the following normal die manufacturing procedure.

In this type construction the work area is composed of a few ounces of expensive tool steel electrodes. 99% of the punch is made with low cost easy-to-machine steel. The punch generally does not have to be heat-treated since by applying the weld in small sections, it quenches upon deposition by heat dissipation into the mass. Thus the die can be made

FIGURE 3



Two preparations for composite die overlay.

Figure B - Only for light work. The steel is rounded and built up with a tool steel weld deposit to form the work area of a tool such as a punch.

Figure A - A superior design.

The work area is recessed to give more support to the work area which is over-laid with a tool steel electrode.

in a workshop not having heat-treating skills or equipment.

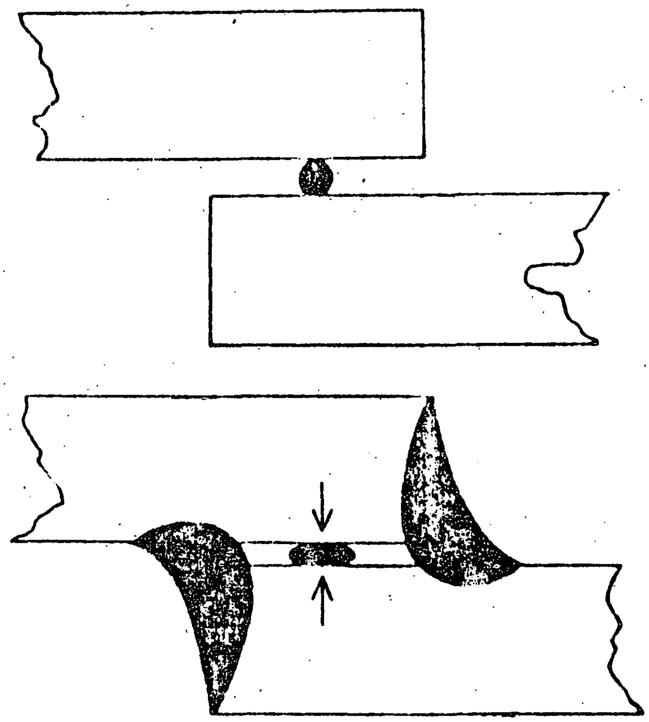
Complex Tool Steel Dies

With today's interest in lower cost production, there is an interest in larger dies that can make larger steel metal assemblies which avoids more stampings to make smaller assemblies which later must be riveted or bolted together. Large rangy dies are exceedingly costly to manufacture, and require great design skill. There is a substantial risk in large complex dies cracking during heat-treatment. The machining and precision metal removal of a complex rangy die from a huge block of steel borders onto skills and equipment far too demanding to produce a "one-off" die. Such a die can be constructed in sections and each section hardened and then the sections welded together at a fraction of the cost - and above all, a fraction of the time. A large rangy die will accommodate only 2 or at the most 3 die makers. However, if the die is made in 4 sections, which are then joined by welding, 2 men can work on each of the sections simultaneously. The finished die can be produced in perhaps 8 days which might require 60 days if made in one piece.

When welding heavy die sections together, the "cushioning technique" is often necessary. Figure 4 shows a copper or constantan shim being used to absorb shock when a large section is to be welded to another large section.

FIGURE 4

Soft wire can frequently be used between heavy structural members to prevent cracking by cushioning, as shown in this figure.



Special Die Consideration

Stainless Steel

Tool steels are normally used for making dies to form sheet metal. Today, however, many fabrications are being made from stainless steel. An example is stainless steel automobile trim. Tool steel will gall when stamping out stainless steel and is totally impractical. Stainless steel requires an aluminium bronze die. Aluminium bronse is 90 Rockwell B or harder, tough and slow deforming, and will not gall in forming stainless steel. However, it is difficult to even find a large block of aluminium bronze and it is expensive. The die can be made of a tough but low cost steel undersized. Then it can be overlaid with two layers of an aluminium bronze electrode on the outer perimeter. Aluminium bronze is not difficult to machine and the die can then be reduced to final dimensions. This is easier to make and less costly made by welding and more functional and more easily repaired as it wears.

Beryllium Copper

Many plastic moulds encounter a heat dissipation problem. An ideal solution is the of beryllium copper as a base plate. Most welders consider welding of beryllium copper as impossible. Actually beryllium copper inserts, such as base plates can readily be joined to other beryllium copper parts, or to steel die parts readily using modern brazing alloys. Beryllium copper is an interesting material for tooling because it has the strength and resilient qualities of steel, but retains most of the high heat conductivity properties of copper.

Composite Construction of High Speed Steel Tools

Probably the most highly used of all tools steels are high speed steel tools.

The most elementary of welding techniques in this area is the extension of drills. If a deep hole is to be drilled, or a hole made in a section a long distance from the tool, it is easily recognised that a long drill would be costly, hard to find, and, because of the lack of elongation of hardened high alloy tool steel, easy to break. A one meter length drill will cost a large amount. However, a short lower cost drill can readily be joined to a mild steel shank with modern brazing techniques at a fraction of the cost. More important this usually results in a great time saving.

Complex high speed tool steels such as a milling cutter or a broach are indeed costly. A 1 meter broach today can cost nearly US$5,000. It can break in operation. Repair joining with oxyacetylene process and brazing is not especially difficult. Correct alignment is actually more difficult than the welding operation. A brazing technique is recommended.

Repair of High Speed Steel Tools

This can be required by the consistent failure of drills, taps, reamers, milling cutters and broaches that fail. If they break or fracture, the repair is usually more simple than it appears.

Circular milling cutters frequently break - usually between the key way and two teeth. This repair has been attempted many times in workshops but the weld causes cracking or breaking of the cutter. The solution is to weld in compression. An example of welding in compression can be found in reparing a circular milling cutter as shown in Figure 5. Often these crack between the key way and two teeth, since this is a highly notched area. If welded without special preparation, the weld upon contracting will cause the high speed steel to crack elsewhere. However, if the fracture is spread open with a small wedge, such as a sharpened electrode end and then tack welded with a gap between the two segments, and the wedge removed before welding, upon cooling the milling cutter will not break, but merely be pulled back into proper location.

One of the most simple and most profita-

FIGURE 5

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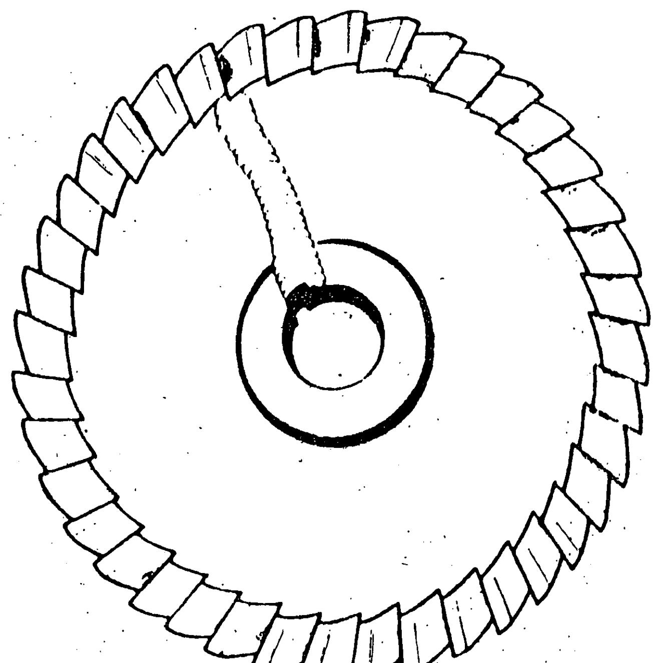

ble and least employed methods of composite tool construction by welding is found in the manufacture of high speed steel tools. High speed steel tools, ranging all the way from milling cutters to boring bars can economically and easily be made by welding.

High speed tool steels are of two major types - the older 18-4-1 (18% tungsten 4% chromium 1% vanadium) to the more modern 6-8% molybdenum with tungsten types. However, all high speed steels are readily repaired, and even more easily compositely manufactured.

The first step in comprehending composite construction of high speed steels is to understand their role in machining. Many people compare a welded high speed steel tool with tungsten carbide tools which is like comparing oranges and apples. Tungsten carbide insert tools are best for high speed machining. High speed steel is best for rough work which tungsten carbide can't withstand. On simple repetitive work which is not rough or where impact is not involved, tungsten carbide will perform at higher speed and lower cost per unit machined. On rough work, such as machining an iron casting which has sand inclusions, tungsten carbide will fail while high speed steel will perform with no problem.

Composite high speed steel tools are exceedingly easy to make using a High Speed Steel Electrode. High speed steel electrodes are available which provide a deposit on any steel, including cheap mild steel, that will provide 60 to 65 Rockwell C hardness as deposited (even when deposited on mild steel), and which will have hardness in the range of 55 Rockwell C at 1100°F. The performance of these electrodes is incredible!

Lathe tools and other metal cutting tools can be made quickly and unbelievably economical.

A theoretical example is the case where a boring bar is required to bore a hub in a steel section. This may require a "gooseneck" boring bar which may even be in the range of one meter long and in a curved shape. It would cost a remarkable sum to buy such a tool and involve, probably at best, a six weeks wait. A quality tool can be made in perhaps 30 minutes and for a few cents in materials by bending and forming a steel bar to the shape required and weld-building a working edge at the end with high speed steel electrode deposit. As little as one or two dollars of electrode deposit may be required to make a tool that could save several weeks delay in waiting for a tool from an outside tool supplying company.

Many engineers do not realize that in using a high speed steel tool, it is only the cutting edges that do the work. There is no reason for a complete broach or milling cutter to be made from costly high speed steel which involves an outside purchase when the tool can often be easily made in-house from a common steel base which comprises 98% of the tool, and the remaining 2% to be made by overlaying the working surfaces with an electrode that lays down a true high speed steel deposit. The concept is so obvious and reasonable - yet still today it is not fully employed. Engineers waste huge sums of money using 100% high speed steel on applications that only require small areas to be of high speed steel.

Tooling today falls into two end use categories.

A major production manufacturing plant which can pre-plan in their budget nearly all tools that are required. These do not represent a major tool manufacturing problem (although they have the greatest tool maintenance problem).

ıe second category is the job shop ç maintenance workshop. Surveys ıdicate these suffer from "under-ooling" and this greatly affects ıeir productivity and profitability. ıis category of industry urgently equires "emergency tooling" methods ıd supplies. They continually suffer rom "under-tooling" and the inability o plan in advance which tools they ill require. Composite welding tooling rocedures can help these companies normously. To a job shop, the ability o acquire tools quickly can mean ıe difference as to whether they an accept a profitable job or must eject it because of lack of tooling s often a "life or death" matters. odern welding techniques can be life-aving in these circumstances.

irksite Dies

ıe lowest cost, perhaps, of all die aterials is kirksite. This is a ow melting, easily castable alloy f mainly zinc composition. It has roven ideal for short run dies, such s those used in the aircraft industry here an intricate die is required, ut may only have to form a few hundred ieces or less.

irksite dies can be repaired or built p or modified using a welding alloy f zinc alloyed with aluminium and in, and a suitable flux. Again the avings are tremendous.

dvantages

ther advantages gained through the e of composite die welding fabrication e:

e die can perform multiple functions ch as trimming, punching, forming d spanking simply by overlaying ssimilar weld deposits at different eas.

isting low-cost steel blanks can used to fabricate dies instead using expensive and hard to machine tool steels. The high quality, high cost tool steels can be reserved for use as welding deposits to use as cutting edges or work areas requiring specific properties.

Die fractures or damage can similarly be repaired by replacing the section with a weld-fabricated new section within hours.

An added advantages is that since the bulk of the die is a common steel (such as a moderate cost nickel alloy steel) which has some resiliency, the die is less apt to break during service.

Conclusion

Tools, dies and moulds are the means by which industry today can produce vast quantities of goods at prices affordable to the common man.

The art of toolmaking requires a high degree of skill and even the simplest die - to make a flip-top plastic cap, for example - takes a few days and at least a few hundred U.S. dollars in labour and materials.

The nature of mass production techniques usually means that in a given industry, there is more than one machine chuming out different parts of the item to be manufactured. One machine would produce a part; another would produce a related part which would be joined to the first part, etc., on the final assembly line.

Due to intense competition, many industrialists have to keep their machinery running non-stop for longer periods and at higher speeds. Tools, dies and moulds get damaged and one machine has to stop. The die has to either be re-made or repaired. A new die may take days or weeks to make as very few industries can afford to carry a "spare". And while that one machine is non-productive, the other machinery either has to stop or the final assembly has to stop for lack of that part. Either way the losses can snowball into vast sums of money.

Repairing tools, dies and moulds by welding holds the key to reducing production costs and keeping machinery operating. Die construction or strengthening using welding can also save industries millions of dollars and weeks or months of lost production time.

In this writer's opinion, one of the first steps that industrialists and manufacturers should take is to take a fresh new look at the production of tools, dies and moulds.

There has been a gradual yet significant "separation of trades" in the toolmaking discipline and therein lies one of the stumbling blocks to more cost-efficient operation.

The welder has been alienated by the toolmaker and is seldom consulted nowadays when a tool is made or when a repair becomes necessary. The toolmaker has become almost exclusively a machinist. He can think in terms of drilling or grinding or cutting or chamfering but seldom does he consider the possibilities of welding. He has gradually forgotten or never really considered how to fully utilise the economies possible by welding tools, dies and moulds in either their constructional phase or to repair them when damaged.

The author hopes that by re-focusing attention on this seemingly forgotten aspect of welding that we will be able to assist industrialists and manufacturers reduce manufactuing costs and improve productivity by repairing and/or constructing tools, dies and moulds using the appropriate welding techniques.