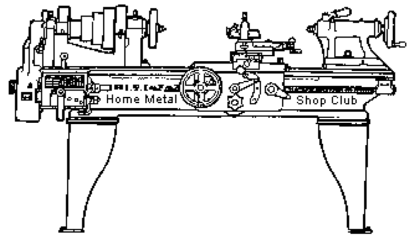
Home Metal Shop Club

January 2011

Newsletter

Volume 16 - Number 1



http://www.homemetalshopclub.org/

Since its founding by John Korman in 1996, The Home Metal Shop Club has brought together metal workers from all over the Southeast Texas area.

Our members' interests include Model Engineering, Casting, Blacksmithing, Gunsmithing, Sheet Metal Fabrication, Robotics, CNC, Welding, Metal Art, and others. Members always like to talk about their craft and shops. Shops range from full machine shops to those limited to a bench vise and hacksaw.

If you like to make things, run metal working machines, or just talk about tools, this is your place. Meetings generally consist of a presentation with Q&A, followed by ***show and tell*** where the members can share their work and experiences.

President *Vance Burns*	Vice President *John Hoff*	Secretary *Martin Kennedy*	Treasurer *Emmett Carstens*	Librarian *Dan Harper*
Webmaster/Editor *Dick Kostelnicek*	Photographer *Jan Rowland*	CNC SIG *Dennis Cranston*	Casting SIG *Tom Moore*	Novice SIG *Rich Pichler*

About the Upcoming February 12, 2011 Meeting

General meetings are usually held on the second Saturday of each month at 12:00 noon in the meeting rooms of the Parker Williams County Library, 10851 Scarsdale Boulevard, Houston, TX 77089. The scheduled meetings for the next 3 months of 2011 are: February 12, March 12, and April 16 (note this is the 3rd Sat. of the month). Visit our website for up-to-the-minute details.

Recap of the January 15 General Meeting

By *Dick Kostelnicek* photos by *Jan Rowland*

Thirty members and one new member, *Jeff O'Malley*, attended the 12:00 noon meeting at the Parker Williams County Library. President *Vance Burns* led the meeting.

Thanks to member *Randy Jacobs* for hosting the tailgate sale held prior to the February meeting. Around 10 members had items for sale.

During the meeting, we learned that both Rutland Tool Co. and Wholesale Tool Co. have closed their doors in the Houston area.

Donations to the library included Tool Steel Simplified given by *Vance Burns* and an audio recording of Trustee from the Toolroom donated by *Dick Kostelnicek*.

Presentation

Dan Harper described the various vises in his collection. Many *of them were bought on the cheap* and required restoration and modification in order to bring them up to his standards.

He showed how to uses a thread restorer (left photo) to clean up the clamp screw on a vise screw. Even some new import vises need their screws restored in this way. Dan suggests that you plug the end hole of the screw so that swarf and dirt do not enter the threaded cavity of a vise.

A major problem with a vise used to hold work on a machine is that the movable jaw tends to lift and elevate the work as the vise is tightened. Dan recommends that you tap the work down with a lead or non-marring hammer in order to seat the work in the vise.

Often the ways on a vise are not perfectly parallel to its base. This means that work seated on the ways or on parallels is not parallel to the machine's working surface. In this case you may have to machine flat the base of the inverted vise set on parallels in order to correct this problem.

Dan explained how a Kurt-style vise keeps the movable jaw from lifting and also allows for slight misalignment of the fixed and movable jaw faces. The movable jaw is pushed forward by an inclined plane which forces the jaw down as it closes against the held work. The flat side of a half ball rides upon this inclined plane and the rounded portion seats in the movable jaw. The ball allows a slight rotation of the moving jaw during tightening.

Comments from the audience: (1) Reduce the width of the vise's keys so that it can be used on machines with different size T-slots. Just push the narrow keys against one side of the slot. (2) Use aluminum for the keys so that if you inadvertently drop the vise, it will not mar the machine table.

Show & Tell

Gene Rowan showed his mill vise that he designed to do milling in a lathe (left photo). Contact him if you are interested in the plans.

Joe Williams talked about his communication with a tool magazine about a strange and incomplete advertisement in their publication.

Mike Winkler showed his brass milling machine drawbar hammer. A member suggested adding a spanner wrench to it so that it could also tighten a vise hold-down.

Dean Henning showed his 4-cycle single cylinder gasoline Webster Engine. He brought all the parts that needed to be remade in order that we could see some common and uncommon mistakes. He used Viton O-rings for the piston rings. The engine can run up to 5000 RPM. A video of the running engine can be seen in the video of the entire meeting.

Joe Sims discussed how he plans to repair a Starrett #98 level. He showed the clamp device for removing and installing the vial holder end caps (photo right). He plans to use plaster of paris to hold a new more sensitive bubble vial in the level's protective tube.

Joe Scott showed a box tool that is used in a turret lathe for sizing bar stock by pushing it over and along the rotating stock (far left photo).

He also brought his mini diamond wheel grinder that he uses on carbide cutting tools.

Rod Shampine demonstrated his Steam Punk Heat Pipe. It uses perflorocarbon as a working fluid. Now, if you are wondering just what this device does? Well, it does nothing useful at all! Rod just loves to build neat looking but ridiculous (PUNK) machines. However, it does have some clever parts. For example: It uses an old soldering gun transformed to generate resistance heating of tubing in order to cause the working fluid to circulate.

John Hoff showed his tight-circle pipe bender that he made in order to bend EMT thin wall tubing. The bent tube conveys sand in his pressurized sand blaster. John also showed a grab bag of 25 new files that he obtained from a local tool supplier.

John Elliot gave a brief presentation on the *chain method* of producing a large hole in a thick piece of metal. First, equally spaced pilot holes are drilled just inside the large hole so that subsequent drillings will not wander. Next, a small drill is used to drill through the material at each pilot. These small holes are then enlarged until they just begin to break through to one another along their flanks. The internal blank is removed by striking the core with a hammer. The large hole is then trued to size in a lathe.

Novice SIG Activities

The novice group, along with several club members, reviewed Rich Pichler's file collection. The novices practiced getting the feel of filing on tool steel with an old file. They noted why you should first use a non-cherished file on unknown steel. Some of the unusual files on hand were lead ("Bondo"-car body) files, lathe files, and wood checkering files. Joe Scott demonstrated draw filing on an octagon rifle barrel and also demonstrated the checkering technique on wood.

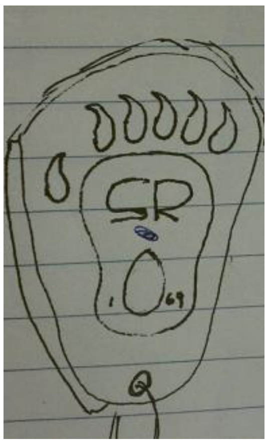
Filing on steel should be about 40-50 strokes per minute as this is about the recommended surface speed for cutting carbon steel. To reduce file tooth loading, they determined that Crayola brand sidewalk chalk clings best to a file. A stick of sidewalk chalk was given to participants. The novices filed steel, lead, aluminum, brass, and various plastics.

Articles

From a Sketch to CNC

Another CAM Learning Experience

By *Bruce Lunde*



A friend of mine is involved in the Boy Scouts, and asked me if I could make some key chains for his group. He said he wanted to give them to the boys after completion of a merit badge effort. As always, I said “sure” before I knew what he wanted! He grabbed a pen and subsequently drew out this design. Little did I know this was going to take several hours and a couple of new learning experiences for me to get it into my CAM program, much less into g-code!

We started by taking a picture of his original drawing (left photo), and placing it into jpg format. I found that my Cut2D CAM program could not import this file. I tried several different ways to get this jpg into a usable format, using LazyCam, and a couple of *trialware* programs, all to no avail. None ended up working for a variety of reasons. Some of the problems were due to the drawing being on yellow, lined paper, and others just were due to the jpg file having varied hues from the camera flash. After failing to get this to convert with the various packages, I went searching for another program and found the open source program named “Inkscape”. This program is very similar to CorelDraw, and is free – the amount of cash I had on hand! This program will work with scalable vector graphics or SVG. I still had much to learn to get this to work. I spent some time in the tutorials and played with examples, and after a couple of days of learning, I finally got back to the project at hand! Remember Martin Kennedy’s article on Why It Takes So Long To Machine a Part totally applies to this one of mine.

Now that I had the program, I went back to the original drawing. I still was having trouble getting it to convert to the SVG format, so I did an extra step to get a good trace by grabbing some tissue paper, and tracing the drawing on to white paper. I then grabbed my Linux system with a scanner and scanned the drawing into a jpg format (left photo) and then imported into Inkscape. I then ran the *trace* function to get the SVG – Success! The right illustration is the SVG trace file. Now I just had to find a compatible format for my Cut2d CAM program, and after looking to see what formats Cut2d imported, I found that a *eps* file would work.

So, I was finally able to work in the CAM program to create the toolpaths. I was quite excited, and this short, easy project had only consumed three days of my free time. The *svg* and *eps* files are nice because they are easily scaled without losing any resolution. Once in the CAM program, I just had to select the traces that were complete, and convert to tool paths. For more details on that you can refer to my July presentation material on the HMSC web site. Now I was able to save the toolpaths and send them over to my Mach3 computer and do some cutting.

My trials and tribulations were not yet quite over, but I was moving nicely along. I was making five of the key chains and I started by cutting the outside shapes. I added tabs to the outside profile cuts so that the pieces were not loose after cutting. I cut the outside profile first, then changed to the engraving bit and did the top of the keychain second. With the material selected (1/4" 6061 aluminum), and the size of my workspace on the HF 44991 mill, I could cut three on one piece, and two on the second. The profile cut went well, and the engraving went perfectly – for the first piece. Then after cutting the profile of the second unit, I was working the engraving, when I heard a little "snap" and my engraving tool had lost its tip (oh, and I only had the one!) Now I was in a predicament. I tried turning the tip in my lathe to get a tip back on it, but my attempt failed. I could not find another tip in town (quickly), so I went out to my woodworking stuff and dug through my router bits, and found a V-bit that seemed to be similar. I did have to go back to my CAM package and make a couple of adjustments, as the reason for the initial failure was that I was engraving at too fast of an IPS (inches per second) for the small engraving bit. Once fixed, I returned with the updated g-code and set to finishing up the key chains. The final result is show in the above photo. My friend was happy with the results, and I added some additional capabilities (and lessons) into my "toolset'.

References:

http://inkscape.org/ Inscape SVG drawing program
http://www.vectric.com/WebSite/Vectric/cut2D/c2d_index.htm Cut2d CAM program
http://www.machsupport.com/ Mach3 Machine Control program

Amorphous Metals and Their Applications

John Elliott

While the structure of the majority of commonly used metals is defined by a regular, crystalline structure, another class of metallic substances is comprised of randomly oriented – or amorphous – atomic structure: these materials are known as amorphous metals or metallic glass. These materials can exhibit extraordinary mechanical and physical properties and are a subject of widespread interest at the leading edge of metallic materials research. This article will provide a brief history of their development, explore some of the unusual characteristics of these materials, reveal applications of these materials that we come into contact with every day, and provide insight into the future of their development.

The primary difference between metals produced by conventional technology and their amorphous counterparts is their base atomic structure. The majority of common metals and their alloys consist of a crystalline structure that has specific forms according to the base elements present. This crystalline structure is a repeating arrangement of atoms that defines the geometry of how the electrons in the outer shells of the individual atoms are shared with their neighbors. The common crystalline structures are identified as body-centered cubic, face-centered cubic, and hexagonal close-packed. Certain materials – such as iron based alloys – attain more than one of these crystalline structures depending on their current temperatures; changing from body-centered cubic to face-centered as a result of applied heat. Only when the metal reaches its molten state does the crystalline structure give way to random arrangement of atoms in the liquid state.

For conventional crystalline metals the rate at which the metal is cooled determines the arrangement of crystalline structure that is formed and retained at ambient temperature. A closer look at crystalline formation gives a greater understanding of the influence that cooling rate has on the mechanical properties of the solidified metal. As molten metal cools, the lowered energy level of the atoms allows them to approach one another and begin to form the metallic bonds between atoms. The first localized points at where these bonds occur are known as seed crystals and the distance between these is a result of not only the cooling rate of the molten metal, but also the influence of alloying elements in the mixture. Additional atoms join to the perimeter of these seed crystals, enlarging them and decreasing the amount of molten metal remaining, until all the available molten metal has joined the crystal structures, leaving grain boundaries where the different crystal orientations are unable to join into a continuous structure[1]. This is the basis of the formation of a polycrystalline solid. The mechanical strength of this solid material is determined by the strength of the interface between individual crystals. This can be altered by the addition of alloying elements that do not assimilate into the crystals themselves, rather, remain at the grain boundaries. When sufficient stress is applied to this crystalline metal, the crystals begin to shift in relation to one another. With an amorphous metal, however, there are no crystalline boundaries – the structure is monolithic in form – thus there are no existing zones of weakness to accommodate the movement. The result is a significant increase in strength and stiffness[2].

Amorphous metals, on the other hand, are – by definition – devoid of any regular crystalline structure. The atomic structure of these materials most closely resembles that of glass, with completely random orientation of the individual atoms. Transmission electron microscopy allows us to see the transition between both states of a sample of zirconium metal below in Figure 1.

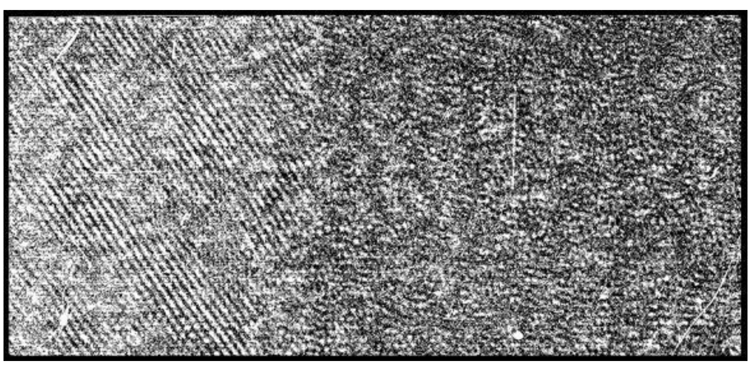


Figure 1: TEM micrograph of zirconium sample at magnification of ~ 5 million[2]

Notice the ordered orientation of crystalline structure to left the side and the completely random nature of the material to the right. This random orientation can be achieved in one of two ways: by cooling the molten metal at a rate greater than that at which crystallization can occur (known as *the critical cooling rate*), or by the careful alloying of the metal in such a way that crystallization does not occur.

The former approach is limited by the solidification process' ability to remove heat quite rapidly – at rates of 10^5 – 10^6 °K / second – a constraint that greatly limits the section thickness of the material produced due to the inherently low coefficient of thermal conductivity exhibited by this material (ref 3) . These first versions of this material were first discovered in 1960 by Pol Duwez – Materials Scientist at the W.M. Keck Division of Engineering, California Institute of Technology, Pasadena, CA – along with R.H. Willens and W. Klement working under a grant from the Atomic Energy Commission[4]. The rapid solidification technology (RST) required to produce these earlier forms of amorphous metal required that the molten metal be sputtered onto a spinning drum cooled internally by liquid nitrogen (ref 5) or physical vapor deposition (PVD), a process that utilizes the condensation of a vaporized material on a substrate within a vacuum[6]. Later developments in thin film production included commercial planar flow casting technology for production of continuously cast ribbons and thin sheets of amorphous metal[5]. Today, the thin-film approach works quite well in molten spray applications for wear and corrosion resistance.

The latter form of amorphous material is known as bulk metallic glass (BMG), its development beginning in the 1970's with H. S. Chen who succeeded in casting 1mm diameter rods of Pd-Cu-Si alloys by casting under vacuum[7]. Around 1990 a team at The Institute for Materials Research, Tohoku University, Sendai, Japan, led by Akihisa Inoue discovered that the desired amorphous properties could be achieved at much slower rates of cooling by careful combination of elements according to three conditions:

1. The alloy must be comprised of at least three elements
2. The atomic size of each element must differ from the others by at least 12%
3. The elements must have a strong attraction to one another

The resulting BMG could be produced in thicknesses up to four inches, substantially changing the versatility of these for a wider variety of applications[8]. The later developments that allowed for a slower rate of cooling permitted more conventional production techniques. Elements that lend themselves well to amorphous structure include zirconium and palladium, although titanium, magnesium, copper, and iron have also been successfully produced.

More recently, in 2004, some two component alloys were successfully produced such as CaAl, PdSi, CuZr and CuHf with diameters of up to 2mm. The significance of this development was that ordinary, binary alloys could possess glass forming ability (GFA) of a high order and might follow different rules than the GFA requirements of three or more component alloys[9].

Other distinguishing characteristics of amorphous metals include superior elastic strain capacities[1], enhanced magnetic properties such as much greater permeability and much lower hysteresis, high electrical resistance, greater hardness properties, and enhanced resistance to corrosion[3]. An example of the higher elastic strain limit is shown by a Ti-base BMG that was tested with a 2% elongation, exceeding any other known metallic alloy. Under impact loading that figure reached 4%[2]. This enhanced elastic behavior was responsible for one of the first consumer applications of BMG: the manufacture of exotic golf club heads using an alloy produced by Liquidmetal Technologies in 1998 that were used by golf pros on the PGA Tour that year[10]. Studies of the impact energy absorbed by a conventional steel club head showed that only around 60% of the swing energy was imparted on the ball, titanium transferring 70%, and BMG transferring an astonishing 99%[9]. Additional sporting goods applications include high-performance tennis rackets from Head, used by Andre Agassi and many other players on the ATP Tour[11], as well as baseball bats, and components for snow skis among other items.

The superior magnetic permeability and the ability to be easily demagnetized have numerous applications; one of which nearly everybody uses on a nearly daily basis without noticing. The security activation tags on high value consumer merchandise utilize thin strips of metallic glass that are designed to resonate at predictable frequencies when excited by ~58kHz tonal bursts at the security detectors located at the store exits. The induced vibration in the strips induces an AC voltage signal in the receiver antennae triggering the security alarm. When the purchases are made legitimately the security tags are deactivated by the cashier's passing the tag over an AC demagnetization coil[12].

Applications requiring great resistance to corrosion benefit from applied coatings of metallic glass, there being no inter-crystalline boundaries to act as initiation points for intergranular corrosion; longer life cycle for boiler tubes is a good example of this advantage. Similarly, applications requiring enhanced protection to surface wear benefit from the high surface hardness and monolithic structure of a surface applied coating of amorphous metal. Currently, applications of these coatings – easily applied using thermal spraying techniques – are being used in wear coatings on oil and gas drilling equipment, dryer and callender rolls in the pulp and paper industry, forming rolls used in glass manufacturing, and other industrial and agricultural applications where high resistance to wear and / or corrosion provide economic returns[13].

Formability of metallic glasses is significantly different from conventional crystalline metals. Metallic glasses have the unique property of becoming *viscous* at temperatures lower than their melting point. This allows the material to be molded at near net dimensions. For example a Zr-based metallic glass becomes malleable at 400°C as opposed to more than 1000°C for steel, making it more like working with a thermosetting polymer than a structural metal. This allows the material to be formed in relatively inexpensive and re-usable molds for high production runs. The finished part has excellent dimensional characteristics, as well as a smooth and shiny surface finish[1]. Because of the lack of crystalline structure the size of finished molded parts can be quite small, as can the features of larger parts, for instance. Surgical Specialties, who began in 2002 to produce ophthalmic scalpel blades using an amorphous alloy that are less expensive , sharper and more consistently manufacturable than diamond blades. These blades are sharper and last longer than steel and cast in net shape – with the cutting edge ready to use in eye surgery, *without additional sharpening* – straight out of the mold[2].

Other exciting areas of application for these unique materials come to the forefront as NASA investigates their properties under near-zero gravity in space. The formation of metallic foams is enhanced in micro-gravity due to the lack of separation between the metal and foaming gasses based on differing densities. Investigation of foamed BMG took place aboard the International Space Station during Expedition 9 with samples returned to earth in 2005 for evaluation[14]. NASA Science Officer Mike Finke performed the testing. He is shown aboard the ISS in Fig. 2.

Fig. 2 Science Officer Mike Finke aboard the ISS 2004[14]

NASA sees “enormous potential” with the development of solid BMG foams as they are the best materials to make large, stiff structures owing to their high strength to weight ratio. An additional benefit of solid foams is their insulation value; the combination of low thermal conductivity and superior structural attributes being prime factors in spacecraft design[15].

This article has discussed some early history, current applications, and future possible developments of amorphous metals, also known as bulk metallic glasses. Research continues in this exciting area of metallurgical science as materials are being developed with increasing mechanical strengths – currently 2-3 times that of their crystalline counterparts – and superior physical properties, including superior corrosion resistance, hardness, and surface finish. Applications using these materials may well take us to new worlds and are currently having a significant impact on the world we live in.

References

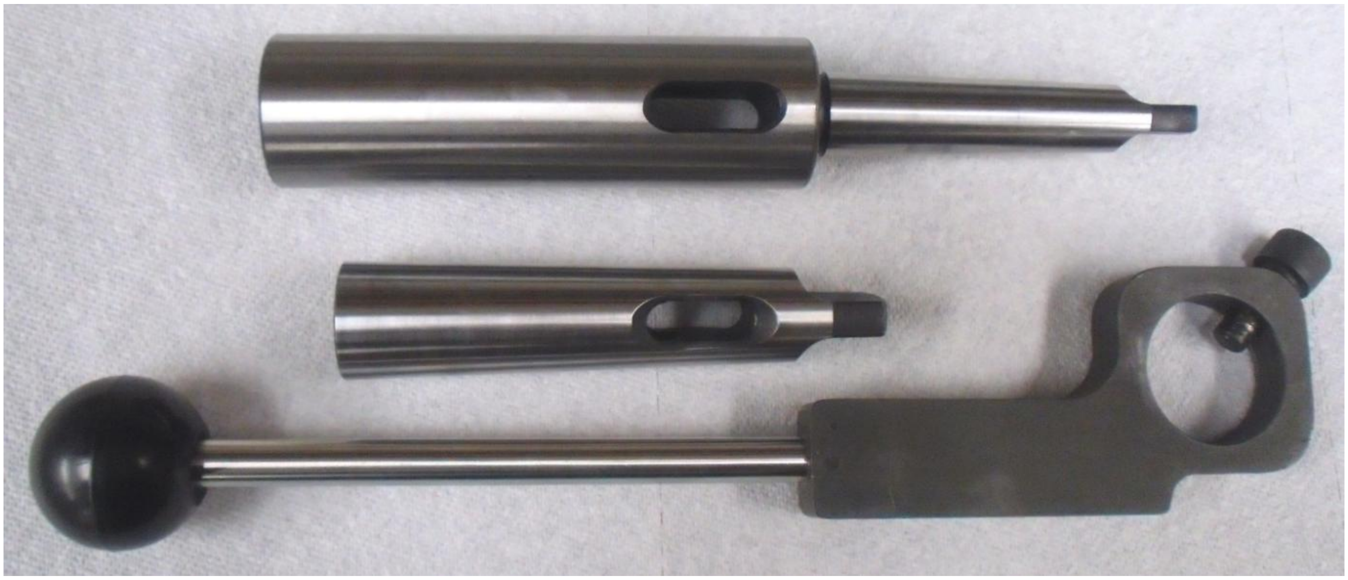
1. Jefferson TB. Metals and How to Weld Them. Cleveland. JF Linc Arc Wld Fdn. 1990. 107-122.
2. [Anonymous]. Advanced Materials: Bulk Metallic Glasses. In: Inst Shock Phys App Sci Lab [Internet]. 2010. Spokane. App Sci Lab, WA St U. [cited 2010 Dec. 5]. Available from: http://www.asl.wsu.edu/site/research/am_bulkMetallicGlasses.html
3. Telford M. Liquidmetal Advocate – The case for bulk Metallic Glass: Liquidmetal in a Nutshell. In: Mat Today [Internet]. 2004 Mar, 7(3):36-43[cited 2010 Dec 5]. Available from: http://liquidmetaladvocate.blogspot.com/2007/11/case-for-bulk-metallic-glass.html
4. Duwez P, Willens RH, Klement WJr. Continuous Series of Metastable Solid Solutions in Silver-Copper Alloy [Internet]. 1960 J App Phys. 31(6).1136-1137. [cited 2010 Dec 5]. Available from: http://resolver.caltech.edu/CaltechAUTHORS:DUWjap60
5. Johnson WL. Bulk amorphous metal – An emerging engineering material. In: J Min, Met and Matls Soc [Internet]. 2002 March. 54(3):40-43 [cited 2010 Dec 5]. Available from: http://www.springerlink.com/content/722m02jl46371785/fulltext.pdf
6. Manufacturing Processes – Physical Vapor Deposition (PVD). In: Eng Hbk [Internet]. [cited 2010 Dec 5]. Available from: http://www.engineershandbook.com/MfgMethods/PVD.htm
7. Chen HS, Leamy HJ, Miller CE. Preparation of Glassy Metals. In: Ann Rev Mat Sci [Internet] 1980 August, 10:363-391 [cited 2010 Dec 5]. Available from: http://www.annualreviews.org/doi/abs/10.1146/annurev.ms.10.080180.002051?journal
8. Reuter B. What is Bulk Metallic Glass? [Internet] 2007 February[cited 2010 Dec 5]. Available from: http://www.content4reprint.com/science/what-is-bulk-metallic-glass.htm
9. Wang WH, Dong C, Shek CH. Bulk Metallic Glasses. Beijing, PRC. Mat Sci Eng Rev. 2004 Feb;44:45-89.
10. [Anonymous]. Sporting Goods and Leisure Products [Internet]. 2010. [cited 2010 Dec 7]. Available from: http://www.liquidmetal.com/applications/dsp.sporting.asp
11. Dye M. Metal alloy making quite a racket (Scripps Howard News Service/Fine Living Network) [Internet]. 2010. [cited 2010 Dec 7]. Available from: http://www.liquidmetal.com/news/dsp.news.030204.asp
12. [Anonymous]. Electronic article surveillance. In: Wik [Internet]. 2010 Dec 3. [Cited 2010 Dec 5]. Available from: http://en.wikipedia.org/wiki/Security_tags.
13. [Anonymous]. Liquidmetal Coatings Industrial Applications. [Internet] 2008. [Cited 2010 Dec 8]. Available from: http://coatings.liquidmetal.com/industrial.applications.asp
14. [Anonymous]. International Space Station Fact Sheet [Internet]. 2010 Oct 19 [Cited 2010 Dec 7]. Available from: http://www.nasa.gov/mission_pages/station/research/experiments/Foam.html
15. [Anonymous].Marshall Space Flight Center Fact Sheet No. FS-2003-09-117-MSFC. [Internet]. 2003 Sep. [Cited 2010 Dec 8]. Available from: http://www.nasa.gov/centers/marshall/news/background/facts/foam.html

Lathe Tailstock Dog

By *Dick Kostelnicek*

Taper shank tools, held in a lathe's tailstock ram, can slip under high torque loads. The ram's tapered socket purposely has no tang slot to arrest tool rotation. A tool's shank must eventually slip in the socket, in order to prevent damage to the key and its slot in the sliding ram. As a general rule, rotational slippage is a problem only for drills, reamers, and threading tools that are much larger in cutting diameter than the mouth of the tailstock's socket.

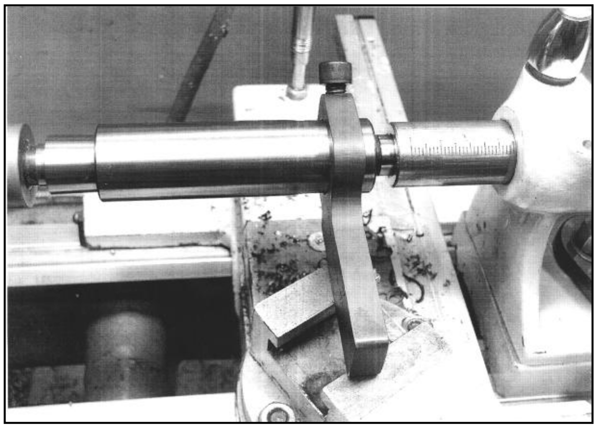
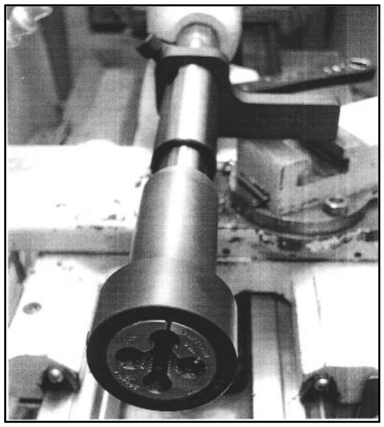
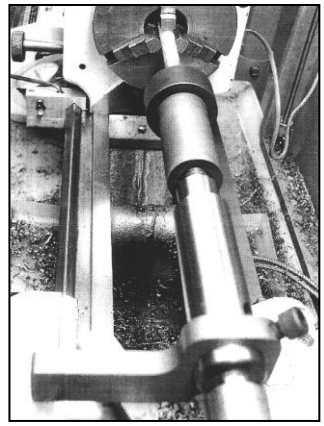
What's needed here is a lathe dog for tailstock tools, similar in concept to that used with a faceplate on the lathe's spindle. There, the dog prevents turned work from slipping and stalling against a cutting bit.



The above photo shows the components of my tailstock dog assembly. It consists of three pieces, of which the first two are commercially available. At the top is a #3-female to #2-male Morse taper extension that is inserted into the tailstock ram. A #3 to #2-reducer (photo center) allows the use of #2-taper tooling. Finally, at the bottom, is my homemade tailstock dog. It slips over than taper extension and locks into its rear tang slot via a Socket Head Cap Screw. That SHCS has the outer threads that engage the slot removed. The dog prevents tool rotation when its arm is supported by of the lathe's compound slide (see photos below) or when the ball-ended extension rod is in held in hand.

Now, someone may ask why I didn't use a #2 to #2-extension and eliminate the need for the #3 to #2-reducer? Well, that's just fine if all your tooling has #2- taper shanks. I have drills, reamers, and die & tap holders that have #3-taper shanks, and my lathe's tailstock ram (Rockwell 9-inch) is fitted with a #2-taper socket. Hence, the #3 to #2- reducer allows my dog assembly to accommodate all my taper shank tooling.

The following pictures show the tailstock dog being used with a large threading die and its holder. When the spindle rotation is reversed to back off the die, I hold onto the ball-ended extension rod. However, a wood block (not shown) placed on the cross-slide just behind the lathe's axis and in contact with the top of the dog's arm, will also provide support during reverse rotation.

The ball-ended extension rod, shown in the photo at the beginning of this article, is constructed from a 3/8-in. D. x 6-in. long SS rod that is threaded on both ends. It screws into both a commercially available 1-3/8-in. D. plastic ball and a threaded hole located on the end of the dog's arm. The dog has been Parkerized to inhibit rusting.