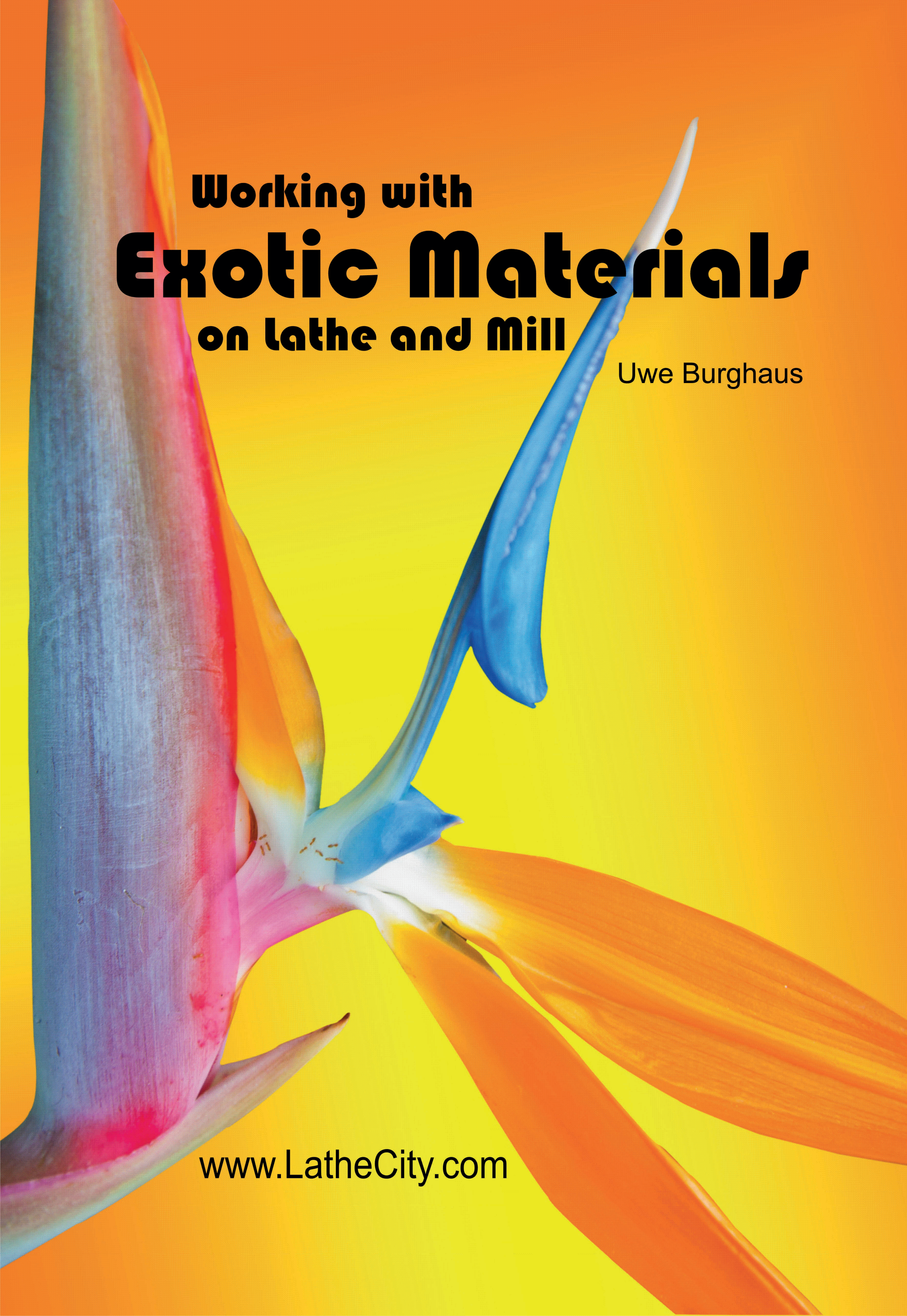
Working with Exotic Materials on Lathe and Mill

Uwe Burghaus



www.LatheCity.com

LatheCity
Safely Working with Benchtop Lathes – Booklet II
Booklet 2 – **Working with Exotic Materials On Lathe & Mill**
1st Ed. January 2012
2nd Ed. July 2012
3rd Ed. February 2013
ISBN-10: 0985136073 ISBN-13: 978-0-9851360-7-9
US Registered copyright: TXu001853168
4th Ed. 2017
ISBN-10: 0-9911530-9-X ISBN-13: 978-0-9911530-9-1
US Registered copyright: pending

www.LatheCity.com **sales@lathecity.com**

Disclaimer

The book has been written carefully and all projects and procedures have been tested thoroughly. However, as always, the author and publisher cannot guarantee that the procedures are perfect and without any mistakes. In addition, it is impossible to predict and prevent all the possible problems someone may possibly run into when working with a lathe/mill. Using a power tool can be dangerous and the proper use is the responsibility of the one who is using the tool. Neither the author nor publisher shall be liable for damage arising herefrom. If you are not perfectly comfortable with working with power tools, then don't do it! In this case, take a metal working class rather than following a do-it-yourself outline. Or, find a different hobby. The author cannot jump in if you make a mistake which results in harming yourself or damaging the tools you use. Don't use half broken or damaged tools, perhaps purchased for cheap at a secondhand store or who knows where. This would be overwhelming to handle in the beginning. Thoughtful work will be your responsibility.

The author makes no representations or warranties with respect to the accuracy or completeness of the contents. The author makes no representations or warranties that the described procedures are best practice.

The author is not a professional machinist or engineer. He is a hobby machinist as you probably are. In fact, the author holds a PhD in physics and teaches physical chemistry at a US college. Therefore, no information provided herein represents professional advice or best practices in machining. All information is provided to help hobbyists and other non-professionals gain a better understanding of using a miniature benchtop (tabletop) lathe/mill for hobby type work.

This book features the Sherline lathe/mill and accessories. However, none of the statements or procedures may coincide with Sherline Inc.'s opinion or interests.

The author is not an employee of, or agent for any of the vendors referenced in the text and does not sell or represent any of the third party products discussed.

Web addresses are given without any warranty or guarantee, web sites may be infected by a computer virus and/or may not provide the best service. Web sites and their content may have changed between the time the author described them in this book and when this book is read. Neither the author nor publisher shall be liable for damage arising herefrom.

You will perform all operations herein described at your own risk in any regard. This disclaimer information is given on our website and it is available before and without purchasing any of our products.

Data such as tensile strength are provided only for reference and not to guide your designs. Any design decisions you make regarding materials are at your own discretion and risk.

This booklet is for advanced hobby machinists and not for the very beginner.

Brief Introductory Note

The Sherline lathe/mill is described in this booklet. However, lathe/mill operations are basically the same on any lathe. If you have a larger system, then you may encounter fewer difficulties than those described here. In addition, I do NOT describe lathe/mill operations as such. Thus, it does not matter which system you may have. Here **lathe/mill work on a variety of materials is described in a generic (mostly system-independent) fashion**. If you are looking for an introduction to lathe or mill work in general, then consider Vol. 1 or Vol. 4. This booklet is for advanced hobby machinists and not for the very beginner.

The section about milling is somewhat short simply because work on a benchtop mill is severely restricted to work on free machining alloys unless one invests in expensive specialty end mills. I did include some notes about these.

Most images illustrate projects rather than showing bare materials. In addition, a few project descriptions are included. I write about unusual materials. The projects are therefore also unusual in nature. However, that’s a matter of opinion.

Second Edition

The 2nd edition of this booklet addresses some of the customer comments we received. In addition, the booklet was reformatted to include pictograms and wider page margins, which make it more appealing. A longer section about millwork was added. The entire text was proofread again, carefully.

Third Edition

Besides small correction here and there, I added a few more descriptions of materials such as free machining stainless steel, solid carbide, and a few tables as well as a long section about materials properties and cutting tools (selecting the right insert, specialty cutters, etc.). Furthermore, text boxes with chemistry type information were added including notes about materials science and nanoscience. If you are interested in that, read the textboxes, if not skip those. Perhaps remember, I am a physical chemist and college teacher … I could not hold back – sometimes. However, all this is written, of course, in plain English.

4th Edition

I did add again more notes about new materials. Also, my lathes and skills did grow. The focus is still, however, on using jewelry type lathes and mills for the machining operation. The main change for this edition: the book is now offered as a professional **paperback print** using the common 6”x9” format. The first editions were produced using desktop publishing, i.e., books were printed as ordered using US letter size paper.

Generic list of pictograms used in the LatheCity books

→

Object of a given chapter / brief introduction.
Start of a project.

Internet

Internet addresses of potentially useful sites. However, web sites may be infected by computer viruses. Use them at your own risk.

STOP

Safety notes. It is not my intention to bother you and this book is meant for adults with advanced machining skills, not for children. Therefore, it's your decision whether you read the safety notes or not. However, don't blame me if you did not take the few minutes to do this and end up in a hospital. All procedures are performed at your own risk.

E

Engineering terms or topics are described here. You may skip these if you are only interested in the operation of the tool. Remember, though, that knowledge also always provides protection (safety), if you know what you are doing... right.

P$_E$

Projects E: Engineering, A: artwork

L/M

Comparison of lathe and mill operations. Most of us started with lathe work, i.e., these comparisons can help gaining a deeper understanding (even of lathe work).

Σ

Summary of the chapters.

Tip: ....

Tips and tricks.

The idea of using pictograms is allowing for fast browsing through the book as well as making it more appealing to read. Only text is hard to digest and boring after a while.

Table of Contents

COPYRIGHT , Disclaimer, Brief introductory note, Generic list of pictograms used in LatheCity books, Table of contents

SAFETY FIRST 13

PART 1: TURNING

Acrylic 27
Alloy Steel 28
Aluminum alloys 29
Aluminum vs. steel 31
Aluminum Bronze 32
Brass 33
Carbide 35
Carbide recycling 38
Cast Iron 38
Cold Pressed Steel C1018 38
Ceramics – Macor 39
Cork 41
Copper 41
Machinable copper 42
Free machining materials 42
Plastics 43
Tips & tricks for machining plastics 45
Rocks 46
Sandwich Structures – Hardened Steel 46
Solid carbide 48
Stainless Steel 50
Free machining stainless steel T-303 52
Sterling Silver 53
Sterling Silver hardening 56
Sterling Silver recycling 57
Styrofoam 57
Teflon 58
Tommy Bars / Spindle Bars / Parallels 59
Grey cast iron 59
Tool steel – A2 61
Tool steel – W1 63
High speed steel- HSS 63
Ledloy, 12L14 65
11L17 67
Magnetic materials (“super” alloys) 68

Pure Manganese 68
Red metals 69
Synthetic spider silk 69
Titanium 70
Wax 72
Wood 74

PART 2: MILLING

Plastics 80
Leadloy 80
Working with steel in a benchtop mill 81
Brass 83
Wood 83
Milling cast iron 84
Tool steel, stainless steel 85

PART 3: MATERIALS PROPERTIES

Cutting tools and cutting materials 87
Cutting tools on a lathe 87
High-speed steel
Carbide turning tools
Inserted tip cutters (inserts)
Standards and nomenclature of turning sets / tool holder
Fast change tool posts
Rake angles
Inserts jungle
Classification of inserts
Grinding wheels
3D printer
Cutting tools on a mill 103
Carbide end mills
Indexable mill cutter
Two flute vs. four flute cutter
HSS tools on a mill
Materials trends and standards 107
What is steel actually?
A few materials trends
A few materials properties
Surface finish 113
Lathe work
Mill work
Chemistry
Saws
Chemistry
INDEX 121

Safety First

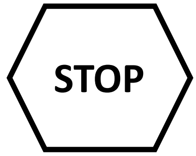


Fig. 1: Safety glasses. Use versions with ANSI Z87 label. ASNI is short for American National Standards Institute. Chemistry goggles, as also shown here, are not recommended for metal work, since they may block the vision too much

Please note that **initially you may be at a higher risk** than folks doing this for living since you will be on your own. Typically hobbyists do not attend safety classes or safety briefings. Therefore, at least read the following.

When it comes to safety the "**buddy system**" is essential. Actually, nobody should work alone with motor tools. This is obviously difficult to organize for a hobbyist. Therefore, you are at a higher risk and have to manage that risk yourself.

However, everyone can learn how to work safely with motor tools. Otherwise I would not offer this type of textbook. In one of the safety briefings I attended, the instructor, a professional machinist, outlined almost proudly how many accidents he had throughout his career ... well ... I still have all my fingers and would like to keep it that way. What about you? Therefore, READ the following general safety notes and hints about how to prepare yourself before switching on your lathe. **PLEASE, take this seriously it only takes 20 minutes.**

Specific safety notes for every procedure are part of every Chapter. Naturally the notes in the beginning are more extensive and become shorter towards the end of the book since I assume that you learn safe working practice along with the operation of your motor tools. (In addition, safety concerns are often similar for different procedures.)

This is one of the main goals and part of the title of this hobby machinist book series: "Safe working ..."

Working at a public university myself, I have to participate regularly in safety classes. However, again I am a hobbyist myself when it comes to metal work. I still have all 10 fingers and two eyes, but there is no legal guarantee that the following notes are complete or even correct. **Read the disclaimer note above.**

- **I did read the safety notes.**
- **I did understand them.**
- **I did read and accept the disclaimer statement.**

- **Use safety glasses** (see Fig. 1). Chemistry goggles, which are also shown here, have the disadvantage that they may block your vision too much which again can generate a safety hazard. You need comfortable glasses and perfect vision. You need to look around. Glasses approved for metal would need to be closed all around the face (at the top, sides, and bottom) and in the U.S. they have the label **ANSI Z87** on them. Some versions additionally block UV light which is better for our eyes.
- At most safety briefings you may come across the term "**situation awareness**", as a general strategy to reduce risks. Knocking over a leg of a storage rack when walking through a metal shop, which carries 500 pounds of steel, would not be it. Heavy footwear is unfortunately very uncommon except in an industrial setting. (We also don't want to overdo it in a hobby shop.)
- Let someone know that you are working in your garage and/or basement. Why? First, you are setting up "a buddy system" in doing so. Second, you are making sure that nobody disturbs you at a critical moment, startling you from behind.

- Have a working phone in reach. Check if your cell phone is working properly in your basement. Where is the closest hospital/emergency room? Emergency number in the U.S. is? Right, 911. At some locations the number may be different.

- Make your shop kid safe. Talk to your kids about the risks. Make sure that they do not sneak around a corner and surprise you when the lathe is running, etc. They often don't see the difference between "playing" and "safe working practices."
- Read the application notes and manuals that came with the tools and/or accessories before starting to use them. Learn the applications and limitations as well as the specific potential hazards of every tool.
- Don't use a tool for a purpose it was not designed for.
- Don't modify a tool yourself.
- Don't push a tool beyond the limits it was designed for. A mini metal lathe/mill is designed to work on small metal stock.
- Don't modify the electrical connections of your tools. Electrically ground all tools. If a tool is equipped a with three-prong plug, then it should be plugged into a three-hole receptacle. If an adapter is used to accommodate a two-prong receptacle, the adapter wire must be attached to a ground connection.
- Don't remove safety guards. Keep guards in working order. (I could tell you stories where a student did exactly that to "save time" and lost several fingers in the process. This is not a joke, but I will spare you the details. Fortunately, I was not involved in this accident, in this case, at a chemistry lab abroad ...) Don't remove safety guards. However, the little safety shields that sometimes come with a lathe provide only very limited protection. Use always goggles, in any case.
- Make it a habit of checking to see that keys and adjusting wrenches are removed from the chuck before turning on any machine. In the case of a lathe, turn the spindle by hand before turning on the lathe

making sure that it runs freely. Don't underestimate the power and torque generated even by a benchtop lathe. A key left behind in a chuck can easily fly off traveling at a significant speed for 10 ft. (3 meters) or more. Full size lathes used to train students professionally are often equipped with **spring lock chuck keys (self-ejecting keys)**. These pop out of the chuck when not pushed down, i.e., it's impossible to leave them in the chuck unintentionally. Typically the chuck key would hit the instructor rather than the student running the lathe which may explain why this feature is eagerly installed in training metal shops. (Don't put your nose over the spindle anyhow.) In any case, just kidding I do like all instructors, safety first. Unfortunately, this type of system is typically not available for benchtop lathes, as far as I know.

This is a long list, but don't blame me if you did not read it and end up in a hospital – as a hobbyist, most

- Cluttered work areas and benches are a safety hazard.
- Do not use power tools in damp or wet locations. This can be an issue for garage or basement shops. Solve the problem if it exists at your location.
- Keep work area well illuminated. This is extremely important for safety issues and any proper work. Do you need new glasses?
- All visitors should be kept at a safe distance from the work area.
- Again make your workshop kid proof. Use padlocks, master switches, remove starter keys. This is of particular concern for hobby work, correct (?) I would in principle encourage you to awaken the interests of young adults for practical and creative work. Fortunately, perhaps in this case, many of them prefer to play dull computer games instead. However, teaching young adults to work with metal tools is particularly difficult and a major safety hazard for everyone involved in this process. At least don't do this in the very beginning. You must be very confident yourself, first. Make sure that they are old enough and have no access to the tools alone.
- Again, do not force tools or attachments to do a job for which they were not designed. Use the proper tool for the job.

- Avoid loose clothing, necklaces, gloves, or jewelry that could become caught in moving parts. We all know this, but taking care of it every day is another thing.
- By the same token, fluffy cloth appears to attract small cut off metal pieces like a magnet. They stick deep in the fabric and can scratch you fingers and skin.
- Wear protective head gear to keep long hair styles away from moving parts! If you would like to see a sad story in this regard, go to:
  http://blog.makezine.com/archive/2011/04/yale-student-killed-in-lathe-accident.html
  http://www.nature.com/nature/journal/v472/n7343/full/472259a.html
  It takes milliseconds to pull you into the running chuck if something gets caught in the chuck. A benchtop system is safer in this regard than a full size system, I guess, but … (A lathe running at 1600 RPM makes 26 RPsec or ~40 milliseconds - 0.040 sec - for one revolution.)
- Use safety glasses i.e. goggles designed for metal work. Yes, this is on the list more than once.
- Use a face or dust mask if cutting operation is dusty.
- Keep your proper footing and balance at all times. Wet floor? Cable? This is dangerous.

Fig. 2: Full face shield with plastic foil that need to be peeled off

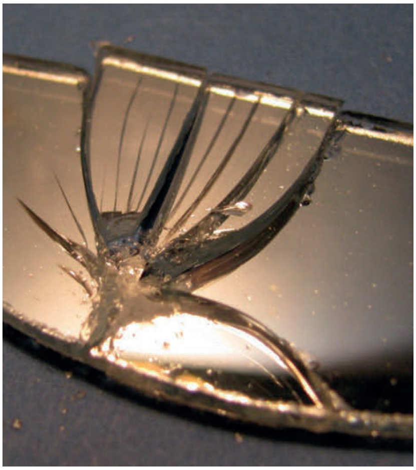
- When using a metal grinder you will generate sparks. Use a full face shield and goggles for these operations. Make sure not to have lots of cardboard boxes, gas containers for you snow blower / lawnmower, paint, solvents, etc. in your basement or garage hobby shop. The sparks generated by grinders or metal saws can ignite a fire. It may start to burn long after you left the shop … Full face shields often have a plastic foil on the shield which needs to be peeled off. Otherwise the shield may not be transparent (Fig. 2) – just a note in case you didn't realize. (I have seen students running around …)

- Keep tools sharp and clean for best and safest performance. Follow instructions for lubrication and changing accessories.
- Use clamps or a vise to hold work. It is much safer than using your hand and frees both hands to operate the tool. This is more of an issue for the use of a drill press, milling machine, or saws than for a lathe, but it must be included here.
- Use only recommended accessories. Read the manual carefully and completely. Use of improper accessories may be hazardous.
- Unplug tool before servicing and when changing accessories such as blades, bits or cutters. Definitely.
- Make sure switch is "OFF" before plugging in a power cord. Double check.
- Again turn spindle by hand before switching the motor of the lathe on. This ensures that the work piece or chuck jaws will not hit the lathe bed, saddle or cross-slide, and also ensures that they clear the cutting tool.
- It is not recommended that the lathe/mill be used for grinding**.** The fine dust that results from the grinding operation is hard on bearings and other moving parts of your tool. For the same reason, if the lathe or any other precision tool is kept near an operating grinder, it should be kept covered when not in use. I do occasionally use a polishing sponge (safer than sandpaper) to polish pieces, but I don't overdo it.
- Make sure that all locking and driving attachments are tightened. However, also be careful not to over tighten these adjustments. They should be just tight enough. Over tightening may damage threads or warp parts, thereby reducing accuracy and effectiveness.
- Don't allow long stock pieces to stick out far in back of the spindle of the lathe. Long, thin stock that is unsupported and turned at high RPM can suddenly bend and loop around.

- **Wear proper safety glasses.** All folks working for a living in metal shops can unfortunately tell you stories such as this one: a piece of metal hit the backside of glasses (somehow) and the reflected piece hit the eye of the machinist. They had to pull the piece out of his eye in a hospital. This is not a joke. You need safety glasses specified for metal work, even if you wear optical glasses. You need glasses fully closed at the sides, the top, and bottom. Goggles that fit over optical glasses are often not very comfortable and restrict the vision. These are better than nothing, but you can purchase safety glasses with optical lenses. If you work every day in your shop, then invest the money to purchase really comfortable and safe glasses. Your eyes are worth the investment.

- This may sound as a talk to a teenage girl/boy, but ... you need proper eye protection before you switch on the lathe/mill for the first time. Safety glasses are perhaps the most important safety feature in a metal shop. Don't start without them with any work on a lathe/mill. Any home improvement store carries them.
- Don't work when you are tired. Rushing home, having a heavy dinner and a few beers, and then going down to the basement shop in your house … obviously not a good idea. Don't do it. Metal work requires your full attention, even if it is a hobby.
- You may realize that the fingers of the machinist are really close to the spindle when cutting certain shapes, in particular when you eventually polish pieces. The edges of the chuck are sharp and turn at perhaps 1800 RPM. It would cause very serious injuries when hitting the rotating chuck with your fingertips. Sherline also offers a tool post for polishing (P/N 8976) which I did not, however, use myself. Polishing operations on the Sherline lathe are, by the way, not recommended by Sherline, mostly due to issues of metal dust which may end up in the motor controller box causing shorts. In addition, a dust mask is generally required for all sanding/polishing operations.

Using a sanding sponge is somewhat safer than using sand paper for polishing since you can even touch the chuck with the sponge and the fingertips are still at an o.k. distance. Sanding sponges are available in any home improvement store.



- Mill cutters are not like lathe tools, they are indeed sharp. End mills are more like a knife or sharp saw blade. Thus, be careful. Recommended is typically not to touch mill cutters directly with your hands. Instead use a rag.
- Never leave a machine running while unattended.
- By the same token, if you experience a power failure switch off the machine (and/or set RPM to zero) since when power is restored machine may start up unintentionally. Considering the rather unstable power lines in the U.S. this does indeed happen.
- If you experience unexpected and/or unusual difficulties using the machine. Stop and get advice (call customer service etc.). Don't ignore difficulties, solve the problem.
- One last thing. Please be aware of that you will carry chips (small cut off metal pieces) with you all over your house. Don't ask how – chips stick to everything, somehow. Aluminum chips are rather soft and mostly "harmless", but steel chips are sharp as razor blades. Never clean up chips with your bare fingers, never.

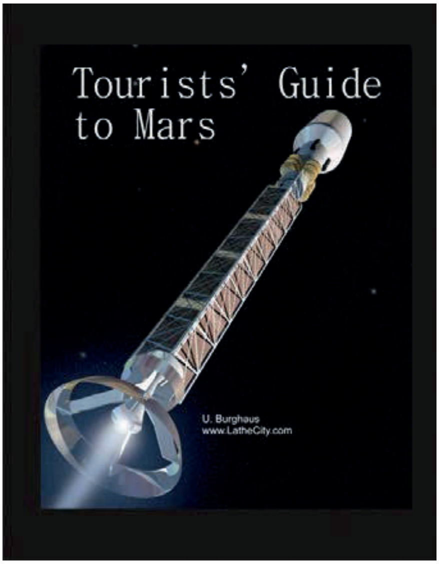
Safety notes can also be found on various web sites, a few links are given here:

http://www.mini-lathe.com/Mini_lathe/lathe_safety.htm
http://www.zeraware.com/
http://www.americanmachinetools.com/how_to_use_a_lathe.htm
http://www.fricknet.com/lp/safety_posters.php?gclid=CPTW6ZfFhaYCFQTNKgodFQoIpA

Safety products can also be purchased on-line, for example, perhaps look at:

http://www.envirosafetyproducts.com/product/magnifying_safety_glasses_magnifying_safety_glass

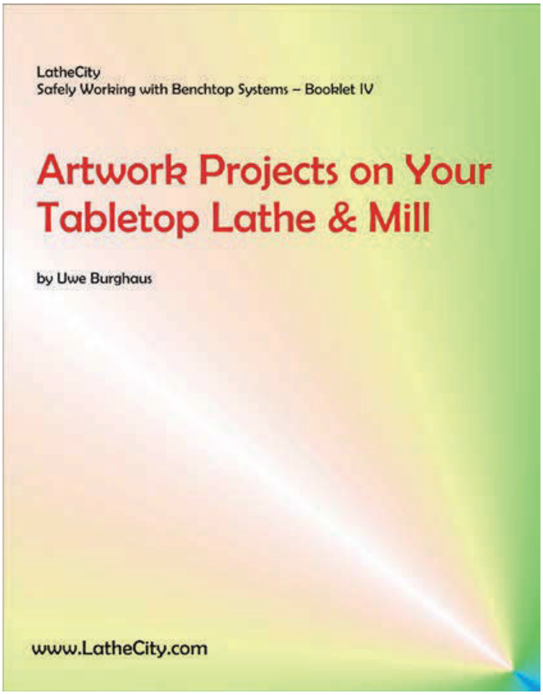
Please note again that this kind of list can never be complete. In addition, different shops have different safety practices. What is OK in one location may get you fired in another. The list here is written for hobbyists and not for professionals in a commercial metal shop. For example, at some locations you may not be allowed to enter the shop without 50 lb. safety shoes on your feet and safety glasses on your nose while crossing the shop on the way to the bathroom or something. (Usually an insurance, “workman’s compensation..” requirement.) Since you will be on your own, “situation awareness” (don’t do dangerous nonsense) is probably the most important concern and of course use safety classes for metal work when running your machine.



Looking for another hobby? Did you ever consider a trip to Mars? The planet Mars. It does become cheaper year after year, though. If you do, we recommend this brief guide that covers everything from the launch, over a smooth cruise, to the soft landing and, of course, growing potatoes (in-situ resource utilization) in just 150 pages. All that you need to know for your trip—all inclusive.

This is the real deal, a serious guide, however: the physics of interplanetary travel, rendezvous maneuvers, transfer orbits, and why astronauts float are explained by a college professor, in plain English. All the nitty gritty details are included, too. How to make O_2 and fuel on Mars? Life-support systems, communication, and navigation—how does that work? Why should we go there in the first place, and who will likely be first? Buckle up and join the ride.

Part 1
Turning

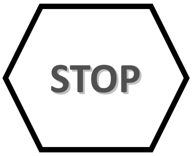


Another LatheCity book; try it out.

The world beyond aluminum – lathe work

Fig. 3: Cut-off chips. Left to right: cold pressed/rolled steel, aluminum, brass. The shape of the chips depends not only on the materials, but also on a large number of other factors including the turning speeds, depth of cut, rake angle of the insert, etc. You can find "chip maps" in engineering books, detailing what turning speed and cutting depth results in the most easy to handle chip type. Here for aluminum and brass a HSS tool was used (and for the steel a brazed carbide cutter), with 2800 RPM and 0.020" (0.0010" for steel) as the cutting depth. The feed rate is difficult to control on a manual lathe. Chip breakers are in use, preventing the chips from wiggling up around the part and blocking the cutting operations. Chip breakers are just geometric features worked into the insert – nothing too exciting. I have been told, however, that production engineers change the materials rather than the cutting conditions to avoid issues with chips

→ **Object:** Irrespective of the small size of a tabletop lathe, you can cut basically "anything" on a good small lathe. (Read the chapter about safety, first.) How to accomplish that is discussed in this book.



After you have gained some experience, you typically start experimenting with more exotic materials. However, be careful and expect (bad) surprises when using exotic materials.

The wrong plastic can melt easily or breaks like glass, steel chips (Fig. 3) can be very hot burning your skin as hot oil splashing out of a cooking pan, stainless steel chips can be very sharp, too soft wood crushes/splinters, etc. In any case, be careful and at least use safety glasses.

I would suggest starting to experiment with materials in the following order of increasing machining difficulties: plastic → brass → cold pressed/rolled steel → tool steel → stainless steel → specialty materials

Experiment with small diameters (O.D. ¼”, 6.35 mm) and short pieces (2” or 50.8 mm) first. Use safety glasses.

The following is an alphabetic list of rather pragmatic and practical suggestions for working with a variety of materials, written by a hobbyist. As always, you will work on your own risk – read the disclaimer statement and the general safety notes. Materials may be toxic or carcinogenic, read the MSDS (Materials Safety Data Sheet). Some materials are flammable or may generate toxic fumes or dust, i.e., safety equipment may be required. When using (special) cutting tools, read the application notes and/or manuals which come with these tools. Some materials cannot be cut on a lathe, including glass rods. Disregarding this can be very dangerous. In the following I do assume advanced machining skills – the procedures described here are not for very beginners. If you have just started to work with a lathe then get volume one of this book series first.

Fig. 4: Left) Machining a 2” acrylic solid round; Center) Here to replace a broken oil cup of a vacuum turbo pump; Right) SIEG lathe

Acrylic (transparent plastic)

Usually one needs a project to work on wired stuff. The story here is as follows. One of my students broke a plastic oil cup for a turbo vacuum pump (Fig. 4) by overtightening screws that hold the thing. Well, too bad. Now, it turn out the piece cost $150 from the vendor of that pump. Kidding me? Besides that, I was really low on funding for my lab – I am a Pchem college professor (mentioned before). The oil cup is made of some kind of transparent plastic just to see the oil level for the pump. Probably mass produced by injection molding. The most common machinable plastics are Acetal, Nylon, and Teflon; described below. None of these are transparent. There are actually not too many transparent and machinable plastic types easily available as stock material. Acrylics turned out to be pretty much the only transparent plastic we could purchase and the vendor labeled it as machinable: use carbide tool was recommended. Indeed, the stuff is easy and perfect to machine, actually better than Acetal. A piece large enough for that oil cup did cost me $20. By the way, acrylic is apparently also used by some artists to carve templates for prints. Or, you have likely seen the show about the fish tank fellows in Las Vegas - they use acrylics.

Machine acrylic with standard tools such as carbide lathe tools and HSS drill bits. It remains nearly transparent without much polishing. It is very easy to work with, it does not overheat much. Cutting oil is not really required. In the meanwhile it is my favorite plastic.

One can find the following at the retailer's website: Color: Clear; Temperature Range: 0° to 150° F; Tensile Strength: Excellent; Impact Strength: Poor; Meet UL 94HB for flame retardant; made from FDA-compliant resins; Rockwell Hardness M94-M103. Available in small amounts from e.g. McMaster-Carr.

Fig. 5: Morse #0 taper (for Sherline) as extensions of the tailstock spindle cut from SAE 4140. See vol. 1 for details about how to cut a Morse taper, or perhaps get the LatheCity angle protractor (Morse taper/arbor cutter)

Alloy steel

What is typically available is "alloy 4140" or **SAE 4140** (Fig. 5) which is a chromium-molybdenum steel. Apparently, its machinability depends very much on the hardening procedure used. Typically it is sold as cold drawn and annealed steel, which has "good" machinability on a lathe, as I read somewhere. It has a higher strength than cold pressed (or cold rolled), low carbon steel varieties (see below). In my experience, this alloy steel is quite difficult to cut on a benchtop lathe. The tip of HSS cutters, for example, is ground off in about 30 seconds when using a somewhat larger cutting depth. Hobby machinist type brazed carbide cutters work o.k., but don't give a nice finish, in my experience. Using inserted tip carbide cutters (inserts) or inserted tip ceramic cutters works well assuming that the work piece is running perfectly true: the smallest vibrations and the cutter chatters. Use a 4-jaw independent chuck or this will not be fun, in my experience. On my own machinability scale (scale of unpleasant stuff to work with), alloy steel has a top (most unpleasant) ranking. You will soon develop your own machinability scale. On a larger lathe with better chucks and more torque one can cut this steel OK.

Aluminum type	**Price for 1 ft. of O.D. 0.5”**	**Hardness**	**Tensile Strength**
2011-T3	$2.51	B60	55 kpsi
2024-T351	$3.28	B75	70 kpsi
2024-T4	$2.38 (O.D. 0.4375)		
2024-T851	$5.85 (OD 0.75)		
6061-T651	$2.64	B60	45 kpsi
6061-T6511	**$1.10**		
6063-T52	$2.60	60	27 kpsi
6262-T6511	$1.86 (O.D. 0.56)	71	32 kpsi
7075-T651	**$3.68**	B87	83 kpsi

Tab. 1: On-line prices in 2012 are depicted. Not all varieties are available in various diameters. Note also that the price does not evenly scale with the diameter, i.e., some varieties become suddenly quite expensive in larger diameters, who knows why? Thus, if price is the main issue, one has to look it up precisely and also compare different vendors. Consider the total price including the shipping costs which also vary widely. The price seems to scale with the tensile strength and hardness. (No guarantee that these numbers are perfectly correct.)

Aluminum alloys – 6061 / 7075

Aluminum is widely used for its good machinability, high strength-to-weight ratio, and basically no corrosion occurrence since the surface is protected by a transparent aluminum oxide layer. Casting and wrought aluminum alloys are distinguished. Different labeling systems are used: xxxx-Xxxx vs. xxx.x for wrought vs. cast aluminum alloys. Casting aluminum alloys are tailored towards the casting manufacturing process (pouring a liquid metal into a mold/template), e.g. their melting temperatures are lower than those of wrought aluminum alloys. Wrought aluminum is typically used for hobby type applications. The first 4 digits specify the composition of the alloy, similarly to steel. For example:

6000	series includes magnesium and silicon
7000	series is aluminum alloyed with zinc
2000	series are aluminum alloys including copper

The symbol following these numbers specify the heat treatment used in the production. For example:

F	as fabricated (which I have never seen)
H	cold rolled
T	heat treated (most common type for hobbyists)

Aluminum alloys available in small quantities on the hobby market include:

6061-T6	(Perhaps the most common, it is an aluminum-magnesium-silicon alloy, it is solution heat treated and artificially aged. It has good machinability including good welding properties.)
2024-T351	(Aluminum-copper-manganese, not weldable, that version apparently corrodes, average machinability, high strength.)
6061-T6511	(Aluminum-manganese-silicon, general purpose aluminum alloy, good weldability, tensile strength about half of 2024-T351.)
7075-T651	(Aluminum-zinc, high strength.)

Brinell hardness of about 60 is common for most Al varieties, but it can be as large as 150. Variations in the yield strength are more significant (20 kPSI to 50 kPSI) as well as corrosion properties, and weld ability.

All aluminum alloys I have worked with so far can be cut easily using HSS lathe tools although these are not too common anymore also not for hobbyists.

Detailed outlines of the metallurgy of aluminum can be found. You may want to check out:

http://en.wikipedia.org/wiki/Aluminium_alloy
http://www.aluminum.org/
http://www.matweb.com/reference/aluminum.aspx

Internet

http://www.hmwire.com/aluminum_alloys.html
http://www.alfed.org.uk (look for "Aluminum Federation")

Fig. 6: Test cuts and chips of aluminum bronze

Aluminum vs. Steel

Most hobbyists work with tabletop-size machines due to space limitations. At some point one starts to machine own accessories and has to decide what materials to use for that purpose. LatheCity often offers the same tool in aluminum and steel, following customer's requests. However, typically I mention the following to our customers.

Yes, you want a steel piece, high quality, durable, bla ... However, would you mount tires rated for 220 mi/h on a Volkswagen? You can, certainly, and at least you would have good tires. No offense, but UNIMATs/Sherlines/Haber Fright are really small benchtop systems. In most cases, an aluminum adapter would do just fine. Steel is more expensive not that much because of greater materials costs, but solely because of greater labor (work hours) costs. Also, tooling costs are greater. Therefore, steel pieces are more expensive. Consider, perhaps, that most Sherline accessories, genuine from Sherline, are machined from aluminum - often they don't even mention this.

Aluminum adapters don't rust and are typically fine for the occasional use by a hobbyist. We do use aluminum screw-on type end mill holders in a quasi-production environment for years by

Index

A

A2 – tool steel, 62
Acetal, 43
Alloy steel, 28
Aluminum alloys, 29
Aluminum vs. steel, 31
Aluminum bronze, 32
Aluminum-nickel-cobalt, 67
American Society for Testing Materials (ASTM), 60, 70, 108
AR, 70
AL, 70
AISI, 38
ANSI, 106
ASTM, 60, 70, 108
Austenitic stainless steel, 53

B

Brass, 33
Bronze, 33
Bronze vs. Brass, 33-box
Brinell, 66
Brazed cutter, 89
BR, 70
BL, 70
Brazing, 89, 90

C

Casting, 29, 59
Carcinogenic, 26, 40
Casting aluminum, 29
Carbide, 34
Carbide end mills, 75
Cast iron, 38
CBN, 36
Cold welding, 32
Crucibles, 36
Ceramics, 40
Ceramic inserts, 61, 90
Cold pressed/ rolled steel, 25, 38
Cork, 41
Copper, 41, 42
Chip thickness ratio, 109
Chip, 110
Chemistry sets, 115
Chili exploding, 73
Chipbreakers, 98
CP GRADE 70
Customer Corner, 120

D

Delrin, 43, 79
Dead soft, 54
Diamond drill bits, 36
Disclaimer, 5, 14, 26
Die steel, 64
DuPont, 58

Dykem, 115

E

E clip, 47
EDM, 36
Electric discharge machining, 36

F

Face shield, 17
Fast change tool post, 92
Ferritic steel, 53
Free machining materials, 42, 52, 103
Free machining stainless steel, 52
Finish, 112
Full hard, 54
Filled wiring, 55

G

Gray cast iron, 106
Grain structure, 108

H

Hardening, 56, 62
Hardness, 109
HSS, 63
High Speed Steel, 63
High carbon steel, 88, 106
Hot rolled, 66
Half hard, 54
Heat-Harden, 56

I

Inserts, 89, 90
Inscribed circle, 97

J

Jewelry, 53

K

Kiln, 56
KF flange, 58

L

LASER, 48
Leadloy, 65,67
Lead angle, 95

M

Manganese, 68
Macor, 39
Martensitic steel, 53
Machinability index, 32, 66
Makrolon, 44
Metallic solid solution, 106
Micrometer, 47
Morse taper, 28, 48

Molecular beam epitaxy, 51
MSDS, 73

N

Nanoscience, 34, 63
Nylon, 43
Nickel alloys, 111
Nickel-silver, 54

O

O-rings, 58
Orthogonal cutting model, 94

P

PCBN, 36
PCD, 36
Plastics, 43
Plain steel, 80
PTFE, 58

Q

Q.F. flange, 58

R

Rake angle, 94
Reamers, 63
Reduced vibration mills, 104
Rocks, 46
Rockwell, 28, 109

S

Saws, 116
SAE, 38
Sandwich, 46
Safety, 9, 13
Safety glasses, 13
Sheet metal gauge, 56
Solid carbide, 35
Soft materials RPM, 56
Solidification shrinkage, 60
Soldering, 90
Stainless steel, 46, 50
Sterling silver, 53
Sterling Silver Recycling, 56
Sterling silver hardening, 56
Styrofoam, 57
Suberin, 40
Super alloys, 67, 111
Surface finish, 113

T

Taylor tool life equation, 66
T-303, 38
Teflon, 38, 46
Tips & tricks, 39, 63, 79
Titanium, 52
TiC, 68
TE, 70
Turning sets, 70
Tool life, 51
Toner cartridges, 52

U, V

Vacuum chamber, 43
Vickers Hardness, 46

W

Wax, 72
Wood, 74
Wiedemann-Franz, 46
Wrought aluminum, 31
Wire gauge, 47

X, Y

Yield strength, 108

Z,

4-jaw independent chuck, 30
A2, 48
6061, 31
7075, 31
2011-T3, 29
2024-T351, 29
2024-T4, 29
2024-T851, 29
6061-T651, 29
6061-T6511, 29
6063-T52, 32
6262-T6511, 32
7075-T651, 32
C36xxx, 34
1018, 38
C1018, 38
C360, 38
12L14, 65
T-303, 52
SAE 316, 50
UNS S31600, 41
T-304, 41
PTFE, 48
6Al-4V ELI, 54

Uwe Burghaus, born in West Berlin, Germany, obtained his education in Physics and Physical Chemistry at the Free*) University of Berlin. He graduated with PhD in 1995, after conducting projects on surface science topics at the Fritz-Haber Institute of the Max Planck Society in Berlin. After postdoctoral positions in Genoa (Italy) and Santa Barbara (USA), he went back to Germany to complete a habilitation (German tenure) in Physical Chemistry. At North Dakota State University, he started to establish a surface chemistry group in 2003 and obtained tenure in 2009. His group is currently focusing on studies about nanostructured catalysts. (His research/university home page is at www.uweburghaus.us if this is interesting to you.)

He is not a professional machinist by training. However, his hobby developed into a small part-time business in 2012. LatheCity currently sells books about metal work (and other topics), software tools, and lathe/mill accessories for tabletop systems: everything that's fun to make and may find customers. The strength of the business is custom-designed tools. Stop by at www.LatheCity.com

*) *It's (still) called "Free University" not because we don't need to pay tuition in Germany (education is indeed free!), but because it was located in the western part of Berlin (West Germany), as opposed to East Berlin ("the Russian sector"). The FU Berlin was founded with the help of the US after the end of the 2nd world war – Google the details, please. (I got a few funny e-mails and did add this note …) LatheCity books are unfortunately not for free, sorry – I also live in the US now …* ☺

www.LatheCity.com

www.LatheCity.com