Disclaimer

The book including the software has been written carefully and all projects and procedures have been tested thoroughly (on a Sherline CNC lathe with EMC2). However, as always, the author and publisher cannot guarantee that the procedures are perfect and without any mistakes. g-codes although tested may include mistakes. In addition, it is impossible to predict and prevent all the possible problems someone may possibly run into when working with a lathe. 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. I 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 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 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) CNC lathe for hobby type work.

This book does not replace Sherline's manuals and/or safety notices. This book does not replace knowledge, training, and/or experience in machining.

This book features in particular Sherline CNC lathes and accessories. However, none of the statements or procedures may coincide with the manufacturer'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.

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Quick Glance
Short Summary of Chapter Contents

Preface
Why do you (?) need a CNC book? Why CNC lathe and not CNC mill for a start?

THE BASICS

1. **Introduction**
   EMC what? - Enhanced Machine Controller
2. **First things first – required safety notes – how to work safely?**
   Please take the 15 min and read this
3. **Benchmarks – facts in a nut shell**
   Read this if you are not sure what CNC system to purchase & what options Sherline does offer? What about other vendors?
4. **What you had better not do**
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5. **Just arrived – getting the CNC lathe set up**
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6. **& 7 Backlash correction / Headstocks / Spindles**
   Engineering background not only CNC related but important, zero backlash ball bearing lead screws, low TIR collet headstock, etc.
8. **My first CNC program – using MDI**
   Simplest way to try out g-code is using a line editor / debug mode which is called MDI - Manual data input
9. **How to run a CNC program directly**
   Managing and running g-code files in EMC (Enhanced Machine Controller), turning operations, absolute/relative coordinates, sub programs, messages comments, features not even mentioned in Sherline's manual
10. **EMC graphics interface & g-codes (summary)**
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PROJECTS

Table of Contents

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Generic list of pictograms used in www.LatheCity.com books

▶ Object of a given Chapter/brief introduction. Start of a project. The Chapter numbers are given in the contents list.

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, whether you read the safety notes or not is your decision. However, don't blame me if you do not take the few minutes to do this and end up in the 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're doing... right.

P$_E$ P$_A$ Projects: engineering/artwork projects

L/M Comparison of lathe and mill operations. Most of us started with lathe work, that is, these comparisons can help gaining a deeper understanding (even of lathe work).

Σ Summary of the Chapters. See contents list for Chapter numbers.
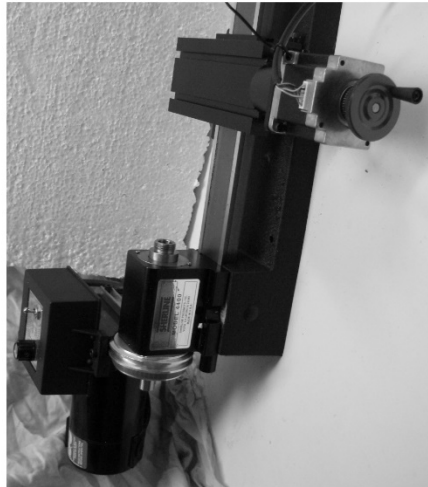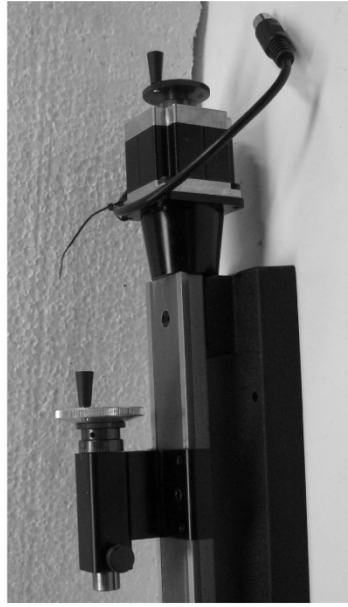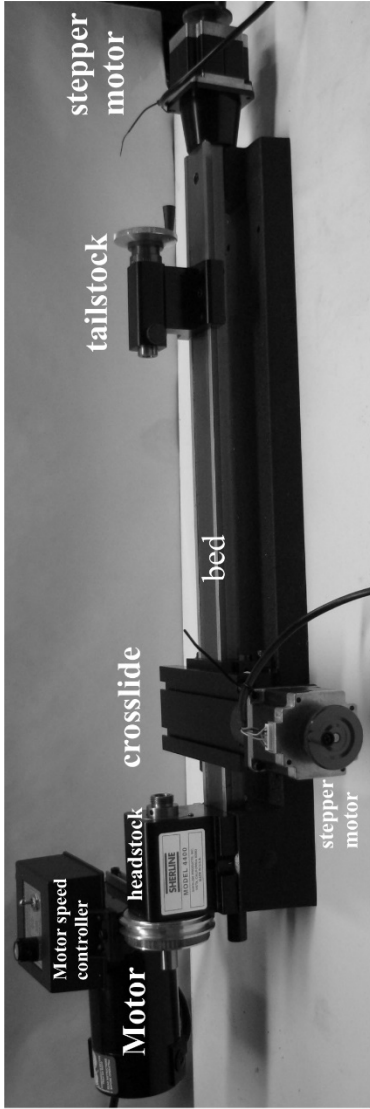
Preface

Why CNC?

What is possibly the motivation of getting a jewelry size lathe as a CNC system which does not even allow for automatic drilling or thread cutting?

      The answer is certainly individually very different, but may include the following thoughts.

- It is a relatively cheap system, in particular when you have already a mechanical lathe and just upgrade to CNC.
- I have not had the space to place a larger system anywhere.
- I did purchase the mini CNC lathe mostly for learning CNC: it was a training system for me.
- Even with a small system, shapes and project become do-able which wouldn't without it.
- The machining precision and consistency increases.
- In the meanwhile, I actually use CNC commercially making some parts for www.LatheCity. Using CNC increases dramatically the throughput, reduces the costs, and/or increases the profit even for a micro-business. I easily got that investment back in.
- Actually, one can add automatic drilling and even thread cutting with some self-made upgrades and/or non-Sherline accessories.
- I have had a CNC mill already, then it costs close to nothing to CNC an existing mechanical lathe.
- Unfortunately, CNC projects come with their own difficulties and limitations which require re-learning a few details.

For what do I need a book for?

- Sherline's don't provide a manual for the CNC lathes just for the mills. That one you have even to print by yourself.
- Just getting in touch with CNC without actually spending lots of $ on the wrong system. The book costs only <$40; a complete CNC lathe package >$2000.

- Won't like to brows from one website to the next, getting a little piece of information here a little there, having a comprehensive book in the fingers is still the real deal.
- Most/all CNC websites are for full size system, these codes and examples don't run directly on a mini CNC lathe.

Why CNC lathe and not CNC mill?

Generally lathe work is a lot simpler to learn than milling. Machinists often consider it as trivial since you have only "two" directions (lead screw, crosslide). The same holds true for CNC lathe work: it's probably the simplest way to get started with CNC. Now, you can reuse the CNC lathe hardware (stepper, controller) and mount it on a mill in case you want to continue with CNC mill work some time later (*vice versa*). If computers and programing is not really your thing, I would urge you to start with a CNC lathe rather than a CNC mill. Also, if you are rusty on manual mill work (see Vol. 4: "*Tabletop Milling*"), don't start CNC milling, it's not getting simpler just because you hook up a PC. You should have (advanced) machining skills before starting with CNC operations. In fact, a small mill poses quite severe machining limitations, a small lathe can even cut tool steel – not a big deal (see Booklet 2: "*Working with Exotic Materials*"). You can write rather sophisticated CNC lathe programs by yourself. Contour milling, engraving, etc. using a mill, requires realistically anyway specialty software which is an entirely separate game.

> **FAQ?** *What is g-code?*
> ➔ A simple computer language to program your stepper motors.

1. Introduction

Who would like to argue with Joe Martin (see box to the left), in particular, when describing his CNC machines? Yep, you won't need to be a computer guru, but it would be important if you would have experience with a mechanical lathe before starting to work with a CNC lathe. That's probably the only requirement to use this book successfully. At www.LatheCity.com we do offer introductory lathe books which also feature Sherline's mechanical lathes. However, this book just describes **CNC** lathe operations and assumes that you have at least basic machining skills. The so-called **g-code** you will use to control the lathe just has ~15 commands. It's probably the simplest "computer" language ever designed. Thus, if you can find the "on switch" on your PC, that's about what you need to know about computers.
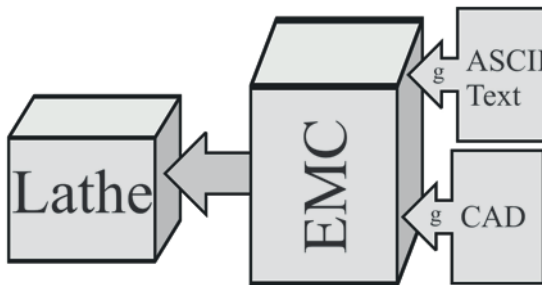
Fig. 1.1 The basic setup

EMC (Enhanced Machine Controller) is the program that controls the stepper motors that will move the cutting tools on the lathe. It was developed by NIST (National Institute of Science and Technology) which is federally funded. That program was released at no cost to the public. Therefore, it has to be provided for free also by Sherline to their customers.

One just needs to generate a simple text file including that g-code and feed it into the EMC program to start making parts (Fig. 1.1). You can do that by typing the commands in a simple text

editor or using sophisticated 3D CAD/CAM programs that generate g-code directly from a drawing. I will walk you through these processes step-by-step, starting with simple projects and of course the start-up of the CNC lathe.

Sherline provide a manual together with their systems, but it's written for a CNC mill and does therefore not

> **FAQ?** *What skill do I need for CNC?*
> ➜ Manual machining knowledge
> ➜ Controller know-how
> ➜ g-code skills

include much direct information for using a CNC lathe. A training DVD from the same source costs sixty-some dollars (in 2015), well, perhaps try our book first - you can find internet movies for free. As far as we are aware of, this book is currently the only one available for Sherline's CNC lathes. You probably can manage without a book, but the start will be easier with some help. In addition, a number of useful g-code programs are included. You can either use these as such, or modify them for your application. That's much simpler than starting from scratch. These files can also be downloaded from our website at

http://www.lathecity.com/CustomerCornerMain.php

Now, let's get started and see what the postal service just dropped off. Guess what? Sherline's CNC starter lathe package.

How to read this book? If you are totally new to CNC then read Chapters 1-10 one by one. I describe how to set up the system and how to write simple g-code programs. You may skip Chapters 6&7 if you are in a hurry. Later Chapters basically describe more advanced projects.

Chapter 10 details briefly the EMC program and g-codes and stands pretty much on its own similarly to Chapter 9 which discusses basic g-code commands. If you are familiar with CNC, but not with the Sherline system, then focus on Chapter 10 and probably the projects in Chapter 11-16.

If you are not sure whether to purchase a (Sherline) CNC lathe, then read Chapter 3.

2. First things first – required safety notes – how to work safely?

Fig. 2.1: 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.

STOP

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 subchapter. 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 and I am at present (2015) in fact the safety liaison for our chemistry department. 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.**

- **Use safety glasses** (see Fig. 1.1). 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.
- 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.

> **This is a long list, but don't blame me if you did not read it and end up in a hospital – most likely on a weekend.**

- 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 safety glasses, 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.
- 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?

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

- 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:

  Internet

  http://www.nature.com/news/2011/110418/full/472270a.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. 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.

- When using a metal grinder you will generate sparks. Use a full face shield and safety glasses 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

Fig. 2.2: Full face shield with plastic foil that need to be peeled off

shield may not be transparent (Fig. 2.2) – 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 crosslide, 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. 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.
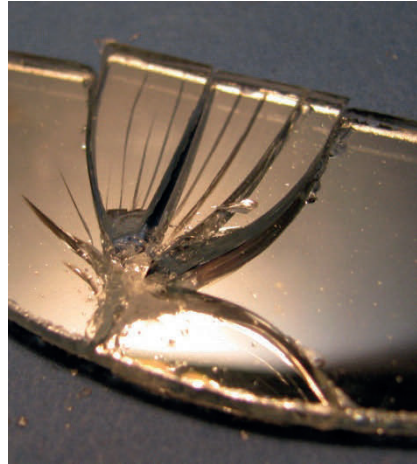
- This may sound as a talk to a teenage girl/boy, but ... you need proper eye protection before you switch on the lathe/mill for the first time. Safety glasses are perhaps the most important safety feature in a metal shop. Don't start without them with any work on a lathe/mill. Any home improvement store 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 on a mechanical lathe, 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.

- 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, also not a **CNC lathe**. For example, drive belt suddenly rips apart, but the stepper motors are still running. This can cause major damage. More examples exist.
- 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 perhaps mostly "harmless", but steel chips are sharp as razor blades. Never clean up chips with your bare fingers, never.
- **CNC lathe emergency switch.** Switch off the controller. That's the fastest way to stop the running CNC program and the Sherline lathe.
- Don't use accessories that don't run true.

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.

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

Internet

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

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FAQ? *Are conventional machining skills still useful?*

➔ Certainly. You can probably start CNC machining with little background in manual machining, but there are still projects that will require these good old skills such as machine maintenance, repairs, prototyping, "polishing-up" something, etc.

FAQ? *Usually I make only a single part. Why should I learn CNC - I don't own a business.*

➔ Soon you will speak g-code as English. Thus, even making only 1-2 parts will become appealing due to higher accuracy and speed. And again, it is simply timely to have at least some basic CNC skills if you are interested in machining. Consider it as an educational enterprise.

3. Benchmarks - facts in a nut shell

Sherline's CNC options

Retrofit kits: upgrade a mechanical lathe/mill to CNC

CNC ready: mechanical lathe/mill with stepper motor mounts, nothing else

CNC packages: complete CNC systems except a monitor (that's odd, no idea why they don't include a screen), they have various packages which deviate by some (over-priced) tooling packages

As usual one has the choice of a short or longer lathe model.

Software

Linux: The newer Linux version that will come with your CNC package is very similar to Windows except that's free, no license fees for Microsoft. It is a quasi "real time" system that allows for multi-tasking which is ideal for computer controlled machinery. You may know the little Eee PC laptops sold for $100 - these run with Linux, too. Microsoft Windows and power point etc. run on these computers - no problem. (The penguin Tux, the Linux Mascot is from Mascothttp://en.wikipedia.org/wiki/Linux#mediaviewer/File:Tux.svg and is freely licensed for commercial or private use. Authors are Larry Ewing, Simon Budig, Anja Gerwinski)

EMC2: Enhanced Machine Controller, free open source CNC control program.

Other options? Various other 3rd party CNC systems are on the market which uses Sherline hardware. Some of these run with Windows, one allows CNC thread cutting (see Chapter 17). If high end software/hardware and thread cutting is important to you then do some research, a 3rd party system may then be better for you than Sherline's CNCLinux package. Sherline's sell lathe/mill hardware and specialize on that. They don't provide CNC software or specialty CNC controller. Perhaps try this link http://www.sherline. com/cncdlrs.htm which includes a list of vendors. See also the appendix to this book.

Documentation? Close to non-existing, in my opinion, not directly from Sherline. Only an online manual about CNC milling is currently available (Dec 2014). Although the CNC package cost ~$2,300, you will not even get a printed manual from Sherline, you need to print the on-line CNC <u>mill</u> manual by yourself. However, a print which is mostly a parts catalog came with the system I purchased. I really like Sherline, but I don't understand this, anyway good for LatheCity, we provide the books. An assembly and instructions guide that explains how to put the lathe headstock together is provided as well as two pages about stepper motor and backlash compensation - that's it. I got my CNC lathe package in Dec. 2014.

Some more specs.

Tailstock spindle	Morse taper 0 (reduced length)
Headstock spindle	Morse taper 1, 10 mm hole through spindle, ¾"-16, TIR 0.0005", two 20 mm bearings
Swing over bed	3.5"
Swing over crosslide	1.75"
Distance between centers	17" (or 8")
RPM	70-2800, variable
Weight	30 lb.
Headstock motor	90 VDC, DC motor

Sherline CNC machines do not have limit or HOME switches; no PC control of spindle speeds; no tailstock control (drilling); no CNC thread cutting.

Summary

Σ

The simplest way to get started with CNC is to go for a complete CNC package e.g. from Sherline. That is a plug and play solution – pretty much. Go from here, I would suggest. Perhaps, sell it at eBay after playing with the setup for a while – Sherline's CNC shop is for the most part a starter hobby type system. If you have already experience with CNC then you may seriously consider some of the 3rd party products rather than Sherline's CNC controller. LinuxCNC is not the only option (Mach3, G540, VFD, etc. – google it).

Appendix

g-code that can be used on Sherline's lathe

g0   rapid positioning (see Chapters 8, 9)
g1   linear interpolation (see Chapters 8, 9)
g2   circular/helical interpolation (clockwise) (see Chapter 12)
g3   circular/helical interpolation (counter clockwise)
        (see Chapter 12)
g18 xz plane selection (see Chapters 8, 9)
g20 inch system selection (see Chapters 8, 9)
g21 metric/millimeter system selection (see Chapters 8, 9)
g40 *cancel cutter diameter compensation*
g41 *start cutter diameter comp. left*
g42 *start cutter diameter comp. right*
g43 *tool length offset (plus)*
g49 *cancel tool length offset*
g90 absolute distance mode (see Chapters 8, 9)
g91 incremental distance mode (see Chapters 8, 9)
g92 reset HOME position (see Chapter 16)
g92.2 go back to original HOME position (see Chapter 16)

Many more g-codes exist, but these can't be used on Sherline's mini CNC systems with EMC2. As obvious, this is a simple language and simple implementation of it on Sherline's lathe.
Complete list http://en.wikipedia.org/wiki/G-code

g-code parameters
x   x-coordinate, crosslide
z   z-coordinate, lathe bed,
f   feed rate, the larger the faster
i   x-offset for arc command, g2, g3
k   z-offset for arc command, g2, g3
r   radius for arc command, g2, g3

EMC commands, M code

(msg, writes a note in the message box of EMC program window

EXAMPLE (msg, change to tool #3 and press resume)

→ will display "change to tool #3 and press resume" in the message box. Resume is s on the keyboard.

m2 End program

m0 Program stop

% Start / end program code, optional for EMC2

(debug, Prints numerical data on screen, see Chapter 9.11

(..) Comments can be enclosed in brakes and will be ignored

; Characters after a semicolon are comments

Nxxxx Line numbers will be ignored

o100 **sub**   start subroutine 100

o100 **endsub**   end subroutine

o100 **call** [0.2] [0.2]   pass data to subroutine

g0 x[#1] **z**[#2]   read parameters in subroutine

Code groups

Grouping g-codes makes it probably easier to find the one you need. Shown here are only those available with EMC2/Sherline on a lathe.

Movements: g0, g1, g2, g3, g80, g81, g82, g83, g84, g85, g86, g87, g88, g89

Plane selection: g17, g18, g19

Distance mode/coordinates: g90, g91, g92, g92.2

Units: g20, g21

Cutter diameter compensation: g40, g41, g42

Tool length offset: g43, g4

Most important g-codes with parameters

g1 x z f   x-coordinate, z-coordinate, feed speed; on larger machines g01 can also accept I and k parameters for chamfering, that does not work with EMC

g2 x z r f   x-coordinate, z-coordinate, radius, feed speed

g3 x z r f   x-coordinate, z-coordinate, radius, feed speed

g2 x z i k f   x-coordinate, z-coordinate, offset, offset, feed speed

g3 x z i k f   x-coordinate, z-coordinate, offset, offset, feed speed

Useful links

> You can find all links on our web site, go to
> http://www.lathecity.com/CustomerCornerMain.ph

http://en.wikipedia.org/wiki/G- code#Abbreviations_used_by_programmers_and_operators List of CNC bubble terms
http://www.sherline.com/CNCmenu.htm *download of Sherline CNC manuals*
http://www.sherline.com/8400pg.htm *Specs of Sherline CNC lathe, scroll down to the bottom*
http://linuxcnc.org/docs/EMC2_User_Manual.pdf
http://www.sherline.com/8760pg.htm

> **Internet**

CNC thread cutting for Sherline lathe

http://www.cadcamcadcam.com/ *commercial*
http://www.cadcamcadcam.com/latheencoderkit.aspx
http://www.imsrv.com/deskcnc/lathe/desktopcncthreading.pdf
http://www.dakeng.com/threading.html *self-made system*

Linux and EMC

http://wiki.linuxcnc.org/cgi-bin/wiki.pl?LinuxCNCKnowledgeBase
http://www.linuxcnc.org/

G-code

http://en.wikipedia.org/wiki/G-code
http://www.sherline.com/gcode.htm *g-code list*
http://carlsonmfg.com/industrial-resources-articles/18-cnc-code-programming *g-code list*
http://gnipsel.com/linuxcnc/index.html *on-line book*
http://www.cnccookbook.com/CCCNCGCodeCourse.htm *on-line book*

http://www.cnccookbook.com/CCCNCGCodeBasicLatheProgramming.html *online book-lathe section*
http://www.deskcnc.com/
http://en.wikipedia.org/wiki/G-code complete list
http://wiki.linuxcnc.org/cgi-bin/wiki.pl?Simple_LinuxCNC_G-Code_Generators g-code generators

Internet movies
https://www.youtube.com/results?search_query=Sherline+CNC+lathe search for movies
http://www.youtube.com/watch?v=Q92C9xd9Ybw intro from Sherline
https://www.youtube.com/watch?v=C8zwXztmpEc thread cutting on Sherline's CNC lathe

Journals
http://www.homeshopmachinist.net/home
http://www.gasenginemagazine.com/
http://www.model-engineer.co.uk/

CNC controller for small machines
http://www.imsrv.com/
http://www.imsrv.com/imservice_controller_model.htm

Startup procedure
Read Chapter 5, briefly:
- Connect stepper motors to controller
- Turn on PC
- Start EMC2
- Switch on controller
- Quick test of stepper motors using jog mode

Shut down procedure
Read Chapter 5, briefly
- Switch controller off
- Exit EMC2 program (File>Quit)
- Exit all other programs
- Exit computer (System>Shut down)

Abbreviations & Glossary

ACSII	American Standard Code for Information Interchange
CAD	Computer aided design
CAM	Computer aided manufacturing
CNC	Computer numerical control
NIST	National Institute of Science and Technology
EMC	Enhanced Machine Controller
NC	Numerical Control, historic version of CNC systems
g-code	Simple programming language for CNC machines, RS-274-D US norm for g-code, also G-code or Gcode.
M-code	Common code to program CNC machines, EMC can also interpret a few of these.
Jog-mode	EMC program command to "manually" move a particular axis, see Chapter 10
USB	Universal Serial Bus used for mouse, flash drives etc.
Controller/	
driver	Hardware (individual circuitry) that controls the stepper motors. On/off switch is on the left side of the PC or on the external driver box.
Linux	Operating system, modern versions look and work very similar to Windows, e.g. double click will open/start a program.
.ngc	File extension, EMC2 program format
.txt	ASCII text format
Ubuntu	Linux version, a Windows like version
Backplot	Test a g-code program without actually running the machine, the path of the cutting tool will be displayed.
SD, LD	Small diameter, large diameter
e.g.	For example
cf.	See, cf. Fig, see Fig
MDI	Manual data input one can type g-codes directly
HOME position	X=Y=0
gedit	Linux text editor; Applications>Accessories>Text Editor
GIMP	Free graphics program, GNU Image Manipulation Program

relative coordinates or incremental mode g91 mode, from my
chair to the window are 3 steps, from there 2 steps to
the wall

absolute coordinates g90 mode, my chair is at x=0, y=0, when I go
to x = 2, y=2 I hit the wall

tool path On a lathe strictly it is the path of the center of the
tool nose radius. In the meanwhile I use only carbide
inserts, the one I use have a sharp tip. Therefore, the
path of the cutter and tool path are identically.

DXF Drawing exchange format, usually vector draw
programs such as CAD software generate that file
format, the tool path may be saved in that format.

Bit map Data formats that include BMP, GIF, JPEG, TIFF e.g. a
scanner generates these

G-code interpreter EMC2 would be one, the software used to
communicate with the controller hardware and servo
motors

DeskCNC ™ Software tool generating g-code

Cutting air Test running CNC programs, run g-code with the
machine off, usually my first test after checking the
backplot of the g-code.

Modal commands A g-code remains in effect unless it is replaced
(over-written) by new code. Therefore, one does not
need to retype, for example, g01 all the time, but just
the coordinates. Or, a feed rate stays in effect unless a
new f command is entered. In MDI mode every enter
key will basically cancel a running process, replacing it
with a new g-code command, see Chapter 8.

Cut & past For assembling a g-code you may use cut and paste
commands (SHIFT C, SHIFT V) to put different code
segments together, often also repetitions and be generated
in that fashion, sure that is simple.

Spindle preload Axial force is applied between the inner and outer
races of bearings in order to remove axial and radial
clearance. Thus, the preload reduces the spindle TIR.
The force is generated, for example, by a nut on the
backend of the spindle which pushes the spindle
against the races of the bearing. Have a look at these
links http://www.sherline.com/ preload.htm or http:
//www.nmbtc.com/bearings/ engineering/preload/

Further reading

Just by browsing Amazon and eBay one can easily find 100 books titled "CNC..". But, most of these focus on CNC mills with perhaps a few notes about lathe work; I could not find a single one featuring Sherline tools. Kindle editions and on-line distance-education classes are booming, i.e., printed text books are not the only option anymore. Anyway, there is not much out there for CNC lathes, hobbyists, and Sherline. Therefore, given here is only a short list of books that may help you to develop your skills further. At least I used these books together with many own projects and test runs: learning by doing. The following is only my opinion, form your own. Prices are on-line prices from Oct. 2014.

Sherline various on-line manuals which are basically close to useless for CNC lathe operations, just my opinion, focus is on CNC milling, not very pedagogical, many g-codes that actually work on their machines are not even mentioned in their own manuals

On-line books try http://gnipsel.com/linuxcnc/index.html this is very good but very brief and not Sherline specific, most of the g-codes used don't run on a small Sherline CNC system, anyway: have a look; it's still very useful and it's free

Digital Machinist from Village Press, 1 year (4 issues) subscription for $14.95 (2014), low price, perhaps good for getting in touch with the community, but usually very specialized articles, I have not seen anything Sherline/EMC specific, mostly an advertisement journal which we also use for www.LatheCity.com Ads

Poor Man's CNC Lathe this is our volume 3 from www.LatheCity.com books, ISBN-13: 978-0-9851360-4-8 ; ISBN-10: 0985136049, book + DVD for ~$50 (Factory direct), $4 shipping (media mail), also at eBay & Amazon, self-published, it is a user-friendly Windows software package that allows for calculating slice tables for various shapes (ball ends, taper, parabolic shapes, etc.), the programs do not generate directly g-code, I may add this at some point, but you can save the slicing tables in ASCII (readable with Linux) and convert these to g-code rather easily, we have a free demo version, try it out, go to http://www.lathecity.com/ Books/Volume3/ Vol3Page.html The package includes a spiral bound manual (book, 95 pages, printed tables, projects, etc.) and a data DVD with several Windows programs.

Easy CNC from D. Benson, self-published, I guess, ISBN none, $34.95+$13.96 = $48.91 (shipping to me via UPS ground!), rudimentary description of g-code, focusses on 3-axis CNC

(mill), mostly a description of software tools, it was of little/no use to me, but it's probably the trend in CNC, use tools, learn software tools rather than learning g-code programing or machining. Well, I don't know, every book adds a little something. That one here provides an introduction into the world of CNC software tools. (11 pages about CorelDraw are included, why?) However, the author focusses mostly on one software tool DeskCNC™, the company that apparently made it, sells also his book. (The same company sells a CNC system for Sherline lathes that allows for thread cutting.) All examples are about wood engraving on a mill, no kidding. Available e.g. at

http://www.cadcamcadcam.com/bookeasycncbydavidbenson.aspx

CNC Trade Secrets   from J.A. Harvey, Industrial Press, ISBN 978-0-8311-3502-7 for $25.41 (in 2014), full color print, low price, mostly trivial notes about CNC milling, nice picture book though, but new information content useable for me close to zero, I sold it at eBay after a few days reading – I could not find any Trade Secrets in that book and I was a very beginner in CNC when I had it in my fingers. Sorry.

CNC programming handbook from P. Smid, Industrial Press, 2008, 3rd Ed., ISBN 978-0-8311-3347-4, 540 pages, hardcover, + CD, $54 (in 2015). The book is advertised basically as "the CNC bible". It's a college style book targeting engineering students and it is indeed very academic. It is a solid book, I guess, but an over-kill for any hobbyist. My main concern, the book appears not to include any complete examples. G-codes are discussed, program segments are given, example "segments", etc., but that's in my opinion not good enough to start learning CNC, also not for engineering students. Many commands discussed won't work on a small CNC machine. If you are an engineering student with advanced CNC skills then go for it and get a copy of this book. Otherwise, save the $54. It is a handbook, indeed, not a tutorial. (I have it on the shelf for looking up things now and then.)

See also the various websites listed above.

LatheCity books   www.LatheCity.com

Vol. 1: Basic Lathe Operations (2nd Ed.)^{S}
Vol. 2: Working with Lathe Accessories ^{S}
Vol. 3: Poor Man's CNC Lathe*
Vol. 4: Tabletop Milling (2nd Ed.)$^{S, G}$
Vol. 5: CNC Benchtop Lathe^{S}

Booklet 1: Thread Cutting on a Lathe (4th Ed.)^{S}
Booklet 2: Working with Exotic Materials on a Lathe and Mill *
Booklet 3: Summary of Basic Metal Lathe Operations *
Booklet 4: Artwork Projects on Benchtop Lathes and Mills *
Starting an On-line / E-commerce Small Business - 7 Step Guide

Some project booklets/manuals are also available.

Volumes in preparation:
Vol. 6: Tabletop China Import Lathes*

^{S}: Featuring Sherline systems
^{G}: Featuring Grizzly systems
*: Completely model independent
(All books include model independent information and generic graphs.)

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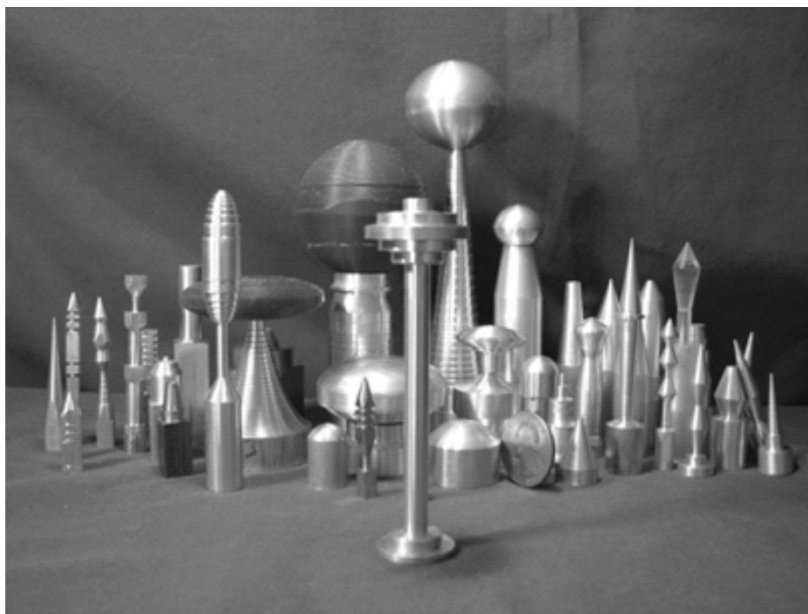
Uwe Burghaus, born in West Berlin, Germany, obtained his education in Physics and Physical Chemistry at the Free University of Berlin. He obtained a PhD in 1995, after conducting his graduate studies in surface science at the Fritz-Haber Inst. of the Max Planck Society in Berlin. After postdoctoral positions in Genoa (Italy) and Santa Barbara (USA) he went back to Germany to complete a habilitation (German tenure) in Physical Chemistry. Now 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. He is not a professional machinist by training. However, in 2012 his hobby developed into a small part-time business. LatheCity sells currently books about metal working including software tools as well as accessories for mills and lathes: everything that's fun to make and may find customers. The strength of the business is custom designed/ customized tools.