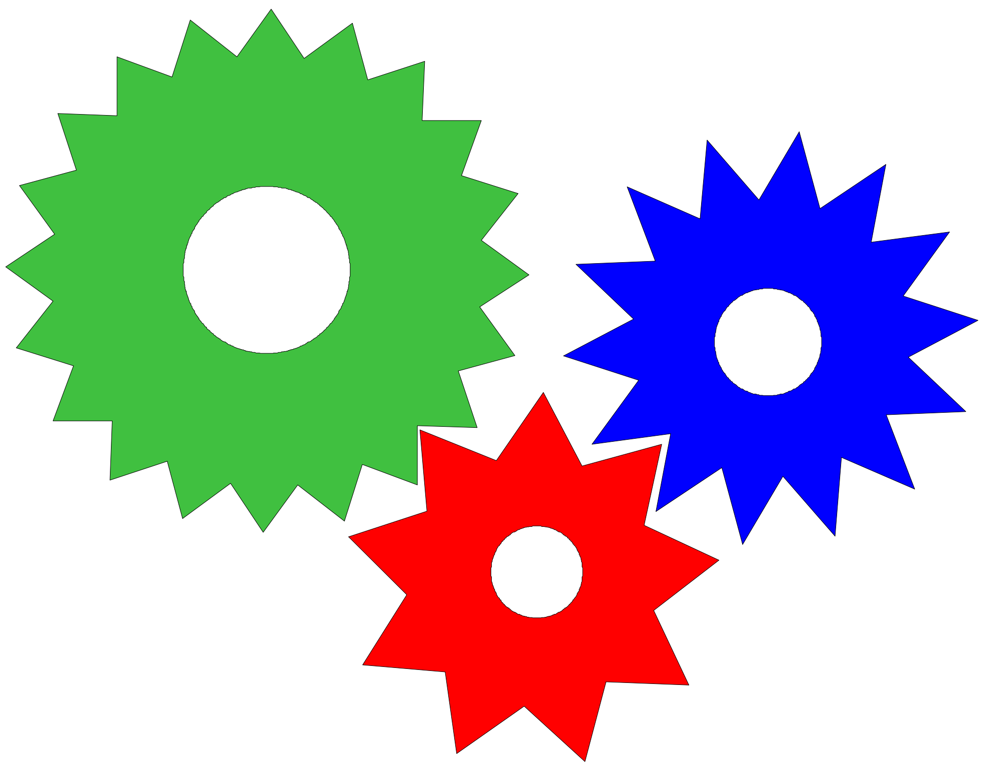
Machinability Survival Guide



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UNDERSTANDING MACHINABILITY

- Defining Machinability

- SMS Quality Considerations

- Screw Machine Terms and Definitions

- Complaint Response Understanding the Metallurgist

DEFINING MACHINABILITY

“The machinability of a metal is similar to the palatability of wine - easily appreciated but not readily measured in quantitative terms."

Rod, Bar and Wire

Understanding Machinability

CUSTOMER DEMANDS

*Has an alloy and temper been specified
*Does the finished part have any tight tolerances
*Are there any surface finish requirements
*Is the OD of the rod used in the finished part
*Are there any secondary machining operations
*Any government or customer specifications

SHOP CHARACTERISTICS

*What kind of screw machines are being used
*What type of coolant is being used
*How established is the shop in the marketplace
*What type of tool material do they use
*How clean is the shop
*Is it a lob shop or captive shop

SMS QUALITY CHARACTERISTICS

*Does the chip size cause you any problems
*Are they able to meet the dimensional tolerance
*Are they able to meet surface finish requirements
*Is the current tool life acceptable
*Is the product consistent from load to load
*Is diameter length and straightness acceptable

DEFINING MACHINABILITY

One of the most important items that needs to be determined when visiting an end user of screw machine stock is the type of characteristics of the rod or bar they are looking for. In other words, what is important to them with respect to quality and machinability of the rod or bar. Determining their requirements is key to knowing whether they will perceive our product as having "good machinability".

The term machinability needs to be emphasized. Machinability is **not** strictly chip size and tool life. There are three categories of variables that can influence a customer's perception as to whether our products have good or bad machinability. These categories are:

THE DEMANDS THE CUSTOMER PLACES ON THE METAL.

THE CHARACTERISTICS OF THE SCREW MACHINE SHOP.

THE QUALITY CHARACTERISTICS OF THE ROD OR BAR.

The demands the customer places upon the metal are usually determined by the screw machine shops end customer. These demands are typically applied to dimensional tolerances, surfaces finish requirements, and any other items that would be normally listed on a blue print or in a specification. The characteristics of the screw machine shop comprise of items such as the type of machine being used, the type of cutting fluids and the type of cutting tools. The quality characteristics of the rod encompass things such as straightness and dimensional control.

Listed below are specific factors from these categories that determine the machinability of the screw machine stock.

Part Design

Cutting Tools

Coolant

Operator Experience

Type of Screw Machine

Rod Diameter Control

Lot-to-Lot Consistency

Production Rates

Feeds and Speeds

Alloy and Temper

Customer's Perception of Supplier

Rod/Bar Straightness

Surface Quality/Finish of Rod

Resulting Chip Size and Tool Wear

A good definition of machinability that will help keep all of this in perspective is: **"That combination of material properties and external machining parameters which affect a material's response to removal by a cutting tool."**

In the following section the three categories of variables that influence machinability have been assigned questions that either need to be asked, or at least need to be aware of, when trying to determine a customer's definition of machinability.

CUSTOMER DEMANDS

Has an alloy and temper been specified?

If an alloy and temper has not been specified then the end user typically prefers to use 2011-T3 because of its superior machining characteristics. However, if the part is to be used in a critical end use then the machining characteristics become secondary and end use performance becomes the major concern.

6XXX series are usually chosen because of the superior corrosion resistance, weldability and ease of anodizing. Non-2011 2XXX series and 7XXX series are typically specified when high strength is required or when very good surface finishes are needed.

Are there any unusual tolerance requirements on the part?

This will obviously be determined by the end use of the part. However, certain characteristics of the final part lend themselves to special tolerance concerns. These characteristics are typically thin walls, very long parts and deep drilled holes.

The TX51 tempers provide the superior dimensional stability needed to produce parts requiring exceptionally tight tolerances.

Are there any surface finish requirements?

Again the need for extremely good surface finishes will be dictated by the end use of the part. A customer will typically be required to achieve a specified surface finish requirement by meeting a maximum RMS value. RMS stands for "root mean square" and are the units generated by the use of a profilometer. Use of a profilometer consists of a stylus, similar to a record player, being pulled across the surface while the amount of up and down motion in the stylus is being recorded. The higher the RMS number, the rougher the surface.

From a product standpoint the rule of thumb is: The higher the strength of the aluminum, the better the resulting surface finish will be. This means that bright and smooth surface finishes from 6XXX alloys are harder to achieve and maintain than for 7XXX alloys.

Is the outside mill finish being used in the part?

More end users are utilizing the OD of the rod or bar in an attempt to reduce material costs and machining time. As we know this has always been the case for hexes and shapes but this is a relatively new trend with round stock. The limitations an end users faces in the use of the mill finish in the part are two fold. First the tolerance of the rod OD must be able to meet the part blue print tolerance requirements. Secondly, the surface finish of the rod OD must be able to again meet print requirements and also be relatively unmarked by processing and handling damage.

Are there any secondary machining operations?

A secondary machining operation is typically necessary when the configuration of the part exceeds the capabilities of the screw machine. Most screw machine shops will do as much machining as possible on the screw machine because of its higher productivity rates and lower costs.

More tolerance of inherently poor machining alloys can be found during secondary operations. Since productivity is generally not an issue at this stage of part fabrication the machinability differences between say 2011 and 7075 begin to close. Again it will be determined by what demands are being placed on the material during secondary machining.

Are customer specifications being called out?

It is important to be aware that there often are special requirements, beyond part dimensions, surface finish, etc., that an end customer of a screw machine shop may require. These may be grain size requirements, special chemistries or non-standard tensile properties. All of these items will affect the way the metal must be fabricated and the way it will machine in the screw machine.

SCREW MACHINE SHOP CHARACTERISTICS

What types of screw machines are being used?

There are basically three types of screw machines available to the end user - single spindle, multiple spindle and Swiss type. These machines can either be mechanically or computer controlled. The best description of the each type of screw machine can be found in the Terms and Definitions section.

What type of coolant is being used?

There are several important functions a coolant plays during the screw machine operation. These functions are:

- Cooling the part and tools.
- Lubricating the machine and the cutting edges.
- Flushing chips away from the tooling.

The biggest enemy to tool life is heat build up during the machining operation. The coolant attempts to take this heat away so that longer tool life can be achieved. The coolant can also have lubricating properties. Some screw machines rely on this property to keep certain moving parts lubricated. The lubricating properties of the coolant also help to improve the surface finish of the part. The velocity and pressure of the coolant is used to flush chips away from the cutting edges. This minimizes the problems associated with chips getting in the way of tool movement.

There are 2 categories of coolants used in screw machining - water soluble and oil base. The water soluble coolants provide the maximum amount of heat removal and are characterized by being light in color and having a low viscosity (not thick). On the other hand water soluble coolants do not have strong lubricating qualities. This will tend to result in more wear on the machine. Oil base coolants are more viscous (thicker) and are darker in color. They do not have the cooling ability of water soluble coolants but do offer superior lubricating characteristics.

How long has the screw machine shop been in business?

Generally if the screw machine shop has been in business for a very long time, you can be more certain that the information coming from them is valid and that they have a fundamental understanding of how each of the aluminum alloys and tempers will respond in their operation. An established shop will also have more experience and more expertise at the machine operator level which can be a valuable asset when trying to determine the root of a customer's machining problem.

Does the customer machine other metals?

If the screw machine shop is involved in difficult to machine metals such as stainless steel of nickel base alloys then they may perceive aluminum, regardless of alloy, as the most machinable, and easiest, material they have ever worked with. This can be easily done by observing their inventory racks.

What kind of tooling is being used?

There are two types of tooling that are used in screw machining - high speed steel and carbide. High speed steel is characterized by being softer and less expensive than carbide. As a result of this cutting tools made from high speed steel are typically used in short duration machining jobs where tool life is not a critical concern. Carbide tools are very hard, brittle and expensive. Since they are so hard they have a significantly longer life than high speed steel. This makes them particularly suitable for long duration jobs.

Most tools can be made from either carbide or high speed steels. However high speed steel is widely used in the production of drilling tools. Their complex shapes makes it difficult to be made from carbide.

<u>How clean is the shop?</u>

This can sometimes give you an immediate impression of the quality of products, processes, services and information that are associated with that screw machine shop.

SCREW MACHINE STOCK QUALITY CHARACTERISTICS

Are the resulting chips causing any Problems?

Depending on the type of machine and the tooling arrangements chip size may or may not be a problem. Machines that are spacious and do not have an "overcrowding" of tools are less likely to have problems even from stringy chips.

Chip collection on the other hand is almost always affected by chip size. Small, broken chips will easily clear tooling and be efficiently accumulated prior to disposal. Stringy chips tend to get caught in tooling and because of their size and shape do not accumulate in an efficient manner. Sometimes additional manpower is required to help in the handling of the chips.

Are tolerance and surface finish requirements being met?

In many instances this is more important than chip size or tool life depending upon how strict the requirement. Once again good machining material is defined by what the end user expects to get out of the product.

Is the current tool life acceptable?

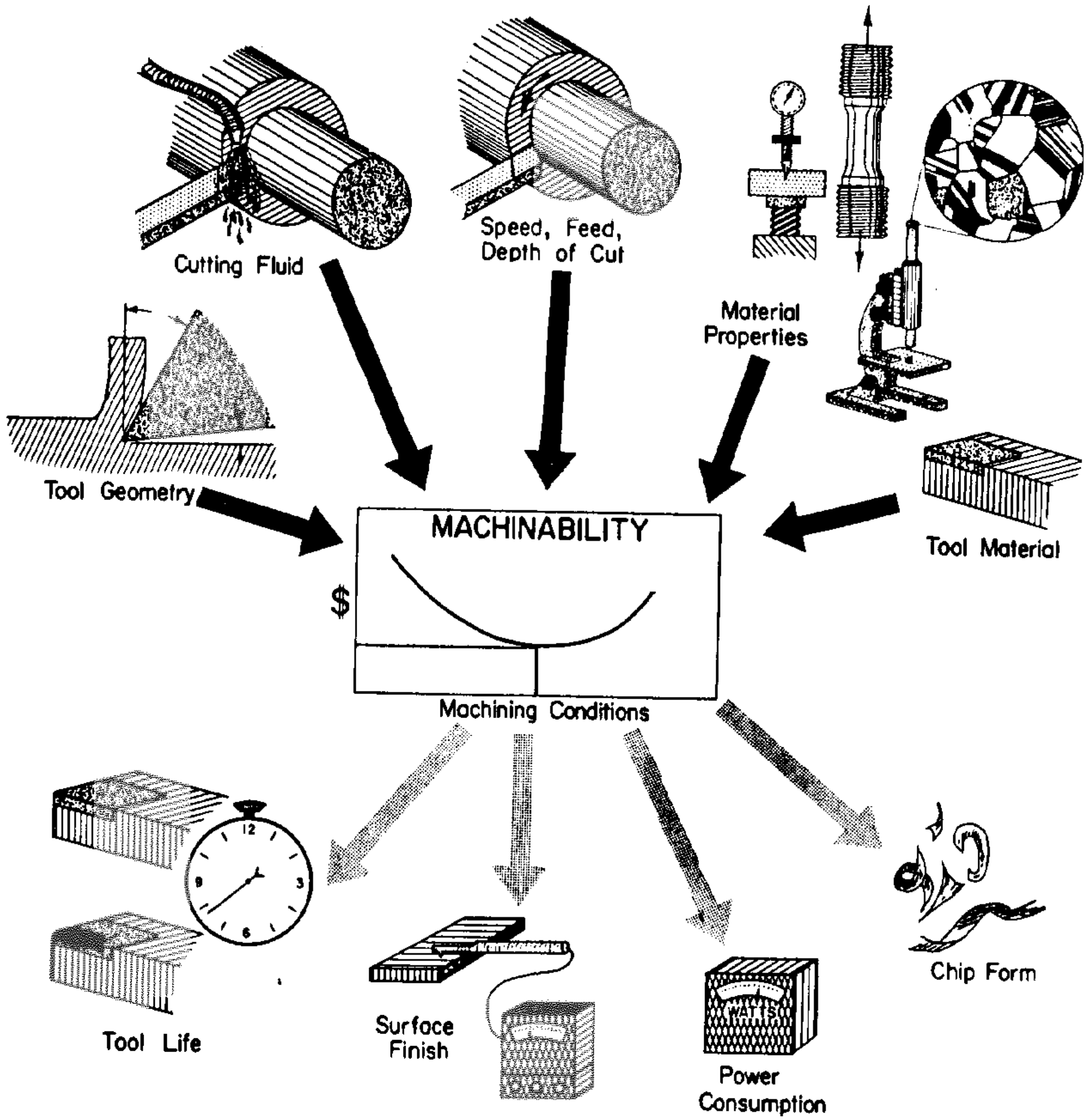
Tool life becomes an issue primarily on long duration machining jobs. Constant tool adjustments, sharpening and replacement costs money to the screw machine shop. Once again the key to long tool life is reducing heat build up at the tool which requires control of all of the variables that influence the tool temperature.

Diameter. length and straightness of the rod acceptable?

These characteristics must be under control prior to any type of analysis of the metal's internal characteristics. The section on SMS Quality Considerations explains the impact these variables have on an end user's perception of how machinable our metal is.

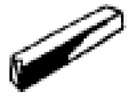
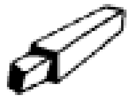
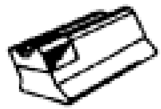
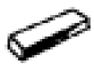
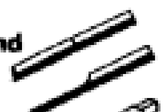
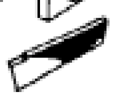
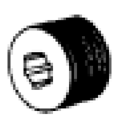
Is the metal performing in a consistent manner?

This is the biggest complaint category against raw material suppliers. Constant adjustment to speeds, feeds and tooling to compensate for inconsistencies in screw machine stock can have a strong, negative influence on the end user's perception of the supplier. These adjustments cause downtime and productivity losses which eventually lead to lost revenues and increased costs for the screw machine shop.



Factors Affecting and Methods of Measuring Machinability.

ROD, BAR & WIRE

	TOOL	PURPOSE
Box		High quality and surface finish for end turning operation.
Knee		Rough turning short, rigid work.
Hollow Mills		Multi-toothed cutting tool for turning long small diameters.
Forming		Turning different diameters at same time.
Shaving		For holding close tolerances.
Skive		Quickly forming irregular diameters to small sizes on a side or long piece.
Twist Drilling		Drilling holes.
Half Round Drilling		Drilling deep holes without pull-outs.
Reaming		Enlarging holes or improving surface finishes.
Taper Reaming		Enlarging tapered holes or improving finishes.
Tapping (Cut Thread)		Threading inside diameters.
Threading (Cut Thread)		Threading outside diameters.
Cut-Off		Parting complete piece.
Knurling		Forming raised serrated patterns.
Counterboring		Boring operation to enlarge existing holes.
Trepanning		Cutting an angular groove outside or around bored holes.
Thread Rolling		Inside and outside threading.

SCREW MACHINE STOCK QUALITY CONSIDERATIONS

Surface Quality

With the increasing trend of end users to utilize the mill finish in their final machined parts, SMS surface quality demands are greater than ever. A mill finish that would be acceptable to the end user must consist of:

* An absence of oxides that were caused by the high temperatures during heat treating and/or artificial aging.

* An absence of surface conditions that the end user would determine as cause for machined part rejection.

* The presence of a finish that, when unmachined, would be acceptable to the end user.

Aluminum oxide (A1203) is always formed on aluminum when oxygen is present. This process is magnified at higher temperatures. One of the characteristics of A1203 is that it is extremely hard - much harder than the aluminum and much harder than some of the cutting tools commonly used to machine aluminum. If the heavy oxide layer that is formed during fabrication was not removed then customers would be using up cutting tools at a phenomenal rate.

Unacceptable surface conditions can not only cause a part to be rejected for cosmetic reasons but also be responsible for excessive tool wear and/or broken tools or reduce the useful life of a part that is in service.

The oxide presence and the final rod/bar finish are taken care of by burnishing or chemical removal. The method of oxide removal is dependent upon the final size of the SMS. The absence of surface conditions is not as black and white.

Final SMS surface quality depend on either the presence or absence of conditions such as:

Die Lines	Blisters
Cracks	Hot Tears
Slivers	Handling Damage
Pits	Roll Marks

The resulting surface quality becomes a blend between the customer's needs and the limitations of the mill fabrication techniques and equipment. The type, severity, and frequency of the condition along with knowledge of the end use of the SMS go into the decision as to what is acceptable surface quality.

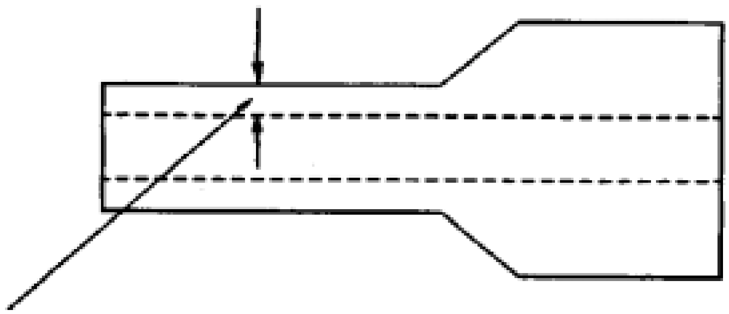
Straightness

There are primarily two major concerns an end user would have about the straightness of the SMS being machined.

* A bowed or bent piece of SMS will make an intolerable amount of noise. This noise is created by the rod/bar hitting the steel feed tube as it is rotated. This can also cause damage to either the feed tube itself or the aluminum stock.

* If the customer is required to maintain a demanding TIR (Total Indicator Reading) tolerance on a drilled hole, the whipping motion of the bowed stock can translate into the area of the metal being

drilled. This small amount of eccentric motion can be the cause of an end users inability to maintain the required TIR tolerance. Refer to the sketch below.



The TIR measurement will determine how much this thickness varies around the circumference of the hole.

SMS Diameter/DAF Control

Consistent diameter or DAF (Distance Across Flats) control is once again important if the end user is going to use a portion of the SMS in the finished part. Besides satisfying the part needs, control of diameter/DAF is also critical to assuring the end user maximum productivity.

If the rod/bar is too small there will be too much clearance between the metal and the collets of the screw machine. As the collets spin with the metal the risk of the rod/bar slipping in the collets is high. The slippage in the collets can result in out of tolerance parts and tool breakage. A piece of SMS that is too large will not fit in the collets and if the operator did manage to get the rod/bar into the machine the risk of the metal sticking in the collets during machining is present. This can also cause tool breakage and rejectable, out of tolerance parts.

Length Control

Length tolerance is not a major concern on the part of the end user which is also reflected in the tolerance by which the mills must adhere to. However deviations from length requirements can lead to several problems.

* If a screw machine job has been carefully planned to minimize scrap minor deviations in length from piece to piece may affect the customer's recovery.

- SMS that exceeds the length tolerance can create problems for the machine operator during removal of scrap from the machine. This scrap is generated when the screw machine reaches the end of the usable length of the rod/bar. If the SMS is too long then it becomes a time consuming task to remove the scrap from the machine.

Lot-to-Lot/Rod-to-Rod Machining Consistency

Consistent machining characteristics from lot-to-lot and even piece-to-piece are of paramount importance to a SMS end user. A long machining campaign on a particular part can be jeopardized by inconsistent machining characteristics. Frequent and unexpected tool adjustments and chip size changes can add tremendous costs to an otherwise trouble free and profitable job.

SCREW MACHINE TERMS AND DEFINITIONS

CNC Machine - The term CNC is an abbreviation for Computer Numerical Control. In a general sense any lathe, machining center or screw machine can be identified as a CNC machine provided the movements of the stock and tools are controlled by a computer rather than by mechanical methods. Typically, however, a CNC machine is a single spindle, usually in a chucking arrangement, machine in which the tools are mounted on a turret opposite the spindle. The metal slugs can be either be loaded manually or automatically. Almost all end cutting and side cutting is accomplished by the tools mounted on the turret. As a result of the computer controls there are infinite positions that the cutting tools can be placed. This allows a large degree of flexibility in the type of cuts that can be made, the configurations of parts that can be produced and the tolerances that can be achieved.

Captive Shop - Typically an arrangement of screw machines within an integrated manufacturing environment whose sole purpose is to produce on or several components of a muticomponent product manufactured at the same or parent facility.

Carbide Cutting Tools - Cutting or forming tools, usually made from tungsten, titanium, tantalum or niobium carbides, or a combination of them, in a matrix of cobalt, nickel or other metals. These tools are characterized by high hardness, high compressive strength and good wear resistance.

Chip Breaker - There are 2 types of chip breaker configurations.

*A notch or groove machined or ground into the face of the cutting tool adjacent to the cutting edge.

*A step formed by an adjustable component clamped to the face of the cutting tool.

The principle behind the chip breaker is for the notch or step to force the chip to bend and/or break as it comes off of the metal.

Chucking Machine - This machine is nothing more than a single spindle type screw machine in which aluminum slugs or semi finished parts are used as the starting material. The slugs or parts are manually loaded into the collet of the machine, the machine is then allowed to perform it operations on the metal and then they are manually removed from the machine. When this operation is performed on a part it can be classified as a secondary machining operation.

Collets - Split metal sleeves used to hold the rod or bar to the screw machine as it is rotated. They are located adjacent to where the stock is actually machined.

Counter Boring - Drilling or boring a flat bottomed hole, often concentric with other holes.

Cut Off Tool - A simple blade like cutting tool designed for parting finished parts from the parent metal. Also available as a rotating circular saw blade.

Cutting Fluid - A fluid used in metal cutting to improve finish, tool life and/or dimensional accuracy. While flowing over the tool and metal the fluid reduces the friction, the heat generated and the tool wear associated with metal removal. It conducts heat away from the point of generation and also serves to wash the chips out of the way of the tools.

Cutting Speed - The linear or peripheral speed of relative motion between the tool and the workpiece in the direction of cutting. The speed can be calculated by multiplying the circumference of the SMS by the Rpm's of the spindle. Units are usually expressed in Surface Feet per Minute.

Deep Drilling - A drilling operation in which the depth of the hole is greater than or equal to 4 times the diameter of the hole.

Depth of Cut - The thickness of material removed from a workpiece in a single machining pass.

Drill - A rotary end cutting tool used for making holes. It can have one or more cutting lips and an equal number of helical or straight flutes to allow for the passage of chips and the admission of cutting fluid.

Feed Rate - The rate at which a cutting tool advances along or into the surface of the workpiece. It is generally expressed in inches of penetration per revolution of stock.

Feed Tube - A hollow, cylindrical tube that extends from the collet of the screw machine in the direction opposite the tooling. The purpose of the tube is contain and support the stock as it is being rotated.

Flute - The channels or grooves formed into the body of drills, reamers and taps that provide cutting edges and permit the passage of chips and cutting fluid.

Form Tool - A single edge, non rotating cutting tool that produces its inverse or reverse configuration onto the workpiece. The terms dovetail, circular and flat refer to the method of attachment to the screw machine's tool holder.

Free Machining - Pertains to the machining characteristics of an alloy to which one or more ingredients have been added to give small broken chips, lower power consumption, better surface finish and longer tool life.

High Speed Steel Cutting Tools - Cutting tools which are made from high speed tool steel. Alloys of these steels include tungsten, chromium, vanadium and cobalt. Tools made from high speed steel provide a good combination of wear resistance and cost when compared to carbide.

Job Shop - A manufacturing organization which will produce finished screw machine parts, for any end user, for a predetermined price.

Knurling - Impressing a design into a metallic surface usually by means of small, hard rollers that carry the corresponding design on their surfaces.

Machinability - That combination of material properties and external machining parameters which affects a material's response to removal by a cutting tool.

Multiple Spindle Screw Machine - These machines, as indicated by name, are comprised of 4, 5, 6 and 8 spindle units. The aluminum stock is moved through these spindles to cutting positions. The spindle carrier indexes the work while power is applied to rotate the spindles. An end tool slide is located opposite the spindle carrier and has as many tool mounting positions as there are spindles. Cross slides are mounted at right angles to the spindles. Most machines are equipped with at least 4 cross slides. Though they typically can not produce the dimensional control that a single spindle machine can, multiple spindle machines can achieve higher productivity rates.

Profilometer - A measuring device designed to determine the roughness of a surface. Values are expresses in units of RMS. Measurements are obtained by pulling a stylus across the surface to be measured. The electronics measure the up and down motion of the stylus and record the average roughness in units of RMS.

RMS - Stands for Root Mean Square. The measurement units of the roughness of a surface. Values are generated by use of a profilometer. (Example: 62 RMS Finish).

Rake Angle - The angle between the cutting edge face and a given reference plane or line.

Reamer - A rotary cutting tool with one or more cutting elements called teeth, used for enlarging a hole to a desired size, contour and/or tolerance.

Recess Tool - A cutting tool designed to cut a groove onto either the inside diameter of a hole or the outside surface of the rod/bar.

Secondary Operation - A non-screw machining operation which is required if the finished part configuration is beyond the capabilities of the screw machine.

Shave Tool - A tool, used in the finishing operation, in which a thin layer of a work surface is accurately removed.

Single Spindle Screw Machine - This type of screw machine uses only one spindle to hold the aluminum rod or bar. The stock is held in a fixed position as it rotates and is conveyed through the spindle to the cutting tools. These tools are mounted on cross slides and turrets and are fed into the work in a pre-determined indexing cycle. The simultaneous cutting action of the cross slide and turret held tools determine, in part, the machines productivity capacity on a given job. These machines are best known for providing a good blend of productivity and part dimensional control.

Surface Finish - Condition of a metallic surface as the result of a final machining operation.

Swiss Type Screw Machine - The characteristics of this metal cutting machine differ considerably from other single spindle screw machines. Basically, single point tools are used to produce precision parts having long, thin cylindrical shapes. The tooling arrangements are such that minimum deflections of the screw machine stock are created by the cutting tools. This type of machine can achieve dimensional tolerances which can not be approached by a single or multiple spindle screw machine, however this machine has the lowest productivity rate.

Tapping Tool - A cylindrical or conical thread cutting tool having threads of a desired form on the periphery. By a combination of rotary and axial motions the leading end of the tool cuts an internal thread.

Thread Rolling - The production of threads by rolling the workpiece between two grooved die plates-one of which is in motion-or between rotating grooved circular rolls.

Tolerance - The permissible deviation from a specified nominal dimension or the permissible variation in size or other quality characteristic of a part.

SMS MACHINABILITY
Screw Machine Types and Features

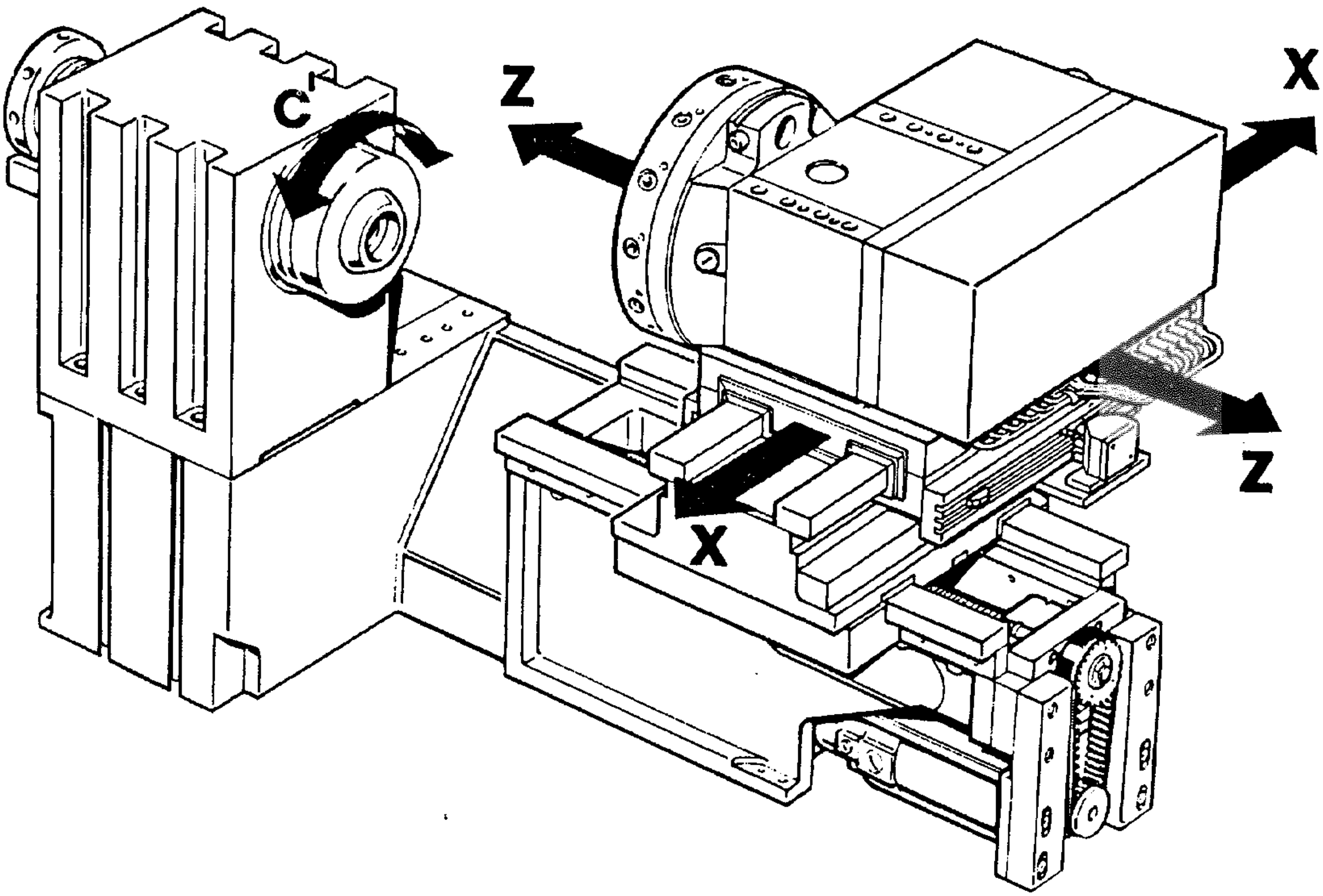
- **<u>Single Spindle Screw Machine</u>**
  - Lower Productivity Rates
  - Excellent Part Dimensional Control
  - Less Complicated to Maintain
  - Available as CNC

- **<u>Multiple Spindle Screw Machine</u>**
  - Higher Productivity Rates
  - Good Part Dimensional Control
  - Complex to Operate and Maintain
  - Flexibility in Tooling Arrangements

- **<u>Swiss Type Screw Machine</u>**
  - Outstanding Part Dimensional Control
  - Ability to Produce Multi Diameters
  - Ability to Produce Long Parts
  - Low Productivity Rates

- **<u>CNC Machine</u>**
  - Excellent Part Reproducibility
  - Easy to Set Up
  - Lower Productivity Rates
  - Maximum Tooling Flexibility
  - Excellent Part Dimensional Control

"Basic CNC Tool Movements"



SMS MACHINABILITY
Tooling Types and Features

- **<u>Carbide Tooling</u>**
  Abrasion Resistant
  Hard and Brittle
  High Cost
  Limited Applications
  Longer Useful Life

- **<u>High Speed Steel Tooling</u>**
  Less Abrasion Resistance
  Low Cost
  Flexible Applications
  Shorter Life

SMS MACHINABILITY
Coolant Types and Features

- **<u>Oil Base Coolant</u>**
  Less Cooling Ability
  Better Lubricating Characteristics
  More Viscous
  Recyclable
  Assists in Machine Lubrication
- **<u>Water Soluble Coolant</u>**
  Superior Cooling Ability
  Low Lubrication Qualities
  Low Viscosity
  Limited Useful Life
  Promotes Wear on the Equipment

MACHINING COMPLAINT RESPONSE

Next to having actual samples of material involved in a machinability problem, information about the customer's operation and problem is the most important item a sales representative needs to leave with from an end user. The reasons for this are simple.

*Having the correct information speeds the complaint response process.

*By asking pertinent questions the customer is left with the impression that everyone in the organization understands the end use of our products and the problems caused when they do not perform to a customer's expectations.

The questions found in the "Defining Machinability" section of this manual provide the basis for the type of information that is required to do a thorough and timely job of investigating and resolving a customer's machining complaint. That knowledge along with the "Machinability Information Record" will provide enough resources and guidance to obtain accurate complaint information.

As indicated earlier obtaining samples of problem metal is imperative. Not only problem samples, but, any metal that represents good performing stock.. Samples should consist of **both parts and metal** that represent:

* Problem Rod
* Good Rod
* Competitor’s Rod

If the problem is chip size related then samples of chips are also helpful.

MACHINING COMPLAINT RESPONSE

Sample and Information Checklist

- ☒ Sample of Problem Rod*
- ☒ Sample of Good Rod*
- ☒ Sample Rod of Competitor*
- ☒ Sample of Good and Bad Parts
- ☒ Sample of Competitor Parts
- ☒ Chip Size Samples
- ☒ Mill Lot Nos. and Order Nos.
- ☒ Tool Life/Surface Finish Data
- ☒ Type and Brand of Screw Machine
- ☒ Feeds and Speeds Information
- ☒ Type of Coolant
- ☒ Tooling Information
- ☒ Description of Problem
- ☒ Distributor and Customer Contacts

***12 inch Minimum Desired Length on Rod Samples**

UNDERSTANDING THE METALLURGIST

Machinability Development

Heat build up on the cutting tools is the biggest enemy to maintaining a material's machining characteristics and the productivity of the machining operation. An excessive amount of heat applied to the tools can create a condition known as **"Built Up Edge" (BUE).**

BUE occurs when the cutting temperature reaches a point in which the metal actually begins to weld itself to the cutting tool. Essentially what begins to take place is that the aluminum SMS begins to be cut by the aluminum welded to the cutting edge. This results in deterioration in:

Chip Size

Tool Life

Surface Finish

Part Dimensional Control

Effectiveness of the Coolant

The effort placed toward improving the machinability of a material is actually an effort to reduce the heat build up on the cutting edge of a tool. Any metallurgical adjustment that can be made to the SMS, which allows the aluminum to enhance the effectiveness of the coolant or reduce the amount of heat generated, can be considered an improvement in the overall machinability of the product.

UNDERSTANDING THE METALLURGIST

There are several fundamental relationships between the metallurgical characteristics of aluminum SMS and the performance of the rod/bar in a screw machine or any other machining application. Below are several metallurgical terms that you have probably heard before but never quite understood their impact on machinability.

Grain Size - The individual crystals or grains that are formed and shaped during the casting, hot working, cold working and thermal operations play a critical role in how the aluminum will machine. Grain size is measured using a standard method specified by ASTM. It uses standard grain size patterns which are compared to the actual metal sample and assigned the pattern number that best corresponds to the sample. ASTM grain size numbers typically range from 0-8. The numbering system is such that the higher the assigned number - the smaller, or finer, the corresponding grain size

When it comes to machinability performance the rule is that the finer the grain size the better the overall machining characteristics. Smaller grains will result in:

* A brighter machined surface.
* A smoother machined surface.
* Better chip formation.
* Less flaky rolled threads.
* Better knurl quality.
* Longer tool life.

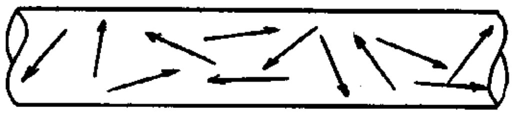
Lead/Bismuth - Lead (Pb) and Bismuth (Bi) are added to 2011 and 6262 to improve the chip breaking characteristics of these alloys. These chemical additions, along with the proper fabrication steps, combine to provide these alloys with "free machining" characteristics.

The Pb and Bi are added to the metal during casting. Upon solidification the Pb and Bi combine to form a "globule" of Pb-Bi. After hot working and cold finishing these globules appear as small, football shaped particles in the microstructure. It's not entirely understood how the Pb-Bi works to improve chip formation but there are theories.

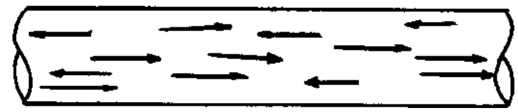
One of the most common theories speculates that the Pb-Bi particles act as a dry lubricant. As the chip slides up along the tool the Pb-Bi particles lubricating action reduces the friction and subsequent heat build up. This reduction in heat serves to improve the life of the cutting tool. The PbBi also acts as~a chip breaker. As the chip curls off of the tool it will strike the bar stock. The Pb-Bi sites act as stress risers and allows the chip to fracture at a significantly lower stress level than if it had no Pb-Bi.

Residual Stress - The processes of hot and cold working, heat treat and quench and straightening can create a large amount of stress in a rod or bar. These residual stresses can manifest themselves into primarily dimensional control problems during machining. As layers of metal are removed from the SMS the machined surface can actually "move" due to the randomness of the stresses in the rod/bar. A higher level of residual stress can be associated with the non-TX51 tempers or the non-stress relieved tempers.

Mechanical stress relief is the method applied to address problem of residual stress without changing the other machining characteristics of the SMS. Mechanical stress relief can also be thought of as stress aligning. By stretching the SMS during straightening (Tx51 tempers) the random stresses are aligned in the direction of stretch. While this method does not eliminate the stresses it does allow for the control of those stresses. During machining the "movement" of the machined surface becomes predictable since the randomness of the residual stresses have virtually been eliminated.



Rod Having A Large Amount Of Residual Stress



Rod After Mechanical Stress Relief (Stretch Straighten)

→ **Designates an individual stress component.**

<u>Microstructural Constituents</u> - The constituents or phases that are formed and examined at the microscopic level play not only an important role in the machinability of the stock but also can reveal something about how the metal fabricated.

These phases can be classified as either soluble or insoluble. The soluble phases contain the elements that "dissolve" into the aluminum during heat treat and are characterized by being relatively soft particles. The insoluble phases are those that do not dissolve during heat treat. They typically contain a large amount of iron (Fe) and are very hard, brittle particles when compared to soluble particles. The amount of these phases that are present is also dependent upon the Fe level in the chemistry.

These phases can be used to help determine the metallurgical history of the SMS. They can tell how well the metal was cast, the amount of hot work, the amount of cold work, and the quality of the heat treat and quench.

From a machinability viewpoint the insoluble particles represent abrasive areas in the metal which can cause excessive tool wear. The amount of these phases present are controlled to a low level. The quantity and arrangement of the soluble particles are less sensitive to tool life and the other attributes of machinability than the insoluble particles. The amount of these particles is very dependent upon chemistry and heat treat variables.

<u>Mechanical Properties</u> - The strength level also has a strong influence on machining characteristics. Typically the higher strength alloys and tempers will result in brighter machined surface finishes, but can create tool wear problems because of the poor chip formation and toughness of the material. 2011-T3 and 6262-T9 take advantage of the fact that their yield strengths are very close to their ultimate (breaking) strengths. This results in the metal being somewhat brittle and therefore allows a curling chip coming off of a cutting tool a better chance of breaking.

Even though 6061 is soft, and at first thought would be easy to machine, it possesses very poor machining characteristics. This is primarily because of the poor chip formation. As a result of this poor chip formation it is difficult to keep the cutting tools cool. Since heat is the biggest enemy to tool quality and life it does not take long for conditions to deteriorate when machining very soft aluminum alloys and tempers.

MACHINABILITY INFORMATION RECORD

Customer Information

Customer: Address:	Contact: Phone: Fax:
Size:	Alloy & Temper:
Sales Order Number:	Material Lot Numbers:

Problem Description

Machine Type:	Coolant Type:

Part Description and Tolerances:

Speeds and Feed Information:

Detailed Description of Problem:

Other Important Information

Provide Details and/or Sketches: