High Speed Machining of Brass: A New Benchmark in Productivity

New findings from an extensive machinability research project demonstrate that brass rod can be machined at cutting speeds and feed rates significantly higher than current practice and recommended handbook values.

Testing Scope

A series of tests were conducted on 5 brass alloys (2 leaded and 3 lead-free) to assess high speed machining capabilities and the impact of higher speeds and feeds on key productivity indicators for machined products. The ranges tested are believed to exceed the limits of productivity that can be achieved by manufacturers using state-of-the-art machine tools. All tests were conducted by TechSolve, Inc. at the M. Eugene Merchant Technology Development Center on a Makino V55 3-axis Vertical Machining Center with 20K RPM spindle capacity. The principal data collected were power factor values (horsepower/metal removal rate), tool wear and chip formation.

Maximum Speeds and Feeds Achieved

For single point turning, cutting speeds up to 4,000 surface feet per minute (SFPM), and feed rates up to 0.015 inches per revolution (IPR) were achieved for practical production periods (>4 hours) on all alloys utilizing a coated carbide insert. The chart below illustrates that the same amount of material can be removed 6X faster than conventional speeds with identical tool wear.

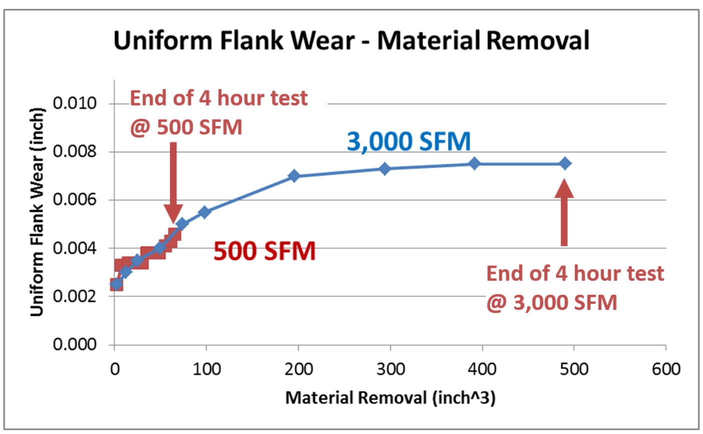


Fig 1: 4 hr. tool wear test on lead-free brass with carbide insert at 2 speeds; 0.045 in. DOC and 0.003 IPR feed rate.

For drilling, cutting speeds up to 2,000 SFPM and feed rates up to 0.015 IPR were achieved for all alloys utilizing an uncoated, 0.50in diameter carbide drill. Over 1,100, 1.5in deep blind holes were drilled into square bar stock to represent a practical production period. At the end of the tests, one lead-free alloy produced minimal flank wear and another produced minor chipping on the rake and flank faces (see Fig 2). Optimizing tip geometry could enable faster speeds and longer tool life.

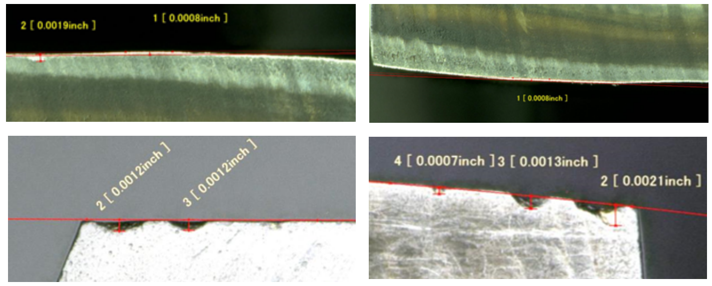


Fig 2: Carbide drill wear on lead-free alloy #1 (top) and lead-free alloy #2 (bottom) after 1,100 holes at 2,000 SFPM.

Impact on Efficiency (Turning)

Cutting forces were measured to derive power factor values across a range of speeds and feeds. Power factor data were fitted to regression curves using software to illustrate efficiency trends. The charts below show that efficiency improves significantly (>25%) for leaded and lead-free brass with increasing feeds. Increasing speed had little effect on efficiency for leaded alloys, but significant gains (>15%) were observed for lead-free alloys.

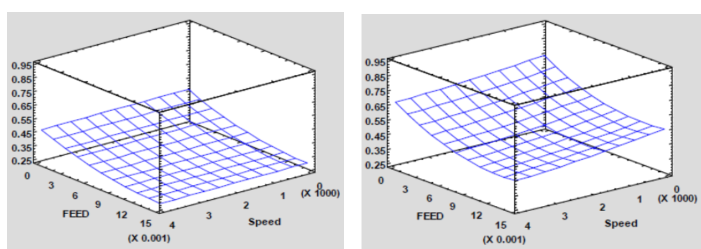


Fig 3: Impact of increasing speed and feed rate on power factor (Y-axis) for leaded alloy (left) and avg. of 3 lead-free alloys (right) at 0.09in DOC. Lower power factor values (HP/in³/min) signify higher efficiency.

TechSolve
MANUFACTURING & MACHINING EXPERTS
www.techsolve.org

Copper Development Association Inc.
Copper Alliance
www.copper.org

High Speed Machining of Brass

Impact on Efficiency (Drilling)

For drilling, efficiency was relatively constant for the leaded alloys across the range of tested speeds and feeds (left chart). In contrast, efficiency improved significantly (>65%) with increasing speeds and feeds for lead-free alloys (right chart) demonstrating a similar trend seen in the turning data. Efficiency trends for turning and drilling suggest that lead-free alloys become easier to machine at higher speeds and feeds.

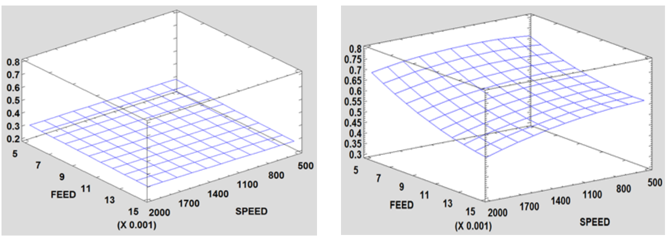


Fig 4: Impact of increasing speed and feed rate on power factor (Y-axis) for leaded alloy (left) and avg. of 3 lead-free alloys (right). Lower power factor values (HP/in^3/min) signify higher efficiency.

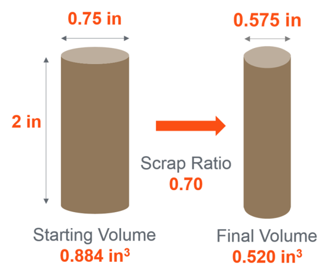
Chip Formation

Chip form data was collected for each tested combination of parameters and evaluated against the chip form specification (ISO 3865). For turning on leaded alloys, most chips were elemental and ideal with occasional short and long conical chips observed at lighter feeds. On lead-free alloys, most chips were elemental and some short and long conical chips were frequently observed at lighter feeds. Long tubular chips were observed less frequently on lead-free alloys at lighter feeds. Overall, chip formation was acceptable during high speed turning for all alloys and could be improved by optimizing tool and chip breaker geometry. For drilling, all alloys produced ideal, elemental chips across the range of speeds and feeds.

Fig 5: Representative chip forms collected during turning tests. ISO 3865 classifications from left to right are: CL 7 (elemental), CL 5.2 (short conical), CL 5.1 (long conical), CL 2.1 (long tubular).

Business Case: High Speed Turning

A theoretical business case can be derived to illustrate the productivity gains and cost savings that can be achieved with high speed machining. Assume that a basic part is made from brass which involves reducing the diameter of a 2in. long cylinder from 0.75in to 0.575in via single point turning as shown in the figure below.



	SLOW	FAST
Cutting speed (SFPM)	500	4,000
Feed rate (IPR)	0.007	0.015
Depth of cut (in)	0.125	0.125

Part geometry and the "slow" vs. "fast" machining parameters shown in the table above can be used to compare metal removal rates and cycle times to assess the impact on productivity and cost per part for machining time as shown below.

	SLOW	FAST
Metal removal rate (in^3/min)	5.25	90.0
Cycle time* (sec.)	4.16	0.24
Parts/hour	865	15,000
Machine time cost/1,000 parts (assumes $75/hour rate)	$86.72	$5.06
>17X productivity increase >94% savings per part on machine time		

*Time in the cut only; does not account for change time between parts

Conclusions

Data from this study establish a new benchmark for machinability and offer practical knowledge on high speed machining capabilities of both leaded and lead-free brasses. Importantly, the data suggest that the machinability of lead-free brasses improves significantly at higher speeds and feeds. The findings demonstrate the value in developing new higher-speed equipment that can further exploit the intrinsic machinability of brasses. Implementing high speed machining in production settings can increase productivity and profitability by reducing capital costs and cost-per-part.

TechSolve
MANUFACTURING & MACHINING EXPERTS
www.techsolve.org

Copper Development Association Inc.
Copper Alliance
www.copper.org

A7049 XX/17