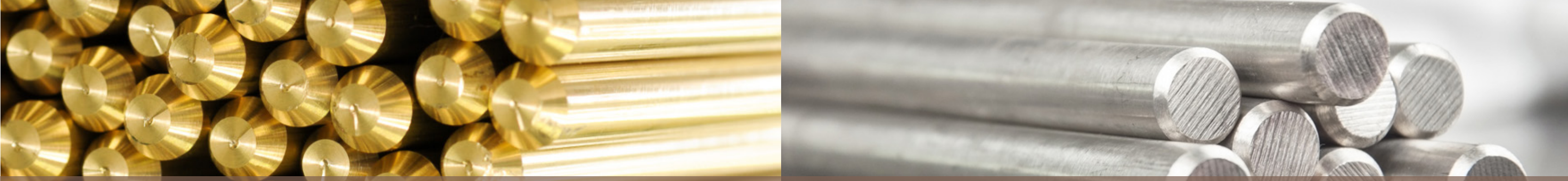

High Speed Machining Advantages of Brass vs. Steel

The high speed machining capabilities of brass rod enable significant productivity advantages and cost-savings compared to 12L14 steel and 304L stainless steel for machined products.

Objectives and testing scope

A series of single point turning and drilling tests were conducted on 5 brass alloys (2 leaded and 3 lead-free), 12L14 steel and 304L stainless steel to assess maximum practical machining speeds from the standpoint of productivity and tool life. All tests were conducted by TechSolve, Inc. in Cincinnati, OH on a Makino V55 3-axis Vertical CNC Machining Center and a Hardinge Cobra 65 CNC lathe. Carbide cutting tools specifically recommended for each respective material were selected with input from a major cutting tool manufacturer. Cutting fluid for all tests was TRIM SOL® general purpose water soluble emulsion coolant at a 10% concentration.

Speed comparison (turning)

Turning speed limits were defined as the maximum speed under which a reasonable tool life could be achieved while maintaining acceptable surface finish. Reasonable tool life was defined as 30 minutes for steel alloys and 4 hours for brass alloys. Criteria for end of tool life were uniform flank wear of 0.012 to 0.015 in., poor surface finish, excessive notch wear or catastrophic failure. Minimal tool wear was observed on brass alloys after continuous turning at extremely high speeds above 3,000 surface feet per minute (SFM) for over 4 hours (Fig. 1). Speeds up to 4,000 SFM exceeding 16,500 RPM were safely achieved on brass for diameters above 0.90 in. without inducing excessive spindle vibration or chatter.

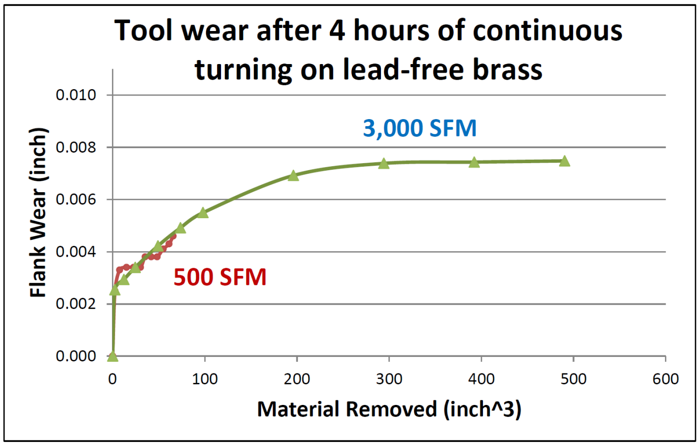

Fig.1: Tool wear after turning lead-free brass at two speeds for 4 hours. KC5010 insert is still within break-in period after 4 hours at 3,000 SFM

After optimization, 12L14 and 304L also exceeded recommended cutting speeds. However, tool life and operating speeds for the steels were significantly less compared to all tested brass alloys (Fig. 2). 304L was limited to 800 SFM or 20% of the top speed for brass (4,000 SFM). 12L14 was limited to 1,200 SFM or 30% of the top speed for brass. Notably, tool life for brasses was at least 8X longer at more than triple the speed.

***Fig. 2:** Tool wear speed limit testing on lead-free brass, 12L14 steel and 304L stainless steel*

Efficiency comparison (turning)

Cutting forces were measured across a range of speeds, feeds and depths of cut to calculate "Power Factor" which is the amount of horsepower required to remove one cubic inch of material in one minute. Values for each material were plotted to compare efficiency. Fig. 3 shows that 304L is approximately 2.7X less efficient compared to leaded brass and 12L14 is about 2X less efficient.

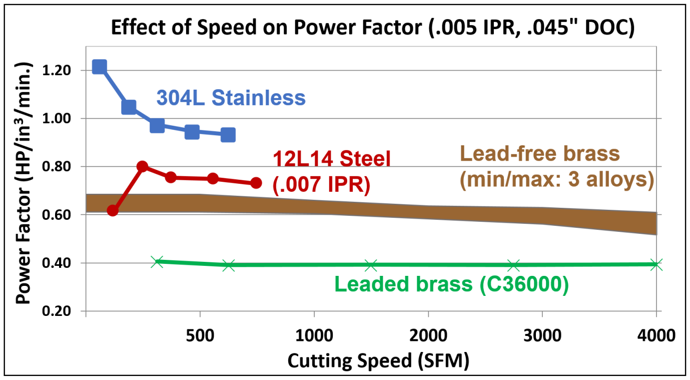

***Fig.3:** Effect of increasing speed on efficiency for all materials at a fixed mid-range feed. Lower power factor values signify higher efficiency*

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Speed comparison (drilling)

Drilling speed limits were based on a minimum of 1,000 drilled holes at 1.5 in. depth before reaching the end of drill life based on 0.012 to 0.015 in. of flank wear or fracture/chipping of the drill. 0.50 in. diameter carbide drills were utilized with external coolant flood combined with low pressure through-the-spindle coolant. Fig. 4 shows tool life based on the number of drilled holes as a function of speed. Fig. 5 shows images from before and after each tool life test at optimized speeds.

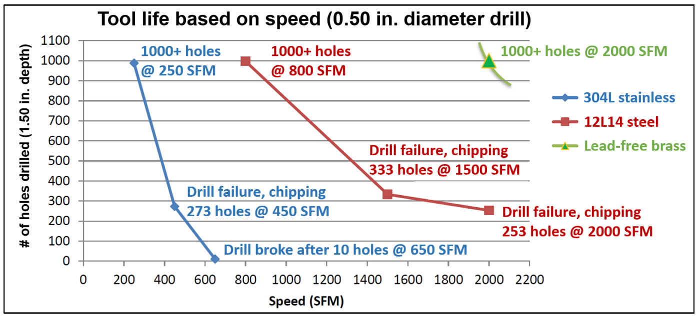


Fig. 4: *Speed limit testing for 304L, 12L14 and a lead-free brass*

All materials exceeded typical recommended cutting speeds after optimization. Tool life and operating speeds were significantly lower for 304L and 12L14 compared to brass alloys which were drilled at extremely high speeds up to 2,000 SFM with little evidence of tool wear. 12L14 and 304L maxed out at 800 and 250 SFM respectively or 40% and 12% of the top speed achieved for brasses.

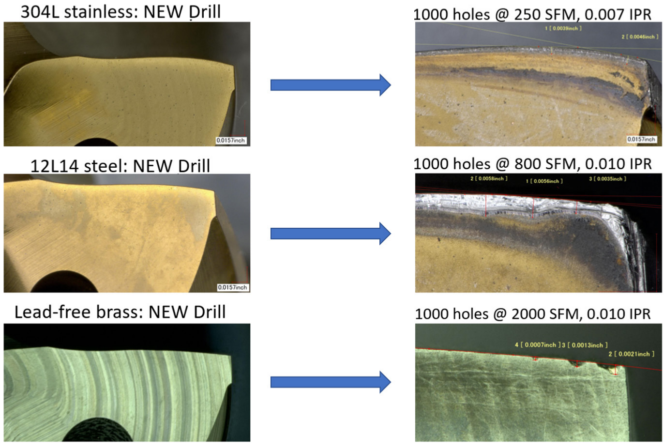


Fig. 5: *Tool wear on carbide drills after 1,000 holes drilled at maximum speeds for 304L, 12L14 and a lead-free brass*

Efficiency comparison (drilling)

Drilling power factor values were calculated by measuring torque over a range of speeds and feeds. Fig. 6 shows that 304L required significantly more power than all the brasses while 12L14 performed similar to the high-end range of the 3 lead-free brasses. Efficiency for 12L14 and 304L was measured at a reduced speed than the brass alloys due to practical restrictions on tool life, thereby significantly limiting the overall throughput compared to identical parts machined from brass.

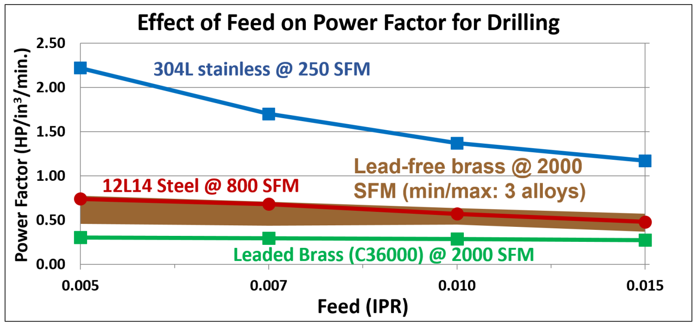
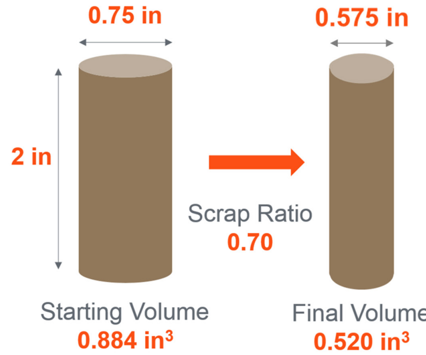


Fig.6: *Effect of increasing feed rate on efficiency at maximum speeds. Lower power factor values signify higher efficiency*

Productivity and cost comparison

The economic advantages of brass are demonstrated by a simple productivity comparison. Assume that a basic part is made by turning down the diameter of a 2 in. long cylinder from 0.75 in. to 0.575 in. as shown below.



	Speed (SFM)	Feed (IPR)
Brass	4,000	0.010
12L14 Steel	1,200	0.007
304L Stainless	800	0.007

0.045 in. depth of cut for all materials

The amount of material removed (0.364 in^3) and the optimized turning speeds for each material shown in the table above are used to calculate the impact on productivity and cost per part for machining time as follows:

	Brass	12L14	304L
Metal removal rate (in^3/min)	21.6	4.54	3.02
Cycle time[1] (sec.)	1.01	4.81	7.22
Parts/hr.	3,564	748	498
Labor/1,000 parts ($100/hr.)	$28.09	$133.74	$200.62
Brass productivity advantage	--	↑ 4.8X	↑ 7.1X
Brass cost savings per part[2]	--	79% ↓	86% ↓

1. Time in cut only; 2. Additional brass savings due to significantly longer tool life not shown

Conclusions

Compared to 12L14 steel and 304L stainless steel, brass alloys can be machined at significantly higher production rates with longer tool life and higher efficiency. Design engineers should account for the combined costs of decreased tool life, more rapid tool wear and its effect on dimensional control, as well as lower throughput when considering steel alloys over brass. The high speed machinability of brass enables significant productivity gains and cost savings for machined products.