Starting Recommendations for Turning Austempered Ductile Iron (ADI)

Studies were conducted to assess the machinability of ADI in turning operations. These experiments focused on varying the cutting speeds when machining various grades of ADI (GR 900 ADI, GR 1050 ADI and GR 1200 ADI). 100-70-03 ductile iron was also machined at several cutting speeds as the reference material. The effects of different cutting speeds on the tool life when turning ADI were analyzed to provide starting recommendations for turning ADI.

The recommended turning parameters for ADI (**Table 1**) were generated using the Taylor tool life equations with an expected tool life of 15 minutes and depth of cut of 0.060 inch. (1.5 mm). These recommendations were also compared with the recommended turning parameters for different grades of ductile iron based on a cutting depth of 0.100 inch (0.25 mm).

Table 1: Recommended initial turning parameters for different grades of ADI.

	Feed rate (in/rev)			
	0.008	0.012	0.016	0.024
Material	**Cutting speed (ft/min)**			
GR 900 ADI		***590***		
GR 1050 ADI		***535***		
GR 1200 ADI		***360***		
For comparison:				
A536 60-40-18	1280		1115	1035
A536 80-55-06	1115		985	900
A536 100-70-03	950		840	770
A536 120-90-02	790		690	640

	Feed rate (mm/rev)			
	0.2	0.3	0.4	0.6
Material	**Cutting speed (m/min)**			
GR 900 ADI		***180***		
GR 1050 ADI		***165***		
GR 1200 ADI		***110***		
For comparison:				
A536 60-40-18	390		340	315
A536 80-55-06	340		300	275
A536 100-70-03	290		255	235
A536 120-90-02	240		210	195

* ADI recommendations are based on the use of SECO CNMG120408-M5, TK 2001 as the inserts and QuakerCool 7020-CG for the coolant.

Research Study Details

The turning experiments (**Figure 1**) were performed on a workpiece in the shape of a hollow cylinder with an outside diameter of 6.85 inches (174 mm) and an inside diameter of 4.5 inches (114 mm) using a HAAS ST-20 CNC Lathe. The workpiece was secured from the inside using step jaws on the chuck and tailstock on the opposite end to provide improved support.

Before placement in an instrumented CNC Lathe for the turning studies, the casting was prepared using a conventional lathe to establish the datum. The casting scale of the workpiece was removed prior to testing in order to maintain consistency with previous milling and drilling experiments.

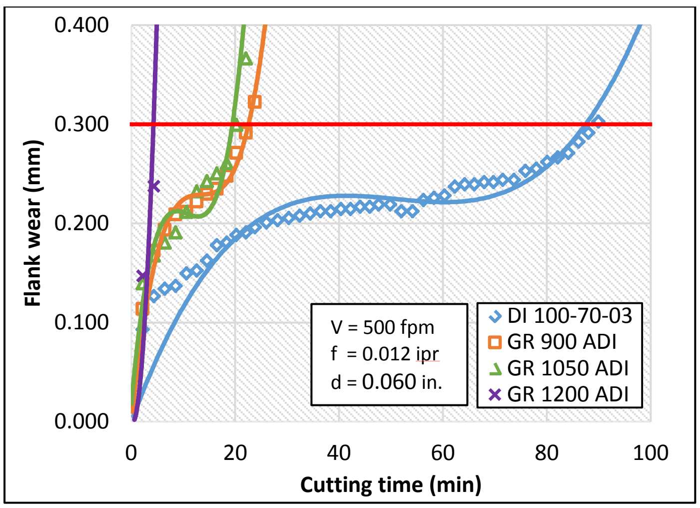
Figure 1: The setup for the turning experiment is shown.

The tool life experiments were conducted according to ISO 3685:1993. Useful tool life was defined as the time when the inserts reached maximum flank wear penetration (VB_{max}) measured from the uniform wear of 0.01 inches [0.3 mm] or localized wear of 0.02 inches [0.6 mm]. Wear land measurements were made over intervals corresponding to the constant volume of material removed (e.g., after each pass) using a stereoscope.

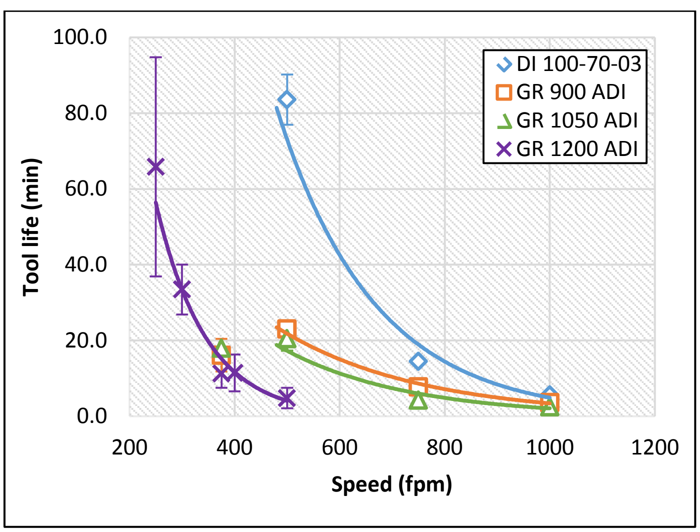
Different cutting speed configurations with a constant feed rate of 0.012 in/rev (0.30 mm/rev) and depth of cut of 0.060 inches (1.5 mm) were investigated per work material with three replications per condition to establish the relationship between cutting speed and tool life. GR 900 ADI and GR 1050 ADI were turned at cutting speeds of 375, 500, 750, 1000 ft/min (114, 152, 228, 305 m/min) while GR 1200 was machined at a lower range of cutting speeds: 250, 300, 375, 400 and 500 ft/min (76, 91, 114, 122 and 152 m/min). As a reference, 100-70-03 ductile iron was tested at cutting speeds of 500, 750 and 1000 ft/min (152, 228 and 305 m/min).

The graphical representation of tool wear progression as a function of cutting time at different cutting speeds for 100-70-03 ductile iron and different grades of ADI is shown in **Figure 2(a)**. A rapid increase in the wear rate was observed at the beginning of cutting, which was then followed by a steady state condition and another rapid wear rate towards the end.

As expected, longer tool life was obtained when cutting the lower strength grades of ADI. However, it is important to note that the tool used to turn GR 900 ADI wore at similar rates to that used to machine GR 1050 ADI. After the wear progression plots of the tool used to turn ADI and 100-70-03 ductile iron were generated, the tool life corresponding to various cutting speeds with a constant feed rate and depth of cut were estimated and plotted as a function of cutting speed as shown in **Figure 2(b)**. The error bars represent one standard deviation of uncertainty.



(a)



(b)

Figure 2: (a) Tool wear behavior during turning of ADI and 100-70-03 ductile iron at cutting speed of 500 ft/min; (b) The effect of cutting speed on tool life in different ADI grades and 100-70-03 ductile iron.

Unusual behavior was observed when turning GR 900 ADI and GR 1050 ADI at 375 fpm (114 m/min). The tools were found to last longer when turning these materials at 500 fpm (152 m/min) than at 375 fpm (114 m/min). This phenomena likely occurred because of a different wear mechanism at "very" low cutting speeds, including 375 fpm (114 m/min).

A linear relationship between the tool life and cutting speed (**Figure 3**) can be observed when plotting these data points in a log-log coordinate. This relationship was used to establish Taylor tool life equations for each material. Note that the cutting data for GR 900 ADI and GR 1050 ADI at 375 fpm (114 m/min) were not included when generating the predictive equation as Taylor tool life equations are established by using only the linear portion of the log-log curve.

Taylor tool life equations for different grades of ADI and 100-70-03 derived from the linear regression model are presented in **Table 2**. Given a specific production rate, these equations will allow machine shops to predict the tool life for the cutting speed used to meet their demand requirements. These relationships can also be used to approximate the starting cutting speed for a desirable tool life.

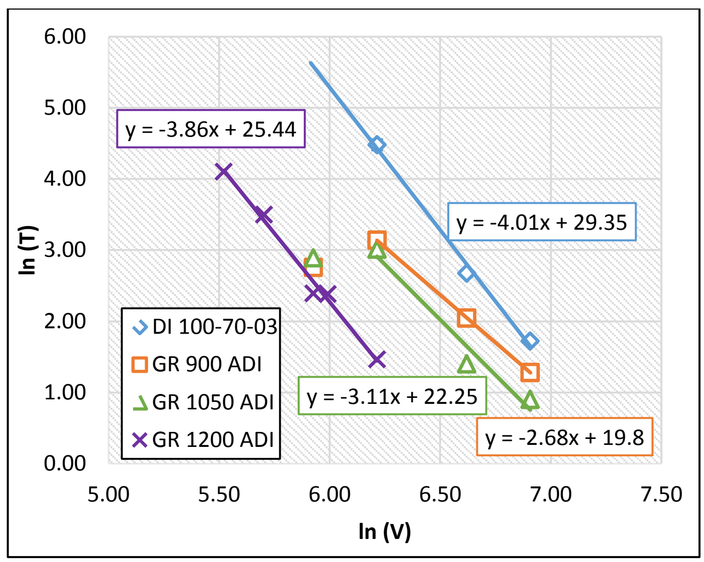


Figure 3: The effect of cutting speed on tool life in ADI and 100-70-03 DI (T = tool life - min; V = cutting speed – ft/min).

Table 2: Taylor tool life equations for ADI and 100-70-03 DI.

Material	Taylor Tool Life Equation
V (ft/min) – T (min)	
DI 100-70-03	$V\ T^{0.25} = 1508$
GR 900 ADI	$V\ T^{0.37} = 1610$
GR 1050 ADI	$V\ T^{0.32} = 1274$
GR 1200 ADI	$V\ T^{0.26} = 727$

Reference: The Pennsylvania State University