

Machining of Austempered Ductile Iron (ADI)- A Tutorial

Austempered Ductile Iron (ADI) is a cast, and heat treated ferrous material that offers the designer a high strength-to-weight ratio at a competitive price. However, the machining of ADI has caused difficulty for some producers. This tutorial is designed to give the user a “starting point” for the machining of ADI.

Microstructure- ADI’s microstructure consists of a mix of ferrite and austenite called “Ausferrite”.

The Austenite in the Ausferrite matrix can transform to **Martensite** when acted upon by a high normal force. This must be understood when machining the structure because a very thin chip may be very hard.

Chip Characteristics and Handling

Machining ADI produces a compact, discontinuous chip that is magnetic and can be 100% recycled.

The user must note that a volume of ADI chips will weigh as much as 2.5 tons/m³ and must make accommodation for emptying the chip container. (Continuous steel turnings may weigh as little as 300 kg/m³).

Thermal Conductivity, Coefficient of Thermal Expansion and Stiffness Related Issues

ADI has a thermal conductivity somewhat lower than that of ductile iron or steel. This must be considered in machining because the workpiece/tool interface will run **hotter** than with ductile iron, gray iron or aluminum. Utilization of high volumes of **coolant** mitigates the effect of the lower thermal conductivity. If **dry cutting** is necessary, tools capable of withstanding high interface temperatures must be employed.

ADI has a coefficient of thermal expansion that is higher than that of carbon steel or ductile iron, so an increase in workpiece temperature will result in growth during machining. This should be accounted for in operations such as deep-hole drilling.

ADI has a yield strength that is higher than most steels but its Young’s Modulus is 20% lower making it prone to vibrations in machining. Therefore, ADI requires an extremely rigid workpiece clamping device and similarly rigid tool holders with short tool bending moments. Failure to account for this reduced workpiece stiffness will result in undesirable vibrations during metal removal which accelerates tool wear, and results in an undesirable surface finish and an increased dimensional standard deviation.

Tooling for the Machining of ADI

Tool materials for drilling, turning, milling and tapping ADI are essentially selected based on the ADI hardness/strength grade. Conventional grades of tool steel can be used for ADI with hardnesses up to nearly 300 HBW. Hard coated steel tools can be successfully utilized in machining ADI with hardness to over 380HBW. Ceramic tooling can be used for cutting ADI at a hardness of up to 500 HBW. It should be noted that ceramic tooling can be damaged when used for interrupted cuts, but collaborative research has shown that aluminum oxide tooling reinforced with silicon carbide whiskers yields acceptable results in both rough and finished cutting over the entire range of ADI hardnesses.

General categorization of deep drilling and broaching are more problematic. Users are, in fact, successfully deep drilling and broaching ADI using coated metal tooling, but the techniques are proprietary and unique to specific applications.

Speed and Feed Settings for Machining ADI

The following algorithms and procedures are intended to provide the machinist with a starting point for their set-up to machine ADI. It is assumed that the machinist has experience at successfully machining ductile iron. The modified set-up for ADI will be a function of the machinist’s experience with ductile iron.

Procedure:

Assumptions:

- Hard coated or ceramic tooling with cooling
- S_O = Original speed for the successful ductile iron application
- F_O = Original feed for the successful ductile iron application
- M_O = Machining Speed Coefficient for a successful ductile iron job with a known Brinell hardness. (From the chart on the reverse side.)

Machining Trials:

- S_{ADI} = S_O [M_{ADI} / M_O]
- F_{NEW} = F_O

If the combination of S_{ADI} and F_O produces adequate tool life and surface finish, increase the feed speed to **F_{NEW} = F_O x 1.05**. Repeat the trial, increasing the feed by 5% each time until the tool life or surface finish becomes unacceptable. Procedurize the speed and feed combination based on S_{ADI} and the highest feed rate that produced acceptable results.

(Over)

Machining Speed Coefficient for ADI

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