Influence of Section Size on the Machinability of Ductile Irons (Observations on the Machinability of Ductile Irons)

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EXTENDED ABSTRACT

Ductile irons are widely specified for many casting applications because of their excellent performance and machinability. However, the machinability of ductile irons is often highly variable. Lot-to-lot and casting-to-casting machinability differences often cannot be explained. Similarly, production practices to produce ductile iron castings with consistently high machinability remain illusive. Small differences in chemical composition, treatment practice, inoculation practice, as well as section size differences can be expected to have relatively insignificant effects on hardness or tensile properties but significant effects on machinability.

Recent studies of the machinability of both gray and ductile cast irons, have demonstrated the role of matrix structure and graphite morphology on the mechanics of chip formation in cast irons. [1,2] The complex interaction between the matrix and the graphite influences the deformation and fracture events taking place at a microstructural level ahead of and beneath the cutting tool during machining.

These previous studies have set the stage for more focused study of machining variations within cast iron grades. The goal of the research is to gain insight into lot-to-lot variations in machinability of production ductile irons and to identify production practices for insuring consistent high machinability.

Comprehensive machining studies are being conducted in the Machining Research Laboratory at Penn State University. Three different experimental methods were used to characterize the machinability of the ductile iron samples as a function of section size and distance from the as-cast surface:

1-Instrumented slow speed orthogonal cutting experiments permitted quantitative video analysis of chip formation during cutting. Figure 1 illustrates a typical video image obtained during these orthogonal cutting studies.

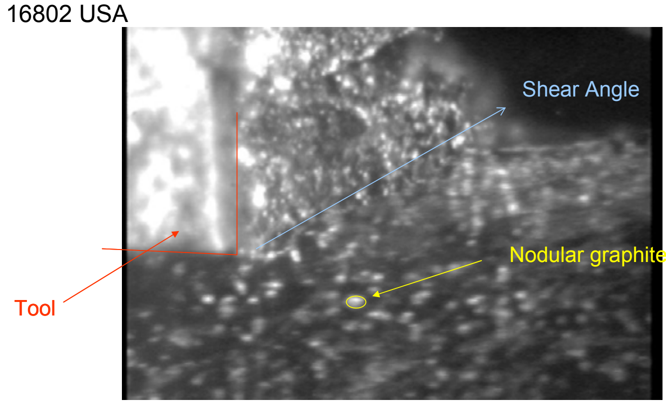


Figure 1 : Orthogonal cutting image of a 0 degree rake angle cutting through ductile iron with a 0.015 in. (0.4mm)depth of cut.

2-Instrumented high speed quick stop machining permitted off-line SEM analysis of fracture and

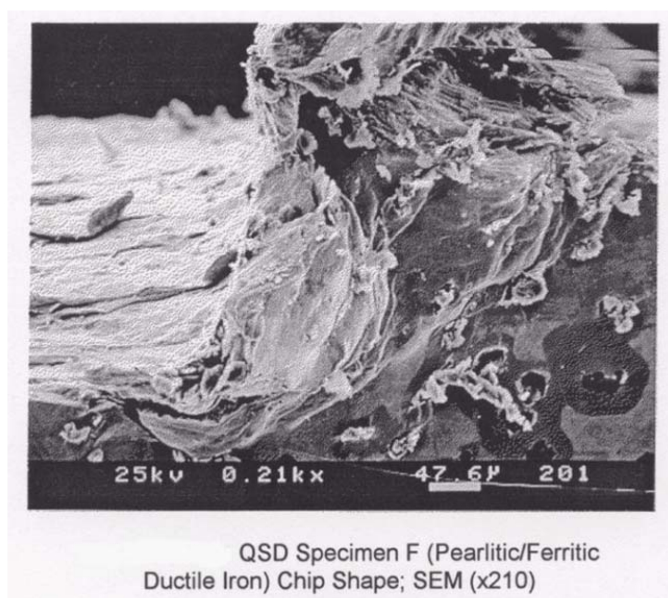


Figure 2 : SEM image of the initial stages of chip formation ahead of the cutting tool during high speed machining.

deformation events occurring ahead of, and beneath, the cutting tool while machining at production cutting speeds. Figure 2 illustrates an SEM image of the machined surface and the chip that forms ahead of the cutting tool.

3-Instrumented drilling studies gave an indication of the relative tool wear that could be expected from each section size of the step block. Figure 3 illustrates the tip of a drill land showing typical drill wear.

Figure 3 : Low magnification image of a drill land with the wear profile shown.

The results have been compared to previous and ongoing machinability studies of gray, CG and ductile irons. The following general observations regarding the machinability of ductile irons can be made:

-The machinability of ductile irons is dominated by the hardness of the matrix which is influenced primarily by the presence of pearlite and other hard micro-constituents.

-Nodule count itself, independent of microstructure also influence machinability. High nodule counts result in more localized deformation and miro-fracture events in the machining-affected-zone (MAZ) reducing overall cutting forces significantly.

-Modern melting and inoculation practices permit foundries to produce consistent ductile iron microstructures and machinability with little section size sensitivity. In general, the variation in machinability for section sizes between 8 mm and 40 mm is small. The presence of carbides in thinner sections can be expected to reduce machinability.

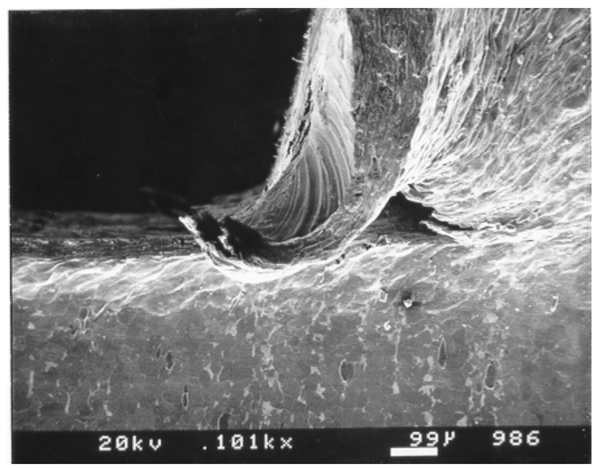
REFERENCES

1. R. C. Voigt, R. O Marwanga and P. H. Cohen, “Machinability of Gray Iron – Mechanics of Chip Formation,” International Journal of Cast Metals Research, vol. 11, No. 5, 1999, pp 567-572.

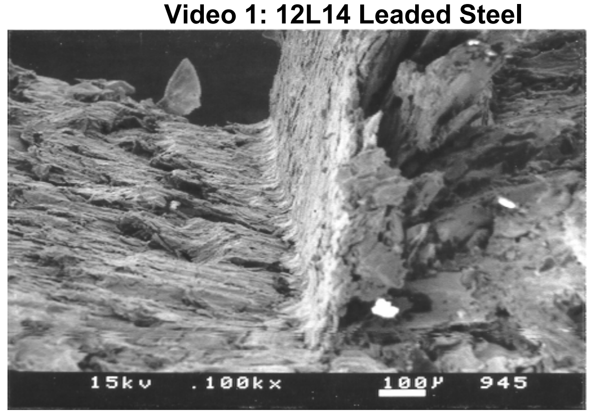
2. R. O. Marwanga, R. C. Voigt and P. H. Cohen, “Influence of Graphite Morphology and Matrix Structure on Chip Formation During Machining of Continuously Cast Ductile Irons", AFS Transactions, Vol. 108, 2000, pp 651-661.

APPENDIX

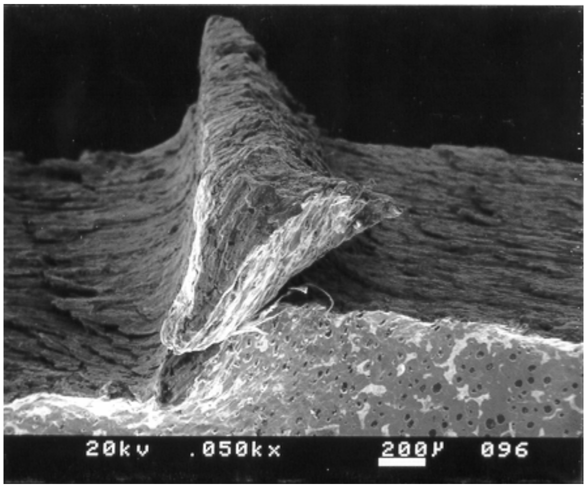
Video images from slow speed orthogonal cutting experiments with ductile irons and other materials can be viewed by simply “clicking” on the bordered images.



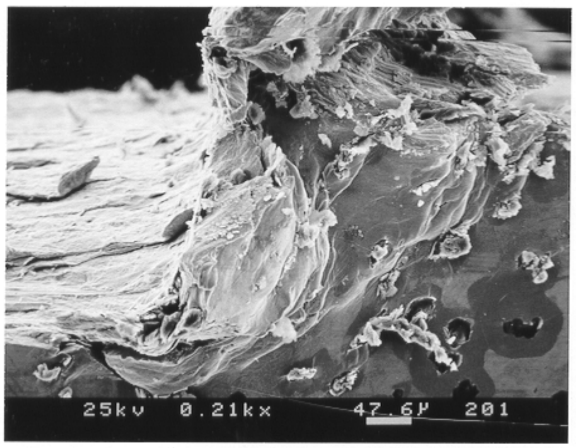
Video 1: 12L14 Leaded Steel



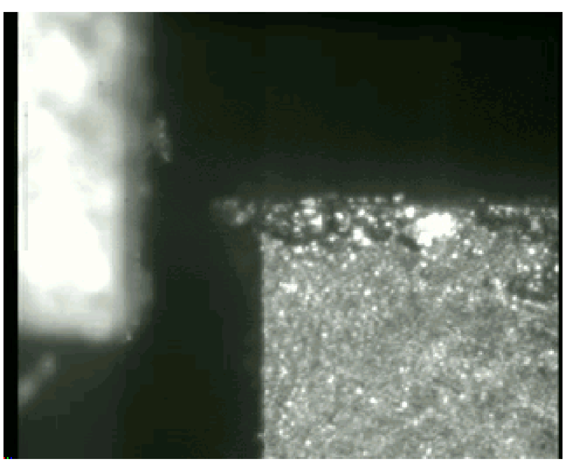
Video 2: Class 30 Gray Iron



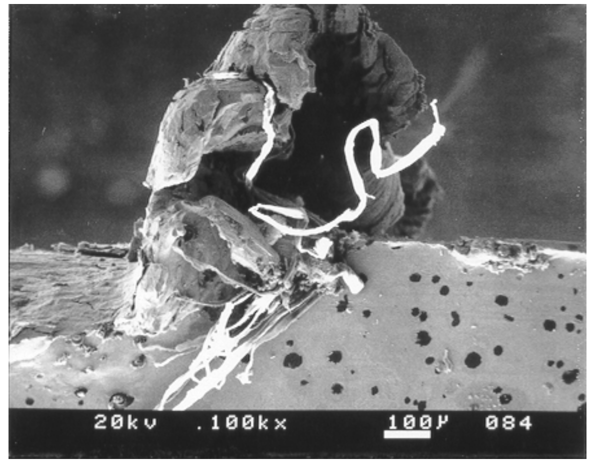
Video 3: 60-40-18 Ductile Iron



Video 4: 80-55-06 Ductile Iron



Video 5: 80-55-06 Ductile Iron (high nodule count)



Video 6: 100-70-03 Ductile Iron