MACHINING CHARACTERISTICS OF ALLOY 718

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ABSTRACT

Machining of alloy 718 is distinquished from other nickel-base alloys by its composition and microstructure. Lower alloyed materials have a more uniform structure, and hence depict better machining behavior. One needs to recognize, of course, in spite of the near-net shapes that can be generated by investment castings and precision forgings, hugh amounts of metals have to be removed to get to the final product. Hence, improved heat treatments as well as better tools are essential to reduce cost and improve quality in the machining of alloy 718. This paper describes select heat treatments imposed to enhance machinability, along with metallographic studies to understand the machining characteristics of alloy 718.

INTRODUCTION

Alloy 718 continues to be used in many cast structural applications in aircraft engines. This alloy fills the need for a low-cost material with flexible mechanical properties in temperature ranges up to 1200°F. It posseses great manufacturing flexibility and performs well in a host of hostile environments. The alloy casts very well. Despite this alloy's ability to be cast to close tolerences, large amounts still need to be "hogged-out" before the end shape is attained. It has been estimated that in many cases less than 20% of the material remains in the final product after machining.

APPROACH

Two approaches were taken in this effort. The first consisted of imposing several heat treatments on cast 718 cylinders.
The overall intent of this effort was to improve cast 718 machinability. Evaluations consisted of the four basic machining processes: turning, milling, drilling and reaming. For breivity, only the results from the turning process are presented here. Two heat treatment modifications, along with the standard heat treatment, were imposed on select cylinders. In addition, a forged cylinder was machined, as a point of machinability reference.

The second approach included a detailed evaluation of cast 718 specimens to evaluate an impaired surface condition, referred to as "mottling".

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CAST CYLINDER HEAT TREATMENTS

Alloy 718 cylinders, six inches, OD, four inches, ID, and approximately 12 inches long were cast under controlled conditions, then select cylinders were given three heat treatments and finally they were machined. Essentially, one heat treatment was standard, while the other two imparted extended solutioning treatments. A typical cast cylinder can be seen in Figure 1. The chemical analysis of the heat from which these cylinders were cast is given in Table I.

Table I.

Chemical Analysis of the Cast 718 Cylinders.

ELEMENT	SPEC.	ANALYSIS
CARBON	0.02 - 0.08	0.054
MANGANESE	0.35 MAX.	0.13
PHOSPHOROUS	0.015 MAX.	0.006
SULFUR	0.015 MAX	0.002
SILICON	0.35 MAX.	0.01
CHROMIUM	17.0 - 21.0	18.37
NICKEL	50.0 - 55.0	52.34
MOLYBDENUM	2.80 - 3.30	2.92
TITANIUM	0.65 - 1.15	1.20
COPPER	0.30 MAX.	.10
NIOBIUM	4.40 - 5.40	5.13
ALUMINUM	0.30 - 0.70	0.39
IRON	15.0 - 21.0	19.16
COBALT	1.0 MAX.	0.25
BORON	0.006 MAX.	0.03

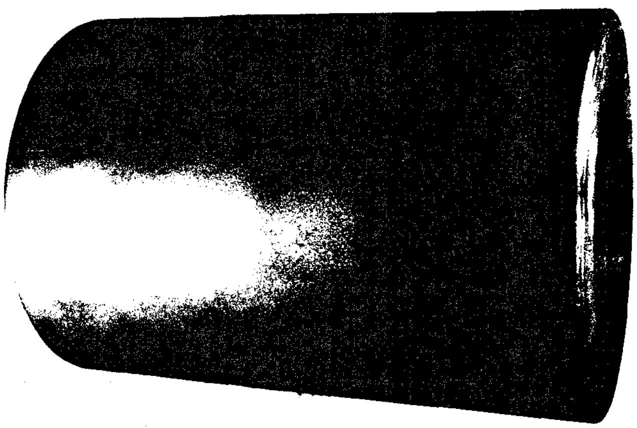

Figure 1. Typical Cast 718 Machinability Cylinder.

It is not the intent of this paper to go into the details on machining superalloys. In the way of a brief background, the machinability is dependent on tool life. Tool life is a function of many contributing factors, but cutting speed is the single most important factor. Hence, to make comparisons for machinability, other variables, as depth of cut, carbide material, rake angle, etc. are held constant. From this standard plots of tool life (minutes) vs. cutting speeds (SFPM) are generally used. Of course, there are the two basic types of cuts to consider: semi-roughing and finishing. Again, for simplicity only the finish machining data are presented. And certainly of greatest importance is the cost analysis for a given machining process. This cost analyses considers a number of variables including cutting speed, feed rate, depth of cut, labor rates, tool life and its ancillary costs. Such analysis entails very sophisticated computer programs and will not be included here.

Earlier metallographic examinations of difficult to machine cast and hipped alloy 718 indicated that the the Ni_3Cb needles distributed in the interdendritic network was the possible cause for this materials' poor machinability. Several heat treatments were evaluated to eliminate the Laves phase and to improve properties as well as machinability.

As an overall part of this machinability study, typical tool life curves in turning have been generated with carbide tools at a specific feed and depth of cut. Figure 2 shows the tool life curves for the cylinder with the standard heat treatment, and the cylinders with the modified heat treatments. For comparison purposes, the tool life curve for a forged alloy 718 cylinder is also shown. The poorest machining characteristic were obtained with the cylinders having the modified heat treatments. Also, the forged material exhibits the best machining characteristics.

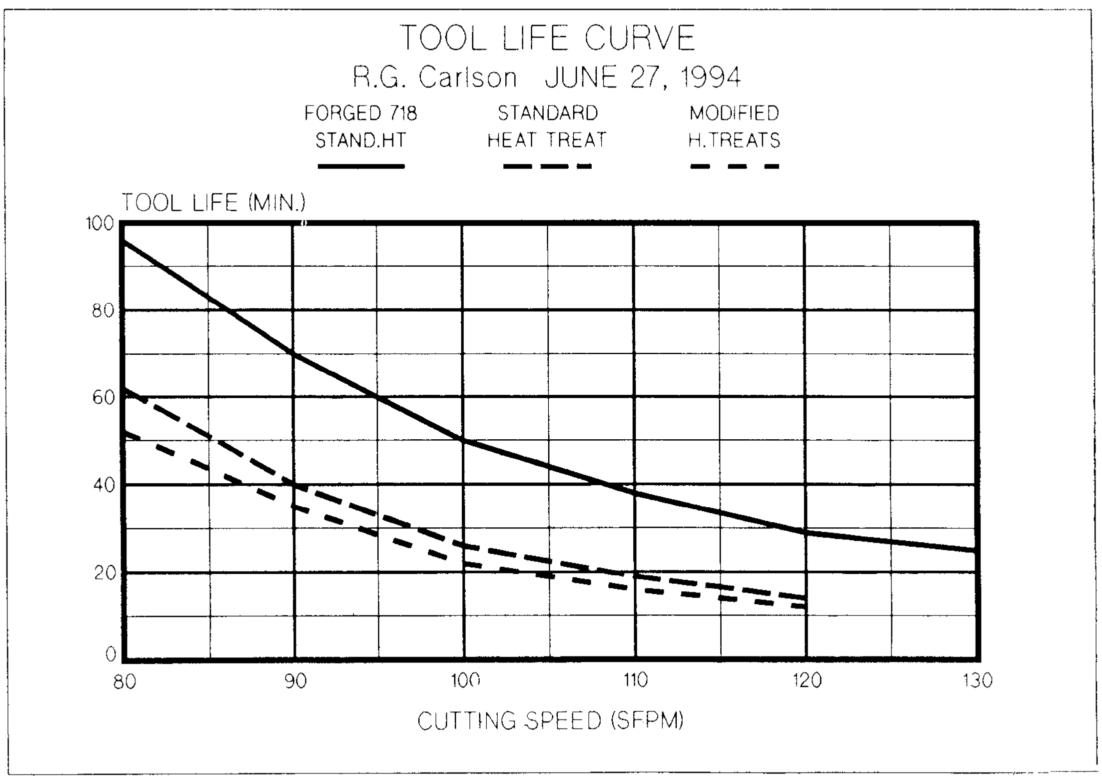

Figure 2. Tool Life Curves From Machining With Carbide Tools.

"MOTTLED" SURFACE FINISH

Surfaces of cast 718 cylinders were metallographically examined after machining under varying rigidity and three different tool materials. In all cases similar "mottling" was produced. These surfaces were examined optically and by scanning electron microscopy (SEM). The SEM examinations included viewing secondary images, as well as, EDAX traces across the surface irregularities.

Examination of the surface, shown in Figure 3, reveals the "mottling". These surface perturbations correspond to the grain size of Cast 718.

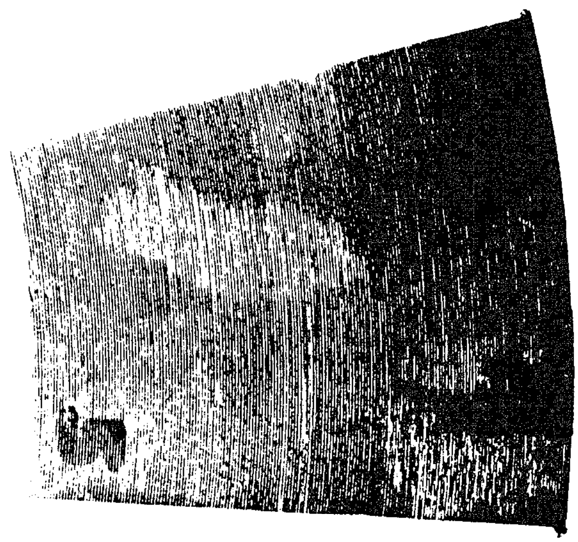

Figure 3. Machine Surface Revealing the "Mottle" Feature (4X).

SEM viewing, at 2000X in Figure 4, shows the region of the interface "wall". EDAX evaluation, see Figure 5, across the "wall" clearly depict the high Nb content in the particle and identify it as a carbide (NbC). The line scan shows the surface irregularities in the NbC particle region, which is confirmed by Back-Scatter-Electron image. This non-uniform tool action can be attributed to the tool bit hitting the hard NbC particle in the soft, tough grain matrix.

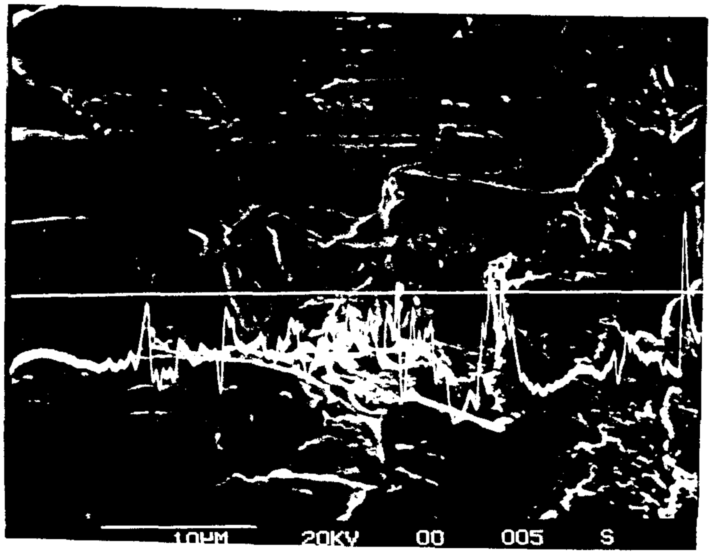

Figure 4. SEM of the "Mottle" Surface At Interface Wall (2000X).

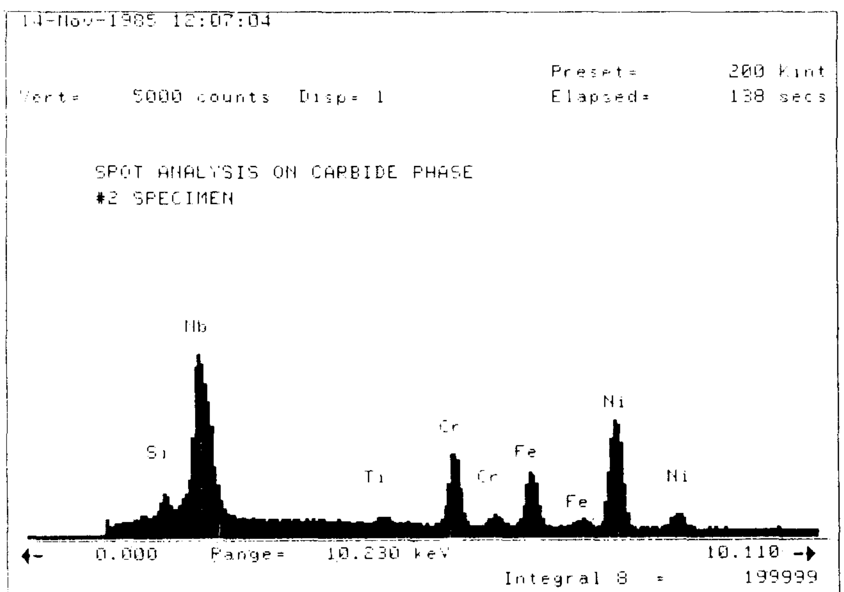

Figure 5. EDAX Analysis On Particle At "Mottle" Surface Wall.

CONCLUSIONS

1. The solution heat treated cast 718 machines with greater difficulty than the fully heat treated material.

2. Compared with the hardened forged alloy 718, the cast 718 yields significantly lower tool life.

3. The "mottled" surface finish can be attributed to the composite machining of the hard intergranular network supported in a "sea" of the tough, ductile grains.