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Difficult Materials Require Special Machines

The proliferation of parts made of the new triple-nickel titanium materials, or "heavy metals," will be reaching new heights, quite literally, within the carbon fiber skins of the next generation of aircraft soon to ply the world's air routes. While today's commercial planes are kept light through the use of aluminum for payload efficiencies, they require overhaul, often skin-off rebuilding, about every 20 years, because of the aluminum skin's flexibility. The new soon-to-be-a-reality aircraft will last some 70 years, thanks to the much greater stiffness inherent to the carbon-fiber skin, reducing operational expense significantly over the life of the aircraft.

To provide compatibility with the new skin, we'll find that triple-nickel titanium will comprise many of the components of the aircraft. These include the skeletal structure, as well as struts, floor ribs, window frames, door hinges, and engine mounts, all parts requiring structural integrity. In all, in each aircraft there will be some 36,000 lb (16,344 kg) of these heavy-metal parts that will be machined from 240,000 lb (108,960 kg) of raw stock. And each of these parts will be held to the highest possible degree of perfection from one end of the quality spectrum to the other—from roughing to finishing to critical verification. But these new materials, although light in weight when compared to aluminum, are extremely tough to machine. Does that put added strain on the manufacturers' need to deliver quality heavy-metal parts efficiently and competitively? Without question.

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Adding so much nickel to the titanium results in a material that has an exceptional ratio of tensile stress to tensile strain, which is the tendency of a part to deform along an axis when opposing forces are applied along that axis. Component fly-to-buy ratios can run from 10:1 for an engine mount, for example, and even higher for other parts. What you wind up with is a part that will not fatigue at all during the most strenuous flight conditions, but can be a real bear to machine. Conventional machine tools just haven't been able to meet the challenge.

At our company, we've been studying the productivity and quality requirements for these parts to develop the necessary machining capabilities. Remember the popular tagline "Where's the beef?" For machining heavy-metal parts, it has to be in the machine tool. These parts need to be machined at very low rpm. A 1" (25 mm), four-flute end mill, for example would be run at about 90 rpm.

Each time a cutting edge strikes the material, it transmits a shock wave into the machine tool. As each cutting edge "hits" the metal in a consistent, repetitive sequence, it drives a low-frequency wave into the machine. Today's machines have a tendency to chatter at low frequency. This affects both the quality of the part and tool life.

Another problem is the tool-taper interface. Pushing the tool through this very tough material at low rpm causes the tool-taper interface to separate, so we have to hold onto the tool harder. In designing our "heavy-metal" machines, we have also paid attention to requirements for handling the low-frequency stresses, such as height:width ratios on columns and tables to accommodate high moment loads, optimal ballscrew locations for axis stability, and hand-scraping throughout to provide the high accuracy needed to machine quality parts from these materials.

Because heavy metal twists and bends during the machining process, we must know how much the material is going to spring back so we know how much stock to leave for finishing. The real tricky factor is to make sure that whatever machining condition we have from part-to-part is the same. When we take the finish pass and get some springback, we want that part to spring back the same every time to ensure quality that is repeatable in every part. Of course, this also means that the suppliers of the raw stock will also have to be accountable for providing stock that is consistent, one piece to the next.

While a certain amount of bench time will still be needed to produce the smooth, polished parts that will be assembled into the aircraft, it will take specially designed four and five-axis machines to reduce that bench time and cost-effectively bring those parts to the level of repeatable quality mandated by the aircraft industry.

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