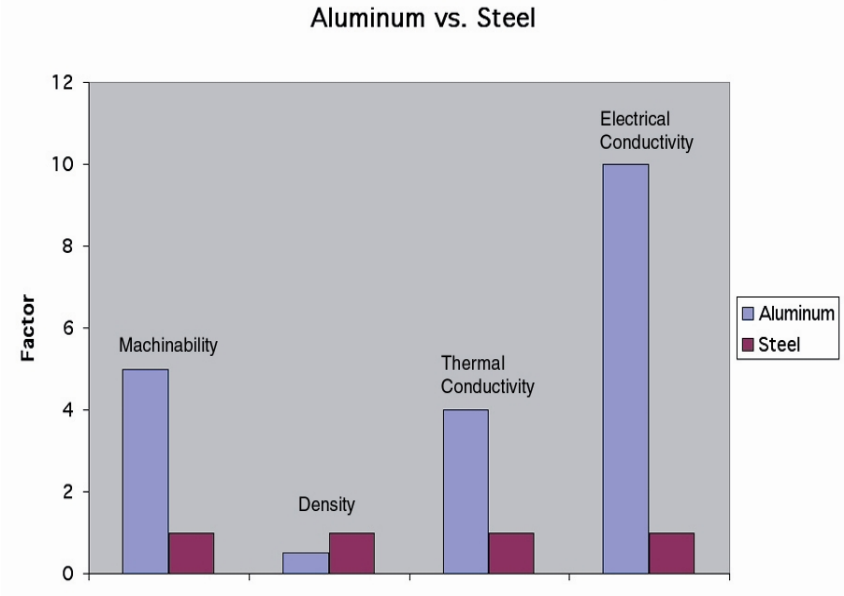
Specialized Aluminum Products for Tool and Mold Applications

With requirements for lowest weight, highest thermal conductivity, and ease of machinability, tool and mold applications are a natural opportunity for aluminum. Aluminum producers have responded with often-proprietary and tradenamed products tailored to meet the diversity of challenges presented by these applications. Hopefully this article can explain some of the key elements.

But, first the question of "why aluminum" needs to be addressed. Alternative materials, particularly a range of steels such as P-20, H13 tool steel, and stainless steels as well as copper-based alloys often containing beryllium, have been employed in tool and mold applications. They offer high strength and wear resistance, and, in the case of the copper alloys, thermal conductivity as well. But no material has all of the desired properties for a given application, and the alternative materials are no exception. They are heavy, often less machinable, and in the case of the steels, have poor thermal conductivity.

Overcoming those deficiencies is where aluminum comes into the picture. Compared to steel, aluminum:

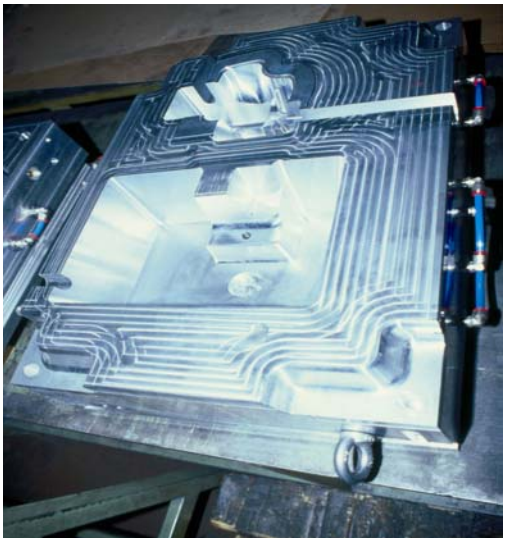
- Has a four-fold increase in thermal conductivity. In molding operations, this reduces the required cooling cycles and also minimizes local hot spots that could lead to part distortion. Aluminum also allows for the design of simpler cooling systems, which require less design and machining time.
- Is lightweight. Aluminum has roughly one-third the density of steel. This makes handling of the tooling and molds easier, and allows faster opening and closing of molds and tools due to reduced inertia. In addition,



lighter weight tooling results in less press wear reducing maintenance and downtime. These benefits are particularly relevant to large tools and molds.

- Can be machined and polished more rapidly. Depending on the specific aluminum alloy, machining rates three to ten times faster than that for steel are possible. This reduces the time required for mold production, particularly for large molds with deep cavities.
- Exhibits high electrical conductivity. This, along with a lower melting point as compared to steel, enables the use of electrical discharge machining of aluminum at a rate four to five times higher than for steel.

As a result of these benefits, one aluminum producer estimates that using aluminum for mold applications can save 30% in cost over steel in mold manufacturing, increasing to 40% if the reduced part production cycle times and hence improved productivity are included.



One area where steel offers an advantage is in the area of surface hardness. In some applications, such as those involving conventional plastic molding, the base aluminum surface has adequate properties. However for those cases where higher wear resistance is required, surface treatments of aluminum such as hard anodizing or nickel plating result in aluminum surface hardness levels approaching those of steel.

Since there is a range of different conditions under which tool and mold materials must operate, different aluminum alloy and temper combinations have evolved to meet the various needs. Both cast and wrought products are available in a wide range of thicknesses, widths, and lengths. Each product type has specific characteristics that have been tailored to application needs.

Cast plate materials have the following advantages:

- Equiaxed grain structure
- Low residual stress
- Extreme flatness tolerance capability
- Good internal soundness
- Excellent surface finish

Commercially available cast plate products (with producers listed in parentheses) include: Al-Mg based Fibraplan and Alca 5 (Alcan); ATP-5 and Duramold-5, both Al-Mg alloys and Duramold-2, an Al-Cu alloy (Vista Metals); Al-Zn based alloy MIC-6® (Alcoa); and Al-Cu alloy M-1 and Al-Mg alloy K-100S® (Alpase). Some of the applications in which cast plate have been used include food machinery molding plate

and other low pressure molding, electrical heating plates, milling machine bedplate, automatic inspection machine board holder, and screen printer base plate.

Wrought aluminum products are also widely applied. The nature of the improvements made to the plate products for use in tool and mold applications involves the following areas:

- Improved uniformity in through thickness properties. This is especially important because the products are available in thicknesses up to 35” in some cases
- Low residual stresses, accomplished by mechanical stress relief by stretching or cold compression after heat treatment
- Excellent flatness

For applications like low pressure plastic and composite molding including thermoforming and resin transfer molding that require a material with excellent corrosion resistance and weldability, 5xxx alloys are preferred. Similar to 5083-O are alloys such as Fibral® and Alumold-110 (Alcan) and Giantal (Aleris). Nevertheless, Al-Cu based alloys are also used such as M-1 (Alpase), which is based on a dilute 2618 composition.

Other applications such as low pressure molding of rubber and other elastomers, which involve temperatures in the 350-400°F range, necessitate a moderate strength material with good property retention at moderately elevated temperatures. Here, aluminum producers offer alloys based on the 2xxx series, often similar to 2618 or 2219, which are traditionally the best conventional aluminum alloys from a high temperature perspective. Tradenamed products in this group include: Weldural, a 2219-type alloy (Aleris); Tempral® and Alumold-350 (Alcan); and Alumec HT (Alcoa).

Another class of applications, particularly injection and compression molding as well as bolsters and force plates, call for high strength properties along with excellent machinability, high polishability, and good shape stability. The 7xxx alloy family meets this need well, and products here include; the 7040- or 7050-type Certal® SPC and Alumold-500 (Alcan); Hokotol, a 7050-type composition (Aleris); and Alumec 79, 89, 99, QC-7® and QC-10 (Alcoa).

A survey of wrought tool and mold plate products would not be complete without mentioning moderate strength alloys of the 6xxx series. Specialized versions of 6061-T6 in stress relieved tempers are available both in plate as compression stress relieved thick 6061-T652 (various producers) or 6061-T651 Type 200 plate (Alcoa) as well as extruded form Acc-U-Plate and Econ-O-Plate (Alcoa). In addition, a higher purity 6xxx for semiconductor applications in which anodizing is needed called Semi6 (Alcoa) is offered. Also, 6013-PowerPlate (Alcoa) is a rolled product with 25%

higher strength than 6061-T6 and improved machinability rating of “B” vs. the conventional “C” for 6061-T651.

While most of the products discussed above are not listed in Aluminum Association publications, and in some cases neither alloy composition nor temper specifics have been disclosed by the producers, there is information available through producer web sites:

- Alcan: www.arp-ravenswood.com or www.alumold.alcan.com
- Alcoa: www.alcoa.com/industrial/en/products/overview.asp
- Aleris: www.aleris-koblenz.com/english/products/molding_tooling/index.htm
- Alpase: www.plasticscommerce.com/alpase
- Kaiser: www.kaiseral.com
- Vista Metals: www.vistametals.com

While conventional aluminum tool and mold products have some obvious advantages in this these application areas, the competition is not standing still. Some developing technologies include both aluminum and steel tools manufactured using rapid prototyping methods, which have been trialed in short production run applications successfully. Rapid manufacturing methods eliminate some of the advantages enjoyed by aluminum in terms of machinability and shorter lead times over conventionally processed steel. This area looks like one that will continue to see significant emphasis and development in the aluminum industry worldwide.

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