Technical Bulletin

Effect of Alloys When Added to Carbon Steel

Alloys are added to carbon steel to enable it to do things that a plain carbon steel cannot do. These extra requirements may be grouped as follows:

1. To secure greater wear resistance for cutting or abrasion
2. To secure greater toughness or strength
3. To secure hardening accuracy and safety - and increased hardenability
4. To give the steel “red hardness” (the ability to do its work when heated so hot that a plain carbon steel would soften)

The effect of each element will usually be as follows:

Carbon: Improves hardenability and provides increased wear resistance. The lowest percent of carbon likely to be found in plain carbon tool steel would be .50% to .60%, for such things as black-smiths’ tools, hammer dies, etc. At about .80% the steel’s capacity to harden is increased to the point that it will become file hard when quenched. Addition of more carbon will increase the wear resistance. The highest carbon normally found in plain carbon tool steel is about 1.30%, in items such as razors, engraving tools, etc. A typical percentage for tool room usage is about 1.05%

Manganese: Practically all tool steel will contain at least .20% manganese and it can run as high as .50% before it would be regarded as a special alloy addition. Manganese helps to make steel sound when cast into the ingot and makes it easier to roll or forge.

Silicon: May be found between .50% and 2.00%, but always in conjunction with some other element such as manganese, molybdenum or chromium to add strength and toughness.

Phosphorus and Sulphur: Usually considered to be harmful elements in tool steels, they are sometimes added to machinery steel to make the steel more free machining.

Chromium: Contributes wear resistance and toughness to carbon steel.

Nickel: Adds to the toughness when used in conjunction with some hardening alloy like chromium.

Tungsten: Adds to wear resistance - must be added in fairly large quantities to effectively increase wear resistance. At about 4% with about 1.30% carbon, hardened steel will be so wear resistant that it will be difficult to grind. When tungsten is added between 12% and 20%, in conjunction with chromium, it gives the steel the property of red-hardness. A steel containing 18% tungsten and 4% chromium can continue cutting and hold its edge even when heated to a dull red (steels like this are known as High Speed steels).

Vanadium: Sometimes added in small quantities (about .15%) to straight carbon steel to impart a toughening effect by keeping the grain size small. It is used in quantities between .15% and 1.00% in conjunction with chromium, tungsten, etc., in hot working die steels, and about 1% to 3% of vanadium is put in High Speed steel for the same purpose.

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Molybdenum: Similar to chromium and tungsten, increasing red hardness and wear resistance. An important application of molybdenum is in High Speed steels.

Cobalt: Used as an alloy in some High Speed steels to increase the red-hardness, or resistance to tempering.

Principal Alloy-Forming Elements and Their Symbols

Aluminum	Al	Cobalt	Co	Mercury	Hg	Silicon	Si
Antimony	Sb	Columbium	Cb	Molybdenum	Mo	Silver	Ag
Arsenic	As	Copper	Cu	Nickel	Ni	Sodium	Na
Barium	Ba	Gold	Au	Nitrogen	N	Sulphur	S
Beryllium	Be	Hydrogen	H	Osmium	Os	Tantalum	Ta
Bismuth	Bi	Indium	In	Oxygen	O	Tellurium	Te
Boron	B	Iridium	Ir	Palladium	Pd	Tin	Sn
Cadmium	Cd	Iron	Fe	Phosphorus	P	Titanium	Ti
Calcium	Ca	Lead	Pb	Platinum	Pt	Tungsten	W
Carbon	C	Lithium	Li	Potassium	K	Vanadium	V
Cerium	Ce	Magnesium	Mg	Rhodium	Rh	Zinc	Zn
Chromium	Cr	Manganese	Mn	Selenium	Se	Zirconium	Zr