Recommendations for molds steels used with engineering plastics

AKRO COMPOUNDS

Two kinds of wear

Abrasive wear

- mechanical wear due to hard surfaces sliding over softer surfaces
- common when using compounds with hard components like glass fibers, carbon fibers and some minerals

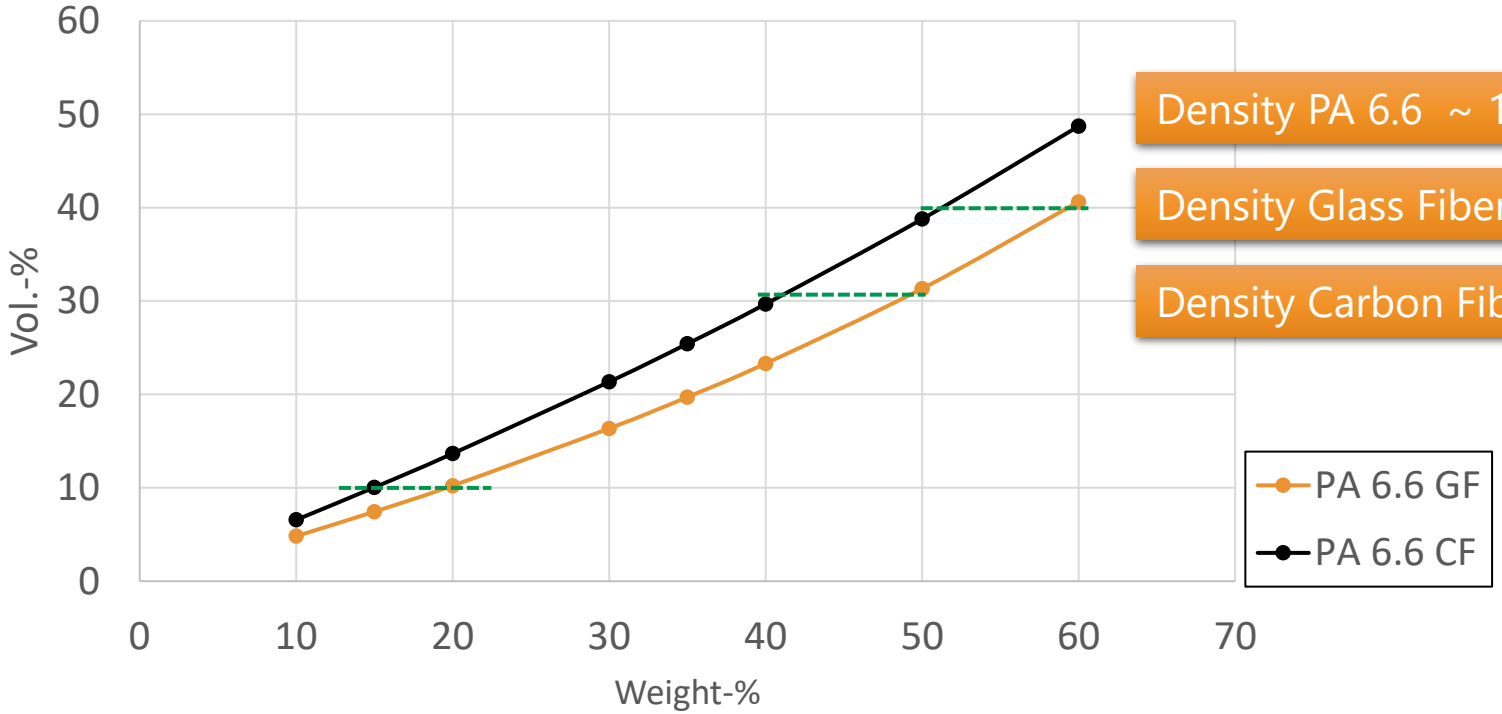
➢ reduced by using harder mold steel

Corrosive wear

- chemical wear due to oxidation of the metal
- common when using flame-retardant compounds

➢ reduced by using anti-corrosive steel

Weight-% and Volume-% of glass and carbon fiber reinforced PA6



Density PA 6.6 ~ 1,14 g/cm³

Density Glass Fiber ~ 2,5 g/cm³

Density Carbon Fiber ~ 1,8 g/cm³

Hardness of glass and carbon fiber is similar

- similar mold wear at equal volume-%, but density of carbon fiber is lower

General Mold Steel Types

Unalloyed steels: Basic steel, only simple applications, not suitable as mold steels

Alloyed steels: Mix with other elements like manganese, nickel, chromium, molybdenum, vanadium or others in order to improve properties like strength, hardness, toughness, wear resistance, corrosion resistance, hardenability, and hot hardness.

- Heat-treatable steel: Hardened by annealing
- Cold-work steel: Hardened by annealing, up to 200°C operating temperature
- Hot-work steel: Hardened by annealing, more than 200°C operating temperature
- Powder-metallurgic steels: Highest hardness, best wear resistance, but expensive and hard to machine
- Anti-corrosive steel: Resistant to oxidation

Steel considerations

- wear resistance is achieved from hardness of the steel matrix and/or due to carbides formed from the alloy elements
  - hardening process is crucial
  - number and size of carbides is most relevant
- steel tenacity and hardness are opposing. Harder steels are:
  - much harder to machine
  - easier to polish
- corrosion resistance: usually achieved by high chromium content
- thermal conductivity differs between steel grades

Hardness Recommendation

- high-quality alloyed steels are recommended
  - only for pre or small series production (<50.000 cycles) lower hardness can be used, e.g. aluminum or softer steels depending on specific mold design and number of cycles
- hardness of steel is greatly influenced by **heat-treatment / hardening** process
- For a good life-time, a ductile steel is recommended.
- Use only as indication:

Glass Fiber content	Carbon Fiber content	Recommended minimum hardness
Up to 20%	Up to 15%	~52 HRC
Up to 40%	Up to 30%	~56 HRC
Up to 60%	Up to 40%	~60 HRC
Above 60%	Above 40%	can be covered with hard coatings

- Sometimes less fiber content can lead to problems by critical geometry and/or high injection speeds

Dealing with mold wear

Mold design

- use harder inserts at high wear areas, e.g. deflector surfaces, gates, runner
  - areas with high flow speeds, deflections and nozzles are most prone to wear
- sensitive or more complex mold parts e.g. thin cores require softer steel to manufacture, use steel as hard as necessary not as possible
- when steel parts move relative to each other, the more expensive one to replace should be harder

During production

- reduction of injection speed greatly reduces abrasive wear (see graph)

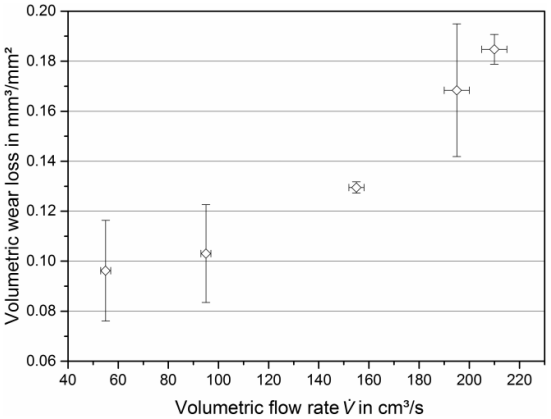


FIG. 7. Volume loss of PM steel specimens for 50 kg injected PA66-GF50 as a function of the effective volumetric flow rate $\dot{V}$.

Source: Abrasive/Erosive Wear on MMCs in Plastic Molds as a Function of Volumetric Flow Rates and Glass Fiber Distribution, https://doi.org/10.1002/pen.24952

Example materials for mold steels

No. (EN 10027)	Hardness HRc	Steel Type	Description	Example Trade names
1.2343	50-52	Hot-work	Standard hot-work steel	Böhler ISOBLOC
1.2344	50-52	Hot-work	Higher max. hardness, higher elevated temperature resistance	Uddeholm Orvar supreme, Böhler ISOBLOC
1.2311	50-52	Heat-treatable	Polishable; suitable for nitration	
1.2767	50-55	Cold-work	Improved wear resistance, high tenacity, polishable	
1.2379	58-60	Cold-work	High wear resistance, high hardness and tenacity, polishable	Uddeholm Sverker 21, Böhler K110
1.2363	58-60	Cold-work	High wear resistance, high hardness and tenacity, polishable	Uddeholm Rigor
1.2842	58-62	Cold-work	High wear resistance, high hardness and tenacity, not polishable	
1.2083	50-54	Corrosion-resistant	Corrosion resistant, polishable	Uddeholm Stavax ESR, Böhler ISOPLAST
	60-66	Powder-metallurgic	Very high wear resistance, hard to machine, pricy	Böhler Microclean, Uddeholm Vanadis, Zapp CPM

More commercial examples by Uddeholm / Voestalpine

Trade name	Hardness HRc	Steel Type	Description	Application
Uddeholm Dievar	48-52	Hot-work	High ductility tool steel, AM-Powder	Powder for AM built inserts
Uddeholm Unimax	54-57	Plastic tool steel	Special high ductile	GF up to 40%, CF up to 30%
Uddeholm Caldie	57-61	Cold-work	Special high ductile	GF up to 60%, CF up to 40%
Uddeholm Vanadis4E	58-64	PM-Steel	High ductility, good wear resistance	High fiber content
Uddeholm Vanadis8	58-64	PM-Steel	Good ductility by best wear resistance	High fiber content, use for stable contructions
Uddeholm Vancron	58-64	Special PM-Steel	Good ductility, high wear resistance, good tribological properties	Good deforming properties, use for stable constructions
Uddeholm Tyrax ESR	54-57	Plastic tool steel	Special high ductile plastic tool steel, corrosion resistance	GF up to 40%, CF up to 30%, flame-retardants
Uddeholm Elmax	57-60	PM-Steel	High abrasive wear, moderate corrosion resistance	High fiber content, use for stable constructions
Uddeholm Vanax	58-62	Special PM-Steel	High abrasive wear, best corrosion resistance, good tribological properties	High fiber content, flame-retardants, use for stable constructions
Uddeholm Corrax	50-52	Plastic tool steel	Maraging steel, Good corrosion resistance, AM-Powder	Flame-retardants, Powder for additive manufactured inserts

Surface coatings for increased wear and/or corrosion resistance

- Surface coating treatments can be used for different effects:
  - increased surface hardness / reduced abrasive wear
  - reduced corrosion
  - improved demolding, improved flow, glossy surfaces
  - reduced surface deposits / better venting
- Even on lower fiber content hard coatings can make sense on critical geometries
- Different coatings have strength and weaknesses
  - please refer to information provided by coating companies

Surface coatings for increased wear and/or corrosion resistance

- PVD coatings (physical vapor deposition)
  - Titanium carbonitride (TiCN)
  - Chromium Nitride (CrN)
  - Tungsten carbide/Carbon (WC/C)
- CVD coatings (chemical vapor deposition)
  - Titanium carbide/titanium nitride (TiC-TiN)
- PACVD coatings (plasma assisted chemical vapor deposition)
  - DLC (diamond-like carbon)
- Diffusion coatings
  - e.g. Caveo® by hotec GmbH

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