Chapter 3 Gear material and Heat treatment

3.1 Selecting gear material

When load to flank of gear is excessive, wearing off (pitting) of flank may occur easily. It is necessary to select material with greater strength of surface durability therefore the case hardening steel is recommended due to higher hardness.

The impact to flank of gear during operations causes damage to the gear tooth, therefore it is necessary to select steel with higher bending strength. Selected material should be able to apply induction hardening after quenching and annealing treatment. Such selection emphasizes on core hardness instead of surface strength.

Take note of the following while selecting material with manufacturing expense and productivity in mind.

1) For necessary strength for gear, select the material character by emphasizing on either Surface durability or Bending strength. Generally, ideal material selected for gear tooth should be tough and hard to withstand damaged by the load.
2) Suitable material for machining.
   Pitting occur easily in free cutting steel even after surface treatment is applied to gear. This material is unsuitable for gear even though it has good machinability.
3) Material which is easy to apply heat treatment and little deformation. Even if deformed after applying heat treatment, amount should be stable.
4) Material should be economical and easily obtained.

Table 1 shows the common gear materials used for transferring power.

Table 1. Iron and steel materials used for gear

Name of Standard	JIS number	Materials
Gray iron casting	G5501	FC200, 250, 300, 350
Spheroidal graphite iron casting(1)	G5502	FCD400, 450, 500
Carbon steel forging for general use	G5101	SC410, 450, 480
High tensile strength carbon steel casting and Low alloy steel casting for structural purposes	G5111	SCC3A, 3B SCCrM1, 3, SCNCrM2
Carbon steel for machine structural use	G4051	S38C ～ 58C, S09CK, S15CK, S20CK
Nickel chromium steel	G4102	SNC631, 836, 415, 815
Nickel chromium molybdenum steels	G4103	SNCM625, 630, 439, 447 SNCM220, 415, 420, 616, 815
Chromium steel	G4104	SCr415, 420
Chromium molybdenum steel	G4105	SCM435, 440, 415, 420, 421, 822
Aluminium chromium molybdenum steels	G4202	SACM645
Stainless steel bars	G4303	SUS304, 440C

Note (1) This material includes Ductile Cast Iron and meehanite

Remarks. For Case hardening, it is common to use SCM415 or SNCM415. SNC815 and SNCM815 are suitable for Spiral bevel gear. Please refer to Table 5 (Pg. 58) for Load, Material and its heat treatment.

Characteristics of Polyacetal

Recently, industries prefer to use various engineering plastics for machinery elements. We would like to introduce you to our commercialized KG-Polyacetal gears (one of the engineering plastics). Note that gear strength and heat resistance should be taken into consideration when comparing with metal gears.
There are 2 types of Polyacetal, uniformed formaldehyde and copolymerizated ethylene oxide. The former is called Acetal - homopolymer, the latter is called Acetal - copolymer. Usage condition: mean load and mean speed or less is recommended.
Polyacetal has following features. Please refer to the below.

- Physical characteristics - Thermoplastic resin. Used for extensive mass production. Polyacetal has excellent physical characteristics compared to all other resins.
- Wear characteristics - Regarding Wear proof, Polyacetal is excellent next to Polyamide due to little absorbency.
- Polyacetal has tendency for minute dimensional changes due to minute absorption. It has excellent fluidity and has less remainded strain for mold items.
- Chemical character - There will be no damages to the Polyacetal properties even after soaking it in organic solvent with inorganic drug without mineral acids for 6 months. However, use of phenol is not advisable. Polyacetal is extremely resistant against erosive Alkali. It will not be damaged by industrial lubricating oils, motor-oil, break-oil and even contact to copper material.
- Heat resistant - Polyacetal has excellent heat resistant features.

Table 2. Properties of Polyacetal

	Testing methods	Units	Numerical value
Specific gravity	ASTMD-792	-	1.41
Water absorption (soaked for 24 hour)	ASTMD-570	%	0.22
(60% RH)			0.16
Tensile strength (yield point)	ASTMD-638	N/mm^2	61
Tensile elongation (breaking point)	ASTMD-638	%	40
Modulus of elasticity in tension	ASTMD-638	N/mm^2	2,830
Flexural strength	ASTMD-790	N/mm^2	89
Flexural modulus	ASTMD-790	N/mm^2	2,590
Compressive strength (Deformation of 10%)	ASTMD-695	N/mm^2	103
Shear strength	ASTMD-732	N/mm^2	55
Izod impact value (with notch)	ASTMD-256	J/m	74
Rockwell hardness	ASTMD-785	M scale	78
		R scale	119
Taper abrasion (1kg.CS17 wheel)	ASTMD-1044	mg/100 cycle	14
Coefficient of dynamic friction (for steel)	Westover style friction testing machine	-	0.13
Poisson's ratio		-	0.35
Melting point	DSC analysis temperature 10°C/min	℃	165
Deflection temperature under load ($182.4 N/cm^2$)	ASTMD-648	℃	110
($45.1N/cm^2$)			158
Coefficient of linear expansion	-25 ～ +25℃	$\times 10^{-5}$/℃	9
Combustion property	UL94	-	HB
Dielectric constant (10^2 ～ 10^6Hz)	ASTMD-150	-	3.7
Dielectric dissipation factor (10^2Hz)	ASTMD-150	-	0.001
(10^6Hz)			0.007
Surface resistance	ASTMD-257	Ω	1.0×10^{16}
Volume characteristic resistance	ASTMD-257	Ω·m	1.0×10^{12}

The above properties are for reference only. They are not covered under warranty.
Extract from Nippon Polypenco Co,. Ltd - Polypenco Acetal catalogue.

Features of Polyacetal gear

Strength of plastic gear compared with metal gear excluding external factors is $\frac{1}{6}$ to $\frac{1}{9}$. However, it is necessary to take factors like temperature, humidity and others into considerations.

Table 3. Circumferential speed and Limitation of frictional speed

Lubrication		Without lubricating oil	Lubricating oil
Circumferential speed for Spur and Bevel gears	m/s	6	12
Frictional speed for Worm gear pair	m/s	1	2.5

Lowest usage temperature limitation -38°C

Backlash for plastic gear

Plastic material has extremely smaller thermal conductivity and larger thermal expansion factor compared with metals. Plastic gear pair has higher tendency to change dimension compared with metal gear. Therefore KG has intentionally fabricated wider backlash plastic gears as compared with metal gears.

Combination of gear materials

The combination of materials for plastic gear pair, assuming combination between Polyacetal, metal material factor is 1.0. When combining two Polyacetals, material factor is 0.75. Therefore gear strength for Polyacetal gear pair becomes 75%.

We believe that engagement between Polyacetal and metal gears are best combination.
However, note that maximum surface roughness 6S at flank for metal gear is advised to prevent wear for plastic gears.