

Studies on Improvement of Surface Durability of Case-Carburized Steel Gear - Effects of Surface Finish Processes upon Oil Film Formation

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American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

It is very difficult to precisely finish a gear tooth surface to the extent of a few sub-micron with grinding. Even if possible, the grinding time of the tooth surface will be very long and a grinding burn may often occur. The authors have adopted a barreling process as a final finish process in order to improve the ground and/or shot peened surface. Though the barreling process is economical from the viewpoint of the manufacturing process, there was a very important question whether or not the process is applicable to gears with complex configurations. The authors have found that the barreling process is very effective for the improvement of gear tooth surface roughness without changes in tooth profiles and tooth traces, which may have small tooth tip relief and/or crowning. In the present research, the surface durability of the high quality gear manufactured by a proposed new method was also investigated using a gear testing machine, which can measure the condition of oil film formation between a pair of gears during running. As the results of durability test, it was confirmed that the configuration of tooth surface of the barreled gear scarcely changed after running, but that of the shot peened gear remarkably changed. The condition of the oil film formation in a running test conducted using barreled gears was very good even during start-up. Also, the duration of oil film formation in the case of the barreled gear was superior to the one in the case of the ground or shot peened ones, because of the difference of metallic contact condition.

Key Words: Gear, Case-Carburized Gear, Surface Durability, Shot Peening, Barrelling, Surface Roughness, EHL, Tribology

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— Effects of Surface Finish Processes upon Oil Film Formation —

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1. Introduction :

From basic experimental results [1]-[3] conducted using a two roller contact fatigue testing machine, it was expected that a high quality gear whose bending fatigue strength and surface durability are appreciably higher could be manufactured, if a compressive residual stress is induced on and below a tooth surface of a gear by the shot peening process after grinding and the surface is smoothed by the barrelling process. In the present study, the authors propose a new manufacturing method for improving the surface property of the gear tooth by employing shot peening and barrelling processes after grinding.

Though gear honing, in which a gear is polished by a worm-shaped grinding wheel made of urethane rubber [4], and gear rapping, in which a gear is polished using abrasive and a helical gear made of cast iron or plastic [5][6], are generally tried in order to improve the tooth surface of gear, their finishing processes are apt to be influenced by the contact pressure and the relative velocity between surfaces of a tool and a gear, and only the strongly contacted regions may be removed. On comparison with them, the shot peening and barrelling processes have a possibility that the whole of the tooth surface is uniformly finished. The surface configuration will hardly change after processing. This method will be

optimum for gear finishing with complicated tooth profile and tooth trace.

Though the gear finished by the manufacturing method proposed in this study has a mirror-like tooth surface, the tooth surface roughness still has waviness component. Therefore, it was questioned whether its surface durability is higher than that of the only ground gear, or not. The surface durability of spur gears was then examined using a gear fatigue testing machine in practice.

2. Manufacturing Method of High Quality Gear:

2.1 Specifications of Gear

Table 1 shows dimensions of gears which were tested. Figure 1 shows shapes and dimensions of gears. The helix angle, β , of a pair of helical gears was 16° .

Table 1 Specifications of gears

Specifications		Gear [1]	Gear [2]	Gear [3]
Module	m	3	3	3
Pressure angle	α°	20	20	20
Number of teeth	z	26	25	25
Dia. of pitch circle	d mm	78	78	78
Helix angle	β°	0	16	-16
Face width	B mm	15	38	38

The tooth profiles and tooth traces of these gears are modified (amount of tooth tip relief; $\delta \approx 20 \mu\text{m}$, crowning amount; $\lambda \approx 20 \mu\text{m}$). The amount of crowning of the spur gear is larger than that of the conventional gear. This aim was due to examine the adaptability of the shot peening and barrelling processes for manufacturing the gear with complicated surface and examine load carrying capacity of the gear under very much large maximum contact pressure.

The gear material was a chromium-molybdenum steel (SCM822H in JIS). A gear prepared by hobbing was carburized at 930 °C, kept at 850 °C for the brief time, and quenched by soaking in hot oil bath at 120 °C. After that, it was tempered at 160 °C. The hardness of the surface was about 750 HV and the depth of effective hardness about 1.2 mm.

The tooth surfaces of gears were finished with a gear grinding machine having a worm-shaped grinding

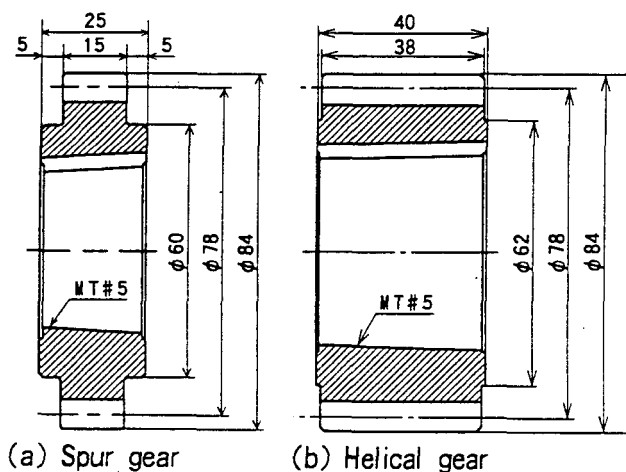


Fig. 1 Shapes and dimensions of gears

Table 2 Method of grinding

<Worm-shaped grinding wheel>		
Kind of wheel	:SN-120-J-V53R	
Outside diameter	:300 mm	
Rotational speed	:1400 rpm	
	(Roughing)	(Finishing)
Feed	:0.6 mm/rev	0.3 mm/rev
Depth	:0.03 mm	0.2 mm

Table 3 Shot peening process parameters

Shot Material	Size mm	Hardness HV	Pressure MPa	Arc height mmA
Steel	$\phi 0.6$	600	0.3	0.37

wheel. The tooth root was also ground together with the tooth surface in order to improve the bending fatigue strength. The method of grinding is shown in Table 2.

2.2 Shot Peening and Barrelling Processes

The shot peening process parameters are shown in Table 3. The shot material is a spherical rounded steel wire. The shot peening process was applied to both sides of the gear tooth surface. The inlet angle of shot peening near a pitch point of a tooth is about 50°. A residual stress was detected at a crystallographic plane (211) by an X-ray diffraction method with Cr-K α rays. Figure 2 shows the distribution of residual stresses near the surface at a tooth root and near a pitch point. All residual

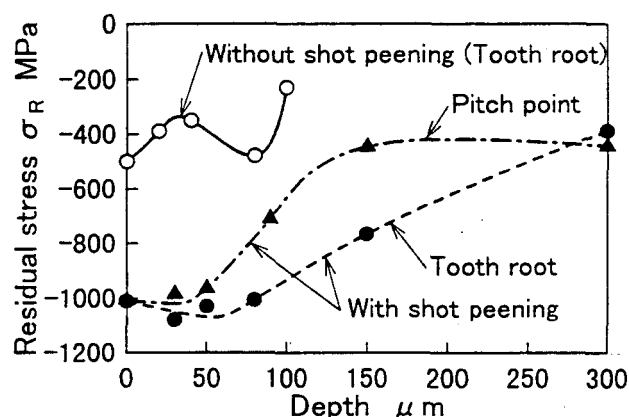


Fig. 2 Distributions of residual stresses

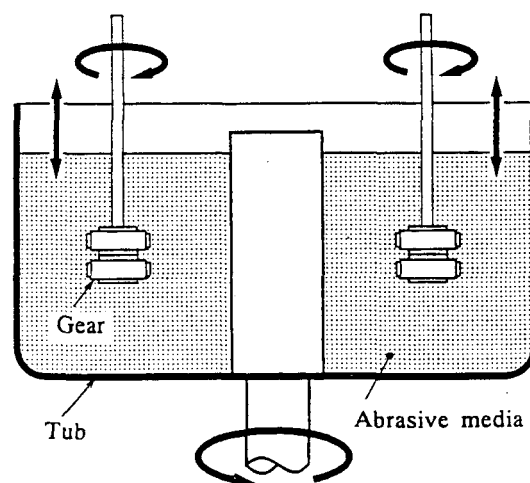


Fig. 3 Schematic drawing of barrelling machining

Table 4 Conditions of barrelling process

Barrel material	Speed of tub m/min	Time min
Alundum(#6~#10)	100	30~60