Gear Reclamation by Hard Chromium Plating - A Case Study

Dr. C.K.B. Nair, Heavy Vehicles Factory, Avadi, Chennai, India -600 054

Planetary gears for transmission systems of heavy vehicles that are supported directly on rollers without bearing races are having shorter lives as a result of roller impressions in the bore of the planet gears. Failure of these gears with this defect is affecting the performance of the vehicles necessitating frequent replacement of gears. In this paper a specific methodology of gear reclamation by hard chromium plating is presented. Parameters to be controlled during pretreatment and post-treatment processes are illustrated. Results obtained after extensive trials are included in the case study.

For more information, contact:

Dr. C.K.B. Nair
Deputy General Manager,
Heavy Vehicles Factory,
(Ministry of Defence),
Avadi, Chennai, Tamilnadu
India -600 054
Phone: 91-44 -638-4599 xt 3233
FAX : 91- 44 -638-3824

Introduction

Bearings are essential parts in transmission systems to transfer torque and motion. Compact transmission systems with minimum volume and weight are basic design requirements of Heavy Vehicles[1]. Therefore, many bearings for high-speed transmission gears are designed without bearing races. The rolling elements (rollers) are directly assembled in between the gear bore and gear shaft. With the impact of rolling load, the rollers will create roller impressions in the surface of gear bore and gear shaft. Gears with irregularities in the bore surface finish will affect the functioning of transmission systems[2] and necessitate replacement with new gears. If effective salvaging techniques are implemented cost of frequent replacement of old gears by new ones can be avoided.

Hard chromium plating was started as salvage measure just after First World War[3]. The list of special uses of hard chromium plating could be extended indefinitely4. Hard chromium plating is now a recognised method of prolonging the life of all types of metal parts subjected to wear by friction and abrasion[5].

Even though technical papers are still appearing with results of laboratory experiments on process improvement[6] and new applications[7] detailed methods of hard chromium plating applications in industry are kept very guardedly as was the practice in the past. In this paper a methodology for reclamation of gear bore surface by hard chromium plating is illustrated based on a case study on practical application.

Gear Overhauling

Transmission systems are to be overhauled for enhancing the life of the vehicles. Abnormal noise and excessive power consumption are symptoms indicating the necessity to carry out overhauling of Transmission systems. Overhauling is also carried out to attend to an unexpected breakdown of the transmission system or to have preventive maintenance at planned schedules. Planned overhauling is based on calendar years or number of kilometers run by the vehicle.

For transmission systems overhauling all gears are disassembled, cleaned, inspected, repaired, reassembled and tested. During overhauling inspection it is observed that vehicles which are taken up for overhauling after completion of the specified kilometers most of the gears are excessively worn out and are beyond repair. When overhauling is carried out based on calendar years the tooth profiles of the gears are normally not damaged.

When gear tooth profile is within acceptable limits the gears can be reused provided bore surface condition is satisfactory. Gears having roller impressions in the bore surface, as shown in the photograph at Figure 1, are normally rejected and replaced with new gears resulting in high overhauling cost. Hard chromium plating is proved to be an effective method to repair gear bore surface. Details of various operations carried out for salvaging the gears by hard chromium plating are briefly explained and test and trial results are discussed.

Pre-Plating Operations

The sequence of operations set up for this reclamation work is shown in Table 1. The condition of gear bore surface is shown in Figure 1. After thorough cleaning in kerosene the gears are checked for lead, profile, spacing between teeth, roll and surface finish. Gears having tooth profile within specified limit are segregated and such gears are only considered for the present reclamation work. For removing the roller impressions in the gear bore surface the gears are mounted on internal grinding machine. Bore is set true by taking reference of pitch circle diameter of the outside gear teeth. Maximum 50 microns (.002 inch) material on thickness is removed by internal grinding. If the roller impressions are still present after removing 50 microns material on thickness those gears are not considered for repair. In this specific application hard chromium platting thickness is limited to 100 microns (.004 inch).

Then the gears are stress relieved by keeping it at 150°C oil for 3 hours and subjected to magnaflux crack detection. Then the gears are shifted from machine shop to electroplating shop.

Process Setting And Controls

The sequence of operations followed in the electroplating shop is shown in table 2

The bath composition is of Hexavalent chromium 250 to 280 gms/l (40 to 45 oz/gal), and Sulfate (SO4) 2.5 to 2.8 gms/l (0.4 to 0.45 oz/gal) Trivalent chromium 3.0 to 5.0 gms/l (0.48to 0.8 oz/gal) and maximum iron content is limited to 18.75 gms/l (3oz/gal). Anodes are prepared from antimonial lead (Lead 92 to 93 % and antimony 7 to 8 %). Length of anode is set to prepare a batch of 7 number of gears at a time. Based on anode design job holding jig is prepared. The jig consists of two polypropylene plates, 100mm (4-inch) square with series of holes drilled at regular intervals. The plates hold the job and locate the anode concentrically. Bath is having periodically calibrated Ammeter and Voltmeter.

The plant can be operated 24 hours continuously. All the processes are controlled and recorded to have traceability of Electroplaters and jobs. These records are clear evidences of efforts made to have continuous improvement in the process. A test piece of similar material is also plated along with the jobs.

Post plating operation

After removing from the fixture the jobs and the test piece are cleaned. Test piece is submitted for thorough inspection. Coating thickness is checked by magnetic thickness gauge. Micro hardness tester tests hardness. All the jobs are subjected to dye penetrant crack detection checks. Acceptable jobs are taken up for internal grinding. Taking reference of external gear teeth pitch circle diameter, the bore is ground to true position. 25 micron (.001 inch) material is removed in three passes. Then jobs are loaded on a vertical honing machine and rough honed and finished honed by removing further total 15 micron (0.0006 inch) material. After honing all the jobs are polished to remove the excess deposit on side faces and on chamfer. Final dimensions are measured and acceptance marks are etched and gears are grouped based on the base tangent length measurement. Figure 2 shows the photograph of cross section of hard chromium plated gear bore surface.

Human Interface

Gear reclamation by hard chromium plating being a special task all the electroplaters in the plating shop are taking special care and attention for each job at each stage of operation. This is carried out in an ISO - 9002 certified environment where continuous efforts are made to motivate the electroplaters to excel in their job.

Even though published literature is not available on reclamation of gear bore surface the electroplaters organised all facilities with a pull approach at each stage of plating to meet the tight schedules. The success of this operation can be attributed to the special skill of the people and attitude to enhance the utilitation of facilities. Plant availability was 99% and bath efficiency was 90%.

Methods to decontaminate spent hexavalent chromium and eliminate hazardous waste associated with chromium plating are developed and a constant pH value is maintained and sludge formation is kept at low level. The facilities were readily available and there was no need for additional capital investments. This salvage method has helped to avoid replacing the gears and to save considerable time and cost.

Test Results.

The facilities available for routine testing of hard chromium plating was only used for testing of this specific application of hard chromium plating on gear bore surface.

Plating thickness was checked by a magnetic thickness gauge having minimum 5micron(0.0002 inch) resolution. Plating thickness was 90 micron(0.0036inch) with 10-micron (0.0004 inch) tolerance. After grinding and honing operation plating thickness was 50 micron (0.002 inch).

Hardness was checked on a microhardness tester applying a load of 500 gms (1.1 lbs.). Hardness value was 950 Vickers Pyramid Number(VPN). This is very high hardness comparing to 58 HRC (700 VPN) minimum on the case hardened base metal

Crack detection was carried out after honing operation using dye penetrant method and surface was found crack-free.

Adhesion was checked in a makeshift arrangement by applying bending load on test piece considering the strength required for the practical application. The plating did not peel-off during the test.

Abrasive wear was tested with normal grinding wheel load and frictional wear was tested using a harder tungsten carbide wheel. The results were superior comparing to that of base metal.

Even though the results were satisfactory, being only comparative in nature a laboratory specialising in this field is assigned to design specific devices for carrying out test of hardness, uniformity of thickness, adhesion, abrasion resistance and other parameters for this specific application to standardise the process.

Trial Results

Hard chromium plated gears were assembled using new rollers to build up the gearbox. Backlash, difference in backlash and clearance between the rollers and bore surface were ensured during assembly. No-load running-in trial was conducted on a gearbox test rig followed by no-load trial run. After no-load trial, gearbox was disassembled and hard chromium plated gears were carefully inspected. No roller impressions were seen and surface condition was very good. The gears were reassembled in the gearbox and gearboxes were re-tested and were mounted in the heavy vehicle. Trial run of 1500 Kilometers subjecting to various load conditions was conducted. There was no abnormality during the trial run. After the trial run the gearbox was removed and disassembled and subjected to profile and other dimensional checks. Profile was tested on Gear Profile tester and there was no deviation on profile. Gear bore wear was 3 micron (0.00012 inch) on thickness and there were no roller impressions. This result was superior to the original case hardened base metal surface.

Photograph of gear with hard chromium plated bore surface subjected to 1500 kilometers trial run is shown in Figure 3. All lubrication and hydraulic system filters were checked after the trial and no chromium sediments were detected.

Conclusion

It has been demonstrated that hard chromium plating on gear bore surface is an effective salvaging method. Pre-plating and post plating operations and sequence of plating processes are briefly explained and test results and functional trial reports prove that wear rate of hard chromium plated surfaces are three times lower than the wear rate of case hardened steel. Electroplaters should understand the importance and utility of hard chromium plating for effective plating operations. This is possible by developing the skill of etectroplaters by common sharing of knowledge through continuos training. This type of cost effective salvaging methods will considerably reduce the maintenance cost of heavy vehicles especially in developing and under developed nations.

References:

1. Rolf Hilmes, "Aspects of future MBT conception", Military technology, 1999, vol XXIII, issue 6, 72-78.

2. Flamang.P., "Design for silence, "New concepts and techniques for industrial use", Gear technology, September-October 1999, 17-23.

3. Durney.L.J, "Electroplating Engineering Handbook", IV Edition, Von Nonstrand, Reinhold Co, 1984.

4. Dubpernell.G., "Chromium", in "Modern Electroplating" Edited by Lowenheium F.A., John Wiley and Sons Inc, New York, 1963.

5. Greenwood. J.D, "Hard chromium plating: A handbook of modern practice" Robert Draper Ltd, Teddington, 1971.

6. Singh K, Wasnik D.N., Grover A.K. Totlani.M.K., Suri A.K., "TiN coatings modified by an interlayer of electroplated Chromium on mild steel", Transactions of the Institute of Metal Finishing, 1999, Vol 77, part 5, 196-199.

7. Rathinam.A.J., Krishnan.R.M., Jayakumar S., Sriveeraraghavan.S., "Energy conservation in chromium plating through use of non-conventional anodes", Transactions of The Institue of Metal Finishing, 1999, Vol 77, part 4, 132-134.

TABLE 1

SEQUENCE OF OPERATIONS FOR GEAR RECLAMATION

OPERATION No.	OPERATION	FACILITIES REQUIRED	PARAMETERS CONTROLLED
10	Cleaning	Kerosene bath	External damages
20	Inspection	Gear profile tester, Gear roll tester, snap gauges	Profile, Roll, Base tangent length, Bore diameter
30	Internal grinding	Internal grinding machine	Bore diameter and concentricity
40	Stress relieving	Oil bath	150°C, 2 hours.
50	Hard chromium plating	See sequence of hard chromium plating operation given in Table 2	
60	Stress relieving	Oil bath	150° C, 2 hours.
70	Internal grinding	Internal Grinding machine	Bore diameter and concentricity
80	Honing	Honing Machine	Bore diameter, concentricity, surface finish
90	Stress relieving	Oil bath	150° C, 2 hours.
100	Inspection	Gauges	Bore diameter and grouping of the gears based on base tangent length .

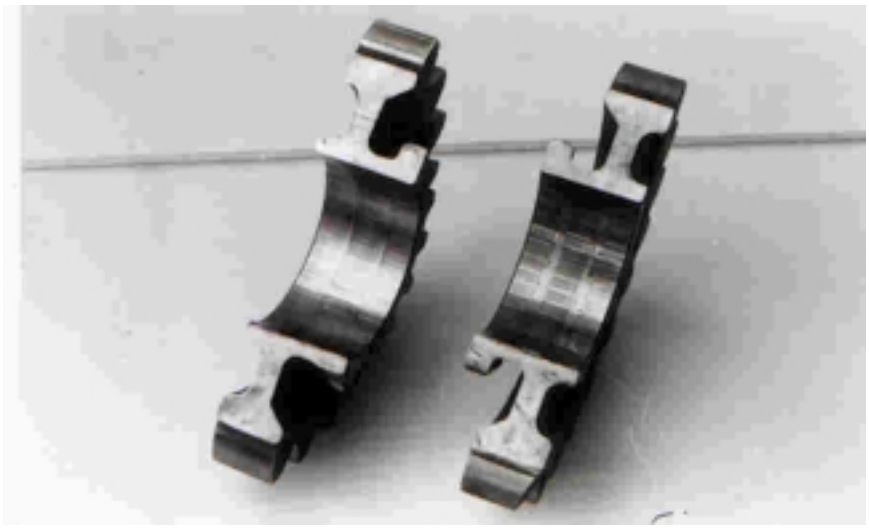

Figure 1 - Cross section of gear before reclamation

TABLE 2

SEQUENCE OF OPERATIONS FOR HARD CHROMIUM PLATING

OPERATION	FACILITIES REQUIRED	PARAMETERS CONTROLLED
Receipt Inspection	Bore snap gauge	Identification Number
Vapor degreasing	Trichloroethylene plant	Bore diameter, 80° C, 5 minutes.
Loading	Fixture	Bore alignment of jobs
Activation	Sulfuric acid bath	5 to 10 minutes
Cold rinse	Water bath	3 to 5 minutes dip
Warm rinse	Hot water bath	60° to 70° C, 3to 5 minutes dip
Chromium plating	Chromic acid bath, Anode	50° to 55° C, 4 volt, 30 to 40 Amperes/DM^2, 10hours
Trapping	Water bath (demineralised)	3 to 5 minutes.
Cold rinse	Cold water bath	3 to 5 minutes.
Warm rinse	Hot water bath	60° to 70° C, 3 to 5 minutes
Hot air drying	Heating element with blower	40° to 50° C
Unloading	Trays	Anode safety
Dehydrogenation	Heating furnace	200° to 220° C, 2 hours.

Figure -2 Cross section of gear after chromium plating.

Figure -3 Bore condition of gear after 1500 Kms. trial.