

Study on Repairing Technologies and Repairing Experiment by Electro-Brush Plating of Camshaft

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Abstract: The surface failure of engine camshaft was introduced. The surface repairing technologies of failure camshaft such as thermal spraying, laser cladding and electro-brush plating were analyzed comparatively. The characteristics of the process of repairing camshaft by electro-brush plating technology were introduced. The effects of plating solutions of rapid nickel, Ni-Co, Ni-Wu and nano Al₂O₃/Ni on surface properties of camshaft coatings were experimentally studied. It is concluded that the electro-brush plating technology can be applied to repair failure camshafts due to simple equipment, fast repairing speed and high bonding strength between substrate and coatings. The surface morphology of the nano Al₂O₃/Ni coating is the most uniform and compact, and the hardness of the coating is higher than substrate's. The hardness of the rapid nickel coating is the highest, but the coating surface morphology is relatively coarse and uneven. Nano particles have a significant refining effect on coatings. Using nano Al₂O₃/Ni electro-brush plating technology to repair surface failure camshaft can improve surface hardness and make it remanufactured and utilized.

1. Introductions

Remanufacturing engineering is a new industry with great development potential, significant economic benefit and green environmental protection ^[1]. It can reduce manufacturing cost, save energy and materials, and have high quality ^[1]. The remanufacturing of automobile engine occupies obvious advantages over the overhaul in terms of performance price ratio, and will be inevitable trend of the development of automobile industry in the future ^[2]. As one of the important parts of engine valve train, camshaft can be damaged and failure due to friction wear and scratch in the working environment of high temperature, high speed and difficult lubrication, which will affect the service life of engine. It has been becoming an important issue to prolong service life of camshaft by means of remanufacturing technologies to repair damaged cam and neck of camshaft due to friction, wear and scratch.

Electro-brush plating technology is a very effective surface treatment technology and widely used in surface repairing and reinforcement of mechanical parts ^[1, 3]. The performance of surface failure camshaft can be restored by electro-brush plating ^[4-6].

In this paper, surface failure of engine camshaft was introduced. The main surface remanufacturing technologies of failure camshaft were analyzed comparatively. The main process characteristics of electro-brush plating technology were expounded. The effects of different plating solutions on coating properties were studied experimentally. Those researches provide theoretical and technical basis for the reutilization of failure camshaft.



2. Surface Failure of Camshaft

Camshaft generally consists of intake and exhaust cam, journal, shaft body, timing wheel and so on. It is an important part of engine valve train. While working, camshaft pushed by tappet and rocker arm controls the intake and exhaust valves to start and close according to a certain working order and gas phase, and ensure that valves have enough lift to achieve ideal engine intake and exhaust operation. Camshaft locating near the cylinder works in an environment with high temperature, high speed and difficult lubrication, and is subjected to the periodic impact load caused by valve opening and closing intermittently. The contact between cam and tappet is mainly heavy load point contact or line contact. There are both rolling friction and sliding friction in the contact area, and the contact stress is larger in friction pairs of engine.

Those working characteristics and environment of camshaft lead to surface failure of cam and journal of camshaft for wear, scratch and even cracks. For failure camshafts, the dimension precision will be reduced, and the roundness and cylindricity of shaft neck will be changed, which affects the normal opening and closing of engine inlet and exhaust valves. Those also result in insufficient intake, unobstructed exhaust and increasing of waste gas of engine. At last, engine power decrease, and engine temperature and fuel consumption increase. The main reason of camshaft failure is wear of cam contacting directly with tappet^[1].

In the past, failure camshaft would be replaced with new camshaft, or be reused after grinding journal and thickening bearing bush. New camshaft is more expensive and some types of camshafts are hard to get. On the other hand, strength of grinded camshaft journal decreases.

In recent years, with increasing of engines' speed and power, inertia force of valves and sliding speed between cams and tappets are further increased, and lubrication condition becomes more severe, which lead to more early failure of camshaft. With maturity of surface repairing technologies, the applications of surface repairing technologies to failure camshafts caused by wear and scratch have been becoming a hot research topic at home and abroad^[6].

3. Surface Repairing Technologies of Failure Camshaft

Working environment of camshaft is harsh, and working quality affect performances of engine. Therefore, the requirements for materials, dimension precision and manufacturing quality of camshaft are higher. Camshaft should have high stiffness, wear resistance, corrosion resistance, fatigue resistance, high temperature resistance and so on. The surface roughness of cam and neck of camshaft should be low.

Camshafts are usually made of high quality medium carbon steel or low carbon steel by forging, and processed through carburizing, quenching, low temperature tempering and so on. Some high strength gray cast iron and alloy cast iron camshafts are also treated by cold shock or carburizing.

At present, the surface repairing technologies applied to failure camshafts due to wear and scratch mainly have thermal spray, laser cladding and electro-brush plating.

Thermal spraying is a general term for various spraying, spray welding process, is the deposition of fine and dispersed metal or non-metal coating materials onto substrate surface in a molten or semi-molten state and form a spray coating^[8]. Repaired by thermal spraying, workpieces usually have the properties of wear resistance, corrosion resistance, oxidation resistance, high temperature resistance, heat insulation and so on^[9-11]. Those properties can meet the properties requirements of camshafts. The thermal spraying coating and substrate are mainly mechanically combined. When thickness of coating exceeds a certain range, strong vibration or impact will cause the coating to fall off. Therefore, attention should be paid to repairing thickness when failure camshafts are repaired using thermal spray technology.

Laser cladding utilizes a high-energy-density laser beam to fuse cladding materials on substrate surface, and form metallurgical bonding thin layer. It has advantages of fine microstructure of coating, high interfacial bonding strength, wide cladding materials, easy realization of selective zone cladding and so on^[8, 12-14]. Camshaft repaired by laser cladding can meet the hardness requirements of design^[7], and can obtain a relatively flat and beautiful surface without reducing material. However, the energy

of laser cladding is higher and easily leads to thermal deformation of substrate. Moreover, laser cladding's equipment is complex and cost of repairing failure camshafts is relatively higher^[15].

Electro-brush plating is a surface repairing technology to rapidly obtain deposited coating on the surface of metal workpieces using the principle of electrochemical deposition. Its advantages include portable equipment, simple operation, various kinds of plating solutions, flexible process, higher bonding strength and efficiency, lower repairing cost and so on. At all, electro-brush plating is an effective means to repair and strengthen failure mechanical parts^[1].

4. Repairing Experiment of Failure Camshaft by Electro-brush Plating

4.1 Main processes Characteristics

Table 1. Main processes and value range of process parameters of electro-brush plating

Process	Function	Process parameters		
		Brush plating voltage/V	Polar relative velocity/(m/min)	Brush plating time/s
Electro cleaning	Remove oil contamination from workpiece surfaces	4-20	8-18	30-60
Activation	Remove oxide film, fatigue layer and other dirt from workpiece surfaces	6-20	6-15	30-60
	Remove carbonaceous from workpiece surfaces	6-20	6-15	30-120
Brush plating bottom layer	Improve bonding strength of coating and substrate	8-18	6-10	30-90
Brush plating working layer	Meet the dimension precision and surface properties of workpieces	6-20	6-13	-

The main processes for repairing failure camshaft by electro-brush plating have electro cleaning, activation, brush plating bottom layer, brush plating working layer, etc. In addition, after finishing each process, the surface of the plated parts should be rinsed with clean water in order to prevent mutual contamination between different plating solutions. The parameter values of each process should be determined according to materials, size, wear and working conditions, technical requirements and so on. There are many technological parameters affecting the quality of coating which include brush plating voltage, polar relative velocity, plating solution temperature, brush plating time, interelectrode pressure, etc. The main influencing parameters are brush plating voltage, polar relative velocity and brush plating time. The main processes and value range of process parameters of electro-brush plating are shown in Table 1.

Plating solutions for brushing bottom layer have special nickel (as references [4, 5, 16]) and alkali copper (as reference [16]). Due to those characteristics of low internal stress, better ductility, faster deposition speed, wide temperature range and so on, special nickel is selected as plating solution of bottom layer for repairing failure camshaft in this experiment.

Plating solutions for brushing working layer have semi-bright nickel (as reference [4]), fast nickel (as reference [5]) and nickel tungsten alloy (as reference [6]). Fast nickel is mostly selected as plating solution of working layer for various materials for its higher hardness and good wear resistance. Composite plating solutions with corrosion resistant property can be formed by adding elements of Co, Cr, Wu and so on into nickel plating solution. The Ni-Wu composite plating solution is generally neutral or weakly alkaline, which can effectively reduce hydrogen embrittlement^[6].

Different plating solutions have different safe thickness of brush plating coating. Within the safe

thickness, the brush plating coating has fine crystallized and little stress. Otherwise, the coating are rough, high stress and easy to generate crack. When coating thickness of failure camshaft exceeds the safe thickness, intermediate coatings are required. Plating solutions used as intermediate coatings have fast nickel (as reference [4]) and alkali copper (as reference [16]).

Nano-composite electro-brush plating is a process in which one or more insoluble solid nano-particles are uniformly mixed into metal coatings to form special coatings. Studies have shown that nano-particles have strengthening effects such as fine grain strengthening, high density dislocation strengthening, nano particle effect strengthening and so on. Those strengthening effects make coatings have better performances than those by ordinary electro-brush plating^[1]. However, being more prone to be reunion, the pre-treatments for nano plating solutions are more stringent. It is necessary to add dispersant into plating solution or to magnetically stir plating solutions in order to accelerate uniform dispersion of nano-particles in solutions.

At present, nano-particles used in electro-brush plating have mostly nano diamond powder such as SiC, Al₂O₃, ZnO, some nitrides such as TiN and sulphide such as MoS₂. Among those, nano Al₂O₃ is a kind of high hardness and anti-wear material with low price and wide source, and has special mechanical and chemical properties, such as high chemical stability and high temperature wear resistance. The nano Al₂O₃/Ni plating solution is used for surface repairing of failure camshafts.

4.2 Repairing Experiment

The 45[#] steel is selected as substrate material, and the special nickel is used as the bottom layer plating solution. The fast nickel plating solution, Ni-Wu alloy plating solution, Ni-Co alloy plating solution and nano Al₂O₃/Ni plating solution are used as working layers respectively. The repairing experiment of failure camshaft by electro-brush plating is carried out.

The surface morphologies of coatings are shown in Figure 1. The process parameters and the surface hardness of coating are shown in Table 2. Figure 1 shows that the surface unit of the nano Al₂O₃/Ni coating is the finest and compact, which indicates that Al₂O₃ nano-particles with higher specific surface area and surface activity are the core of grain growth, which increase the nucleation rate, and effectively hinder the grain growth of the coating. In addition, Figure 1 also shows that the surface units of fast nickel and Ni-Co coatings are larger and more uneven.

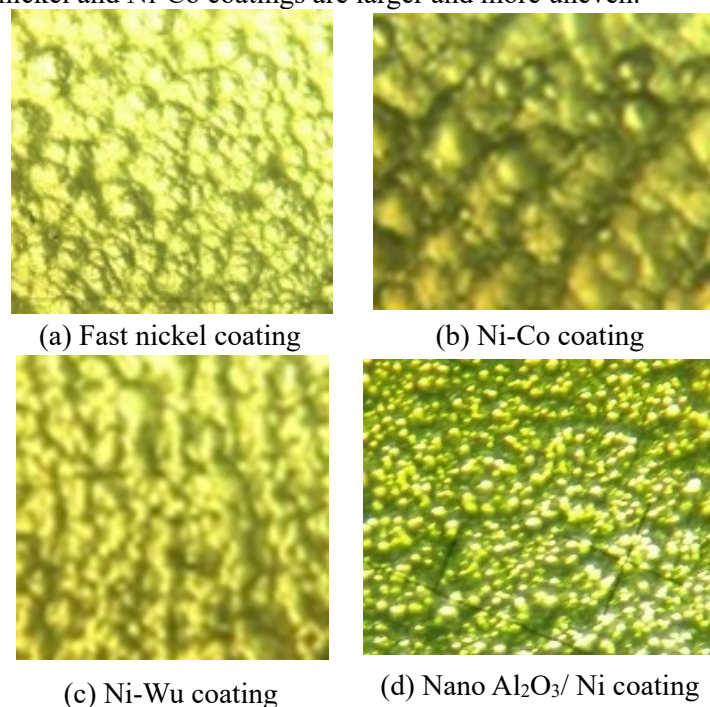


Figure 1. Surface morphologies of coatings

Table 2. Process parameters and hardness of coating

Working layer plating solution	Brush plating volgate (V)	Polar relative velocity (m/min)	Brush plating time (min)	Hardness (HV)
Fast Ni	12	10	25	513.0
Ni-Co alloy	10	10	15	377.1
Ni-Wu alloy	8	10	15	405.5
Nano Al ₂ O ₃ /Ni	12	6	15	350.7

As shown in Table 2, all of hardness is higher than that of 45[#] steel which is 247.6HV, and is higher than that of the design requirement. The hardness of fast nickel coating is the highest, reaching 513 HV, followed by the Ni-Wu alloy coating'. The hardness of the nano Al₂O₃/Ni coating is the lowest.

5. Conclusions

(1) The working characteristics and environment of camshaft easily lead to surface damage such as wear and scratch on the cam and journal.

(2) Compared with other surface repairing technologies such as thermal spraying and laser cladding, electro-brush plating technology has the advantages of portable equipment, fast repairing speed, higher bonding strength between substrate and coating, low repairing cost and so on. It can be used for surface repairing of failure camshafts.

(3) Compared with fast nickel, Ni-Co alloy and Ni-Wu alloy coating, the surface morphology of nano Al₂O₃/Ni coating is the most uniform and fine, and the hardness is higher than that of 45[#] steel, which indicat that nano particles have remarkable refinement effect on coatings.

(4) Compared with that of nano Al₂O₃/Ni, Ni-Co alloy and Ni-Wu coating, the hardness of fast nickel coating is the highest.

(5) The service performance of failure camshaft repaired by electro-brush plating is further experimented by bench experiment and vehicle assessment.

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