Proceedings of the ASPF 2003 (The 8th Asian Symposium on Precision Forging), October 15 - 18, 2003

A New Technology for Strengthening Surface of Forging Die

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Abstract

The Electro-thermal Explosion Coating (EEC) technique is a new surface treatment technology emerged in recent years. It uses an electrical discharge (with very high voltage from 5 to 30 kV or more) to produce a pulse current with large density inside the material to be deposited, the metal wire undergo the heating, melting, vaporization, ionization and explosion processes in a very short time (from tens *ns* to several hundreds μs), and the melted droplets shoot at the substrate with a very high velocity (3000 – 4500 m/s), so that the coating materials can be deposited on the surface of the substrate. Coatings with nano-size grains or ultra-fine grains can be formed because of rapid solidification (cooling rate up to 10^6–10^9 k/s). Surface of the substrate (about 1-5 μm in depth) can be melted rapidly and coatings with very high bonding strength can be obtained.

Keywords: the electro-thermal explosion coating, surface treatment technology

1. introduction

The die is the one of important technical setup in the fields of mechanical, electrical, plastic, automobile, instrument and so on. The industry of die will be the "emperor" of metal forming industry. The cost of die is 10-20% of cost of products, so the performance of die uses effect on the quality and cost of forging products. Now the die life in China is only 1/3-1/5 in developed countries. This is the big problem that will be resolved in die industry. There are many factors in effect on die invalidation, for example, invalidation factors, material heat treatment, structure, machining, lubrication, manipulate. It is indicated that the rate which these factors action in die invalidation are 16, 42, 15,10,7, 10 per cent respectively by the analyze of statistics. The material of die and heat treatment play important role in die invalidation. As we know, the costs of forging die maintenance is about seventy percent in the costs of the full forging process and the fifty percent costs of die maintenance is brought by die wear and tear. A new technology is being expected for increasing the ability of die anti-wear and tear, especially for the big and middle type of dies. Besides having higher strength and tough in body of die, surface property of die is also important for working property and life of die. Surface property includes all kinds' capability of anti-rust, anti-wear

and tear, anti-fatigue, and friction coefficient and so on. It isn't enough and economic that surface properties are increased by only relying on improving body property of die. The surface treatment technology is a more efficient technology for improving surface properties, that is why surface treatment technology is be developed rapidly.

The surface treatment technology of die is that configuration, chemical composition, microstructure and stress state of die surface are changed by surface smearing and covering technology and compound treatment technology. It is also system engineering for getting good surface properties. The surface treatment methods include chemical, physics, physics-chemical and mechanical. The main methods used in die are seeping nitrogen, seeping carbon, deposit of vulcanize film. A new surface treatment technology for die is developed recently, that is "Electro-thermal Explosion Coating (EEC)"

2. Electro-thermal Explosion Coating (EEC).

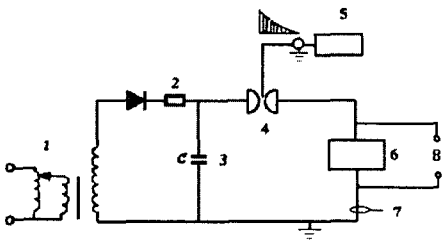
Melting particle can get higher coating velocity by Electro-thermal Explosion Coating technology than by other explosion coating technology. The principle of EEC is that metal wire is heated by pulse big current, when the density of current is getting over some value and the processes of solid heating, melting, liquid heating, vaporization expanding, striking electrical arc and explosion of metal are finished in very short time (from tens nanosecond to hundreds microsecond), and then the compress gas and melting particle deposit on surface of workpiece with very high velocity, so the high link intension of coat is got[1,2,3,4,5].the first research of inner hole thermal coating of wire explosion were made in Japan in 70' last century, the inner surface of workpiece can be coated [6]. The new technology that the metal of high melting point is deposited on the inner surface of big gun pipe for getting coat is developed in Germany .the patent is approved in 2001. Using this technology, the life of artillery is increased than that of chromeplating pipe distinctly. But the pressure of shock wave and the velocity of particle reduce rapidly with diameter of workpiece increasing, the technology is only used for coating inner wall of small diameter of workpiece (less some centimeter usually).

The electro-thermal supper-high velocity direction coating technology is a new coating technology used for big dimension workpiece surface; base the inner hole coating technology. There is only Japanese professor H.Tamura that publishes the article about the new technology in end of 19' in 20 century. The innovation of the technology is that the hybrid of metal steam and melting particle after explosion move in nearly one dimension direction in explosion room entrance, and the coating velocity can be 3000-4500m/s. because the action of shock wave, the high pulse pressure is made on the surface of workpiece coated and the temperature of metal of microns thickness on body material is over melting point of metal, so the combine of cost and body metal is metallurgy combine; because also the action of self-rapid cooling of body material, the rapid concretion make the nanostructure (the diameter of grain 100nm) and supper-fine grain (the diameter of grain 500nm).Professor Liu Zhongde have been researching the electro-thermal explosion coating technology and have

made the coat set for The electro-thermal supper-high velocity direction coating, and have got the patent in China. His technology can coat with multi-wire explosion simultaneously, increase the work efficient greatly. Using WC-Co、Ti6Al4V、16Mn、1Cr18Ni9Ti、Cu as the coating material,the coats of nanostructure and supper-fine grain are made.the haedness of WC-Co coat can arrive Hv2600 and is 1.63 time than the original hardness of WC-Co; the hardness is higher than that of pile weld WC(Hv500-700),so the anti-grind of coat is improved distinctly.recently, professor Liu Zhongde and professor Lu Xin are researching using The electro-thermal supper-high velocity direction coating technology for forging die.

Fig. 1 and Fig. 2 show the EEC coating system and the illustrative drawing of the explosion spraying cell respectively. The electro-thermal explosion directional spraying apparatus consists essentially of a set of energy storage capacitors, a three-electrode switch and an explosive spraying device made of insulation material. The working principles of the EEC technique differ from all other existing coating methods and surface treatment technology, such as CVD, PVD, thermal spray, ion implantation, etc. It uses the high current density generated from electric discharge to vaporize the coating material and to induce the explosion, and the explosive force can accelerate the melted droplets to a very high velocity. By proper design of the explosion cell, the droplets can

be directed towards the substrate material. Thus, compared to traditional coating technologies, the EEC technology has the following advantages:



1. Transformer	2. Resistance
3. Capacitor	4.Switch
5.Ignition system	6.Spraying device
7. Rogowski coil	8Voltage measuring instrument

Fig.1 Schematic of Electro-thermal Explosion

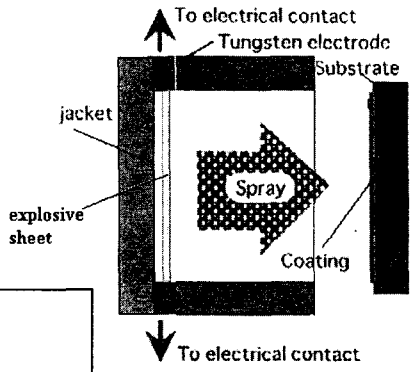


Fig.2 The Explosion Spraying Cell Coating System

- The coating speed is much higher and therefore high coating productivity;
- Nanostructured (grain size in the range of 30-100 nm) coating or ultra-fine grain coating (grain size in the range of 100-300 nm) can be achieved;
- The coating hardness is higher due to lower coating porosity and the nano-class grain size;
- Only a very thin layer of the substrate material is heated and the melted depth of the substrate is from 1to 5 μm), so no distortion takes place while being coated;

- The bonding strength between the coating and the substrate material is much higher. The bonds are in general **metallurgical** type;
- Substrate can be of any variety of materials such as any type of Metal, Ceramic, etc., and no special cleaning operation is required (e.g., that for PVD);
- There is no limitation to the dimension of the workpiece, also very large component can be coated by the EEC technique;
- There is no limitation to the geometry of workpiece, also in-wall surface of a cylinder can be coated;
- Coating materials are unlimited. Metals and conductive ceramics can be used directly as explosive wire. For other non conductive materials, powders can be used by wrapping them inside a conductive metal.

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