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Analysis of Hard Chromium Coating Defects and its Prevention Methods

L.Maria Irudaya Raj, Sathishkumar.J, B.Kumaragurubaran, P.Gopal

Abstract*— This paper mainly deals with various Chromium coating defects that occur while electro plating of different mechanical components and methodology adopted to prevent it. It also covers suggestions to minimize this problem. This paper contains new suggestions to minimize the problems by using recent technological developments. Since the chemicals used for chromium coating are posing threat to environment it is need of the hour to minimise the use such chemical consumption. The reduction in defective components will increase productivity as well as protect the environment to some extent It also describes the various alternate coating methods for chromium coating through which we can achieve the required surface properties. India being a Developing country .for various coating application chromium is used. Since the process is slow and involves lengthy cycle time unless the defects are minimized the products cannot be delivered in time which will create loss to the Industries. Being the cheaper & simple technological process it is being used for coating applications. Disposal of effluents generated by this chromium coating process has to be taken care of by the Industries which are using the process. By using the chromium along with other materials, defects can be minimized as well as better surface properties can be obtained. This paper describes the techniques and gives details of chromium coating applications in various Industries.

***Index Terms* — Chromium Coating, Defects, Prevention methods, Surface treatment..**

I. INTRODUCTION

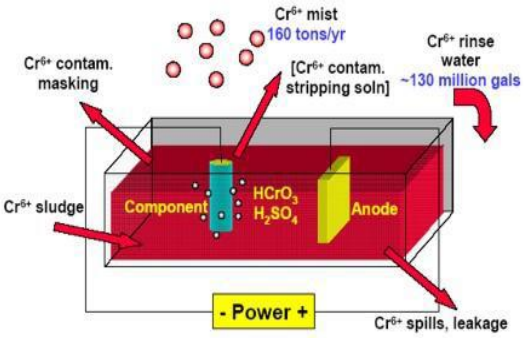
In Developing Countries like India, Chromium coating plays an important role in many coating application. Chromium coating has found extensive use as a final finishing operation on many articles. It may be divided into two categories. In the first category, generally known as decorative chromium, in which chromium is coated as a thin coating on bright nickel to serve as a non tarnishing, durable surface finish on metals for decorative purposes. The second category is known as hard chromium coating wherein heavy deposits of chromium are directly coated on a base metal so as to take advantage of the special properties of chromium. Defect in any product is not acceptable .Defective parts will not only produce resource losses but spoils the Image/ Identity of an Industry. At the same time in some processes defects always become a part of the production .However, in the following chapters will describe defects involved in chromium coated parts and their general prevention methods ,properties of chromium, application of chromium coating etc. in detail.

II. COATING

Coating may be defined as a coverage that is applied over the surface of any metal substrate part/object. The purpose of applying coatings is to improve surface properties of a bulk material usually referred to as a substrate. One can improve amongst others appearance, adhesion, wetability, corrosion resistance, wear resistance, scratch resistance, etc.

III. HARD CHROME COATING PROCESS

The coating process consists of Chrome Chemical Bath, Anode, Cathode potentials, part to be coated, Heaters, rectifiers & Electrical control systems. Initially the bath has to be heated up to the required temperature. Cathode potential has to be connected to the part to be deposited and anode electrode has to be connected to the + potential .Before starting the process the part should be thoroughly cleaned and it should be ensured that it is free from all kinds of surface marks/defects. Then deposition of hard chrome deposit is started by separation of ions from the chemical bath due to the flow of current to the part to be deposited. The amount of current flow and the duration of process will vary depends upon size of the component. Generally 30-40 Amps is applied for 1 square decimeter. The deposition rate will vary from 25-30 microns per Hour fro the above given current flow. DC power source is used for the process.



The various types of coating defects are listed below.

IV. COATING DEFECTS

In Industrial hard chrome coating the following coating problems are observed through data collection.

1. Coating peeled off
2. Coating Chipped off

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***** Correspondence Author (s)
L.Maria Irudaya Raj, BIT Campus, University College of Engineering, Tiruchirappalli, 620024, TN India.
Sathishkumar.J, BIT Campus, University College of Engineering, Tiruchirappalli, 620024, TN India.
B.Kumaragurubaran, BIT Campus, University College of Engineering, Tiruchirappalli, 620024, TN India.
P.Gopal, BIT Campus, University College of Engineering, Tiruchirappalli, 620024, TN India.

3. In sufficient coating thickness
4. Absence of coating.
5. Uneven coating thickness
6. Rough coating Deposition
7. Dual colour coating
8. Marks/Scratches in coating
9. Dent
10. Pitting

V. OBJECTIVE

The main objective of the project is to improve the hard chromium coating quality of components thereby increase in productivity by preventing the production of defective components. Other objectives are

1. Reduction in defective parts.
2. Reduced workmen fatigue.
3. Reduction in amount of waste generation.
4. Enhanced job satisfaction
5. Establishing plating standards for different parts.

VI. REASON FOR DEFECTS

1. Improper selection of Electrical parameters.
2. Improper anode setting
3. Usuage of old/discarded anodes.
4. Improper anode size and shapes.
5. Improper bath temperature selection
6. Poor chemical conditions
7. Insufficient/poor cleaning of parts before coating
8. Improper/Insufficient pre and post heat treatment cycle
9. Frequent fluctuation of power supply.
10. Too high machining
11 .Lack of polishing
12. Lack of poor testing Gauges/Tools
13. Improper pre coating conditions
14. Too high testing conditions.
15. Poor Working Conditions of equipment

VII. METHODOLOGY

The methodology covers collection of data pertaining to various hard chromium coating defects through Experimental setup as well as in shop floor level conditions. Data collection of

1. Pre coating conditions of the base metals
2. Plating parameters during plating
3. Post coating conditions of the base metals

In addition to the above, various process parameters, measuring tools & Gauges, finishing methods also taken account for analyzing purpose.

VIII. PROPERTIES AND APPLICATIONS OF HARD CHROME PLATING PROPERTIES OF HARD CHROMIUM

Elemental Chromium is a hard and brittle metal with high lustre, greyish-white appearance and has a high melting point of 1850 °C. Electroplated chromium can withstand heat up to 400 °C and has a lustrous appearance. Properties of chrome plating vary with a number of factors including plating parameters, testing environment, and components of electrolytic bath. A range of values of hard chromium plating properties which make them attractive for numerous applications typical properties of hard chromium are

These properties make the underlying industrial component perform satisfactorily under conditions like high temperature, impact forces, grinding, etc. Hardness values cannot be considered to be a direct indication of the resistance to abrasion or wear. The wear-resistance is determined by ductility and elasticity also. The types of mechanical abrasion may vary when testing by different methods. The

Property	Value for electroplated Cr
Hardness, as plated	450 – 1000 VPN
Hardness, on heating 400 °C 600 °C 800 °C	450 – 800 VPN 420 – 500 VPN 250 VPN
Coefficient of linear expansion	8.1 x 10-6 (°C)-1
Density	6.9 – 7.2 g/cm3
Static coefficient of friction	0.17 (on steel)
Sliding coefficient of friction	0.16 (on steel)
Resistance to corrosion	Resists attack by almost all organic and inorganic compounds, except muriatic and sulphuric acids
Resistance to heat	Resistant to changes in temperature until 400 °C
Paramagnetic properties	It is paramagnetic and hence can be used to make the surface non-magnetic

condition of the substrate or the coating below a chromium deposit can very often have an influence on its abrasion resistance. Internal stress in chromium deposits spans a broad range from compression to tension. Stress reaches an equilibrium value when the thickness is 30-50um. Chromium with a high tensile stress, eg.35 kg/mm2 contains relatively few cracks (of about 20 cracks/cm), whereas that with a low tensile stress or a compressive stress contains more than 400 cracks/cm.

The tensile stress in deposits reduces the fatigue strength of coated steel, the loss of which becomes appreciable when steels of high tensile strength are coated upon.

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This can be eliminated or minimized by shot peening the steel substrate before chromium plating. Baths containing sulphate give rise to deposits with a tensile stress while those containing fluosilicate and sulphate produce deposits with a compressive stress.
The high corrosion resistance of chromium depends on the formation of a thin film of oxide which protects it from further oxidation. This passive oxide film confers protection against numerous chemical influencers so that chromium, though a non-noble metal exhibits a high degree of resistance to attack by many oxidizing and reducing chemicals. Where chemical attack occurs as in hydrochloric acid and in moderately concentrated sulphuric and nitric acids, it generally originates from the cracks in the deposit. Also the poor wet ability of chromium deposits prevents easy access of corroding liquid to the narrow cracks in them. To ensure an acceptable degree of protection, chromium deposited for use in a gaseous environment should be about 30 um thick and where stronger chemical attack is possible, at least 50 um thick, although no definite criteria can be laid down in view of the variable nature of attack. In the case of weaker corrosive effects, thinner deposits of 15-20 um thickness provide adequate protection. For parts subject to light corrosive conditions in service, 8-10 um thick deposits are adequate. Chromium deposits do not tarnish even at temperature as high as 300'c. Only prolonged heating above 300'c causes darkening of the surface because of gradual increase in thickness of the oxide film. Still greater oxidation occurs only above 500'c. A desirable property of electrodeposited chromium is its low coefficient of friction. In particular the coefficient for dry friction is the lowest of all metals. The coefficient of friction for steel on steel, steel on chromium and chromium on chromium are 0,30,017 and 1.14 respectively. Friction is generally reduced by using suitable lubrication of steel, is ineffective in the case of chromium coated surfaces.

IX. PREVENTION METHODS

1. Usins latest PLC panels for proper control of voltage & Current.
2. Using automated Computer integrated plant
3. Contineous monitoring of plant parameters.
4. Periodial servicing of devices &electrical components.
5. Using online measurement & Inspection
6. Proper cleaning of parts before coating
7. Ensuring pre coating condition of the components.
8. Proper training of personnel involved in the process.
9. Transformation & Switching over to newer technology coating methods.

X. INDUSTRIAL APPLICATIONS

Electro deposition of hard chrome deposits is widely recognized and being extensively used for many years in applications involving sliding or revolving parts like rotating shafts, parts of moving components like pistons, valves, rolls, compressors, etc. It enhances the life of a variety of metal parts that experience wear due to abrasion, friction, and corrosion. The low surface energy of chromium makes it more significant in such applications. This plating has very high rigidity, low coefficient of friction and high corrosion resistance making it prominent in many applications for enhancing the life of components. The main advantage of this process is that it is relatively low temperature process and hence can be used to impart hard surface to any component without actually deforming it. These electrolytic coatings with high hardness/strength and wear/corrosion resistance are widely used in the industry to prevent damage to substrate materials.

The poor wet ability of chromium coated surfaces has an undesirable effect in sliding contact conditions, as there is little opportunity for formation of a coherent film of lubricant on smooth chromium deposits. The non-uniform distribution of lubricant on sliding surfaces can cause sever damage to them but such difficulties may be overcome by the use of porous chromium deposits, where the desired porous structure is intentionally produced. Chromium coated surfaces exhibit very good running characteristics on opposing surfaces of white metal, lead bronze, on fine grained cast iron, if they are thoroughly lubricated, and if the bearing loads are not too great, also on soft and medium hard steels. Light alloys and phosphor bronze are not recommended as counter surfaces; chromium against a chromium surface is also highly un satisfactory. The poor wet ability of chromium. However, it is of great significance, in applications where sticky materials like food preparations are handled. Chromium is paramagnetic. The Para magnetism is of interest in prevention of steel swarf adhering to the teeth of a file and in use of base plates on industrial lifting magnets and of swarf separators.
Though hard chromium coated surfaces are not as lustrous as those with decorative chromium plates, the deposit can be applied under conditions such that a satin, semi bright finish is produced, which is attractive to the eye, and capable of good service and does not provide any imperfection even when worm through. The scope for hard chromium plating is already vast and new applications are being continually examined and put into industrial practice. Hard chromium coated components with light or ground heavy deposits find use in agricultural machineries, aircraft industry, chemical, electrical and other industries like plastics food, metal, automotive, optical, paper, photographic, printing, railway and textile. Though the various applications army be based on one deposit characteristic, the other characteristics give rise to additional advantages.
Hard chromium deposits can be applied for salvaging of mis machined worn out components, production of wear resistant surfaces, improvement of performance of tools and various other uses. Components like crankshafts for diesel and gas engines and for compressors which are too costly to be replaced are restored to original dimensions by hard chromium plating. Parts like rotor discs and spacers of jet aircraft engines, of which the dimensional tolerances are not always met correctly in machining them, can also be salvaged. The average life of a component like piston ring is increased approximately five times by hard chromium plating as the wear resulting from abrasion is significantly reduced. Various types of tools, plug gauges, deep drawing dies, steel dies for drawing bars and tubes, cutting tools like tapes and reamers, and steel or beryllium-copper dies for molding especially of vinyl or other corrosive plastics are some examples where hard chromium planting has proved advantageous.

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A double hard chromium layer composed of softer, crack free chromium and micro cracked chromium, as well as a nickel-chromium deposit consisting of semi-bright nickel and micro cracked, hard chromium top coat have high corrosion resistance and hence can be great use for severe, corrosive service services such as in mining and nautical environment respectively. A combination of electro less nickel and hard chromium has superior wear ability to either electro less nickel or chromium at high temperatures.

Mechanical	Drills, cutters, turning tools, lathe spindles, mandrels, mounting jigs, files, bearings hydraulic rams, plates, sheaths, tablet punches,
Chemical	Anticorrosive coatings, glass moulds
Electrical	Non-magnetic parts, turbine blades, contacts
Metal	Dies, spinning tools, tube rolls, punches
Plastics	Plastic moulds, hoppers, cylinders, nozzles, mixer arms, spreaders
Fluid power	Valves, rams, cylinder cranks, shafts
Agriculture	Spades, garden shears. hoes, plough shares
Aircraft	Crankshafts, rams, gun barrels, camshafts
Railways	Locomotive slides, dampers, cams, joints for brakes, shafts, buffer pistons
Textiles	Bobbins, protective coatings, tension parts, thread guides, printing cylinders

XI. ENVIRONMENTAL AND HEALTH HAZARDS

Hard chrome plating consists of hexavalent chromium in the deposit that is more dangerous and carcinogenic when compared to trivalent chromium (which occurs in nature usually); trivalent chromium is an essential trace element in the body for human metabolism. There are several issues with the plating process and the bath used imposing severe risks on both the environment as well as the personnel. Hard chrome plating uses chromic acid solution which is responsible for the release of chromium (hexavalent) ions that are hazardous even in minor quantities. These ions cause problems on exposure and when inhaled. The process of depositing these coatings is environmentally harmful due to disposal of toxic materials as associated wastage.. Some of the problems relating to risks imposed on human health and environment are detailed below.

XII. ENVIRONMENTAL EFFECTS

These ions enter into environment in the form of chromate and dichromate anions from the industrial wastes, thus, contaminating air, water and soil to a considerable extent These risks are not limited to humans (or workers); they also affect the mammals, plants and marine life. Taking all these factors into consideration, several federal regulations have been imposed by the Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) on specific industries to protect against the adverse effects by restricting the levels of exposure. Also, several acts have been formulated by the government, namely, the clean air act, the clean water act, the resource conservation recovery act, and the emergency planning & community right-to-know act to determine the measures to reduce and control the levels of pollution. These measures have increased the complexity of plating and also the costs of waste disposal increasing the process costs.

XIII. HEALTH HAZARDS

Inhalation and contact with skin is the primary source of exposure for workers who happen to be the worst victims of adverse effects. Short term effects include skin irritation, sneezing, headache, and ulcers in the nasal septum. It can also cause respiratory problems, cancer in kidneys, lungs, etc when inhaled in large quantities.

XIV. RECENT DEVELOPMENTS

Apart from the above adverse effects, it has disadvantages like the formation of micro cracks in the plating layers, decrease in rigidity with increase in temperature of the surroundings, low deposition rates, complexity of plating, etc. Owing to all these problems, there has been increased momentum towards finding environmentally accepted alternatives to hard chromium coatings in the recent years. A number of electrodeposited alloys are of interest due to various properties like low internal stresses, magnetic properties, hardness, malleability, ductility and resistance to corrosion.

Electro deposition is chosen as it is one of the most common, relatively simple, and economical coating technologies capable of depositing metal and alloy coatings with improved surface properties and microstructures. ll the above stated factors contributed to the development of environmentally acceptable alternatives for hard chrome plating. Progress has been made by several researchers to introduce an alternative by several methods including thermal spray, weld facing, heat Treatment, vapor deposition and electro deposition. Electro deposition has proved to be a better deal for hard chrome plating when compared to all the above processes resulting in enhanced properties, also satisfying economic consideration.

The recent technological developments like Arc spray ,Plasma ,HP Plasma CrO,HP HVO/NiCrBSi,HP/HVOF WC/Co, Thermal spray etc. have not completely eradicate use of Chromium .Being a developing country due to economical & social constraints the advanced technological process could not be replaced with old conventional process. But in the Developed countries, the use of Chromium has already been banned due to its undesirable effects of its effluents to environment and ecological system. Similarly, one fine day in all the use of chromium metal will be eradicated with use of easily available, best cheaper alternative suitable material which will meet the Indian & Other Developing countries Industrial needs. Current alternatives for chromium plating Alloy and composite plating can be made to possess superior properties, especially hardness, wear, abrasion and corrosion resistance, in comparison to that of metal plating. Several alloys have been deposited and investigated for the desired properties, to produce an environmentally acceptable alternative for hard chrome plating. Shows superior hardness of few electrodeposited alloys which are being investigated demonstrating the effectiveness of the technique in producing deposits with enhanced properties. There has been significant progress in the development of replacement to chrome plating resulting in a number of potential alternatives to the same. Several technologies like HVOF, plasma spraying, electrodeposition, laser cladding, plasma nitriding, electro-spark deposition, etc have been investigated with a view to develop a coating which matches the chromium in its performance and also addresses the safety concerns . A list of technologies and the corresponding alternative coatings is given in Fig. Among the listed technologies, electrodeposition is gaining lot of importance as the process meets all the general, technical requirements and is economical. HVOF, plasma and laser processes also produce coatings with excellent properties, but they have limitations relating to the size of the component to be coated, post processing of the coated parts (machining is required due to the surface roughness), availability of the equipment and complexity of the process involved. In general, electroplated coatings possess better properties than the chromium ones and hence, can be used in many applications directly.

XV. CONCLUSION

The above mentioned defects are commonly noticed while data collections during the experimentation and in the production shop floors. A detailed report consist of amount of defective component produced under each category and its ways and means of preventing it will be summarized in Second phase of the Project report.

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L.MARIA IRUDAYA RAJ, D.M.E., A.M.I.E (I), presently is doing final year ME in manufacturing Branch at BIT campus of Anna University. He is having 15 years of industrial experience in various fields. At present working as Junior Works Manager. Email. irudayarajl@yahoo.com

Sathishkumar. J ME final year student in Anna University college of Engineering, Tiruchirappalli. He completed his BE in 2000 from Bharathidasan University and PGDIB in 2002 from Pondicherry University. He is having 13 years experience in various domains like Automotive, Semiconductor and Industrial application. Currently he is working as Senior Team Leader in an Engineering Design Center. He is Certified AVS from INVEST (Indian Value Engineering Society)

B. Kumaragurubaran is working as an Asst. Professor in in Anna University College of Engineering, Tiruchirappalli. He received his BE from University Of Madras in the year 2003and did his ME from Annamalai University, Chidambaram2005. He is pursuing Ph.D in engineering material. He is having 7 years of experience in the field of teaching. He has attended 18 conferencesand he has published 7 national and international journals. He is life member in Indian Welding Society from 2004.

P.Gopal, B.E.(Mech), M.E.(Auto) is working as an Asst. Professor in Anna University College of Engineering, Tiruchirappalli. He is having 13 years of experience in the field of teaching. He has attended 24 National and international conferences and he has published 8 national and international journals.

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