ELECTROFORMING - A PART OF ENGINEERING PLATING PROCESSES
(TREATISE ON USE OF NICKEL ALLOYS)

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ELEKTROFORMOVÁNÍ - SOUČÁST PROCESŮ POKOVOVÁNÍ PRO INŽENÝRSKÉ ÚČELY (ÚVAHA O POUŽITÍ SLITIN NIKLU)

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Abstrakt

Jsou stručně uvedeny přednosti výhody elektroformování a jeho místo mezi procesy katodického vylučování.. Zlepšení mechanických vlastností vylučovaných vrstev, což je cílem uživatelů, lze dosáhnout užitím slitin namísto jednoduchých kovů. Byly zkoumány dva procesy vylučování slitin niklu, tj. NiFe a NiCo se snahou snížit makropnutí vylučovaných vrstev. Byla užita přísada neobsahující síru, aby nevzniklo nebezpečí sírové křehkosti. Lze dosáhnout nulové úrovně makropnutí za popsaných podmínek a parametrů.

Abstract

Advantages of electroforming and its position among electrodeposition processes are concisely shown. Improvement of mechanical properties of deposited laers, which is an aim of users, can be reached by use of alloys instead of simple metals. Two types of nickel alloys processes, i.e. nickel-iron and nickel-cobalt have been investigated to lower macrostress of deposited layers. An additive not containing sulphur has been used to avoid sulphur embrittlement. Zero level of macrostress can be reached at described conditions and process parameters.

Key words: galvanic precipitation, electroforming, NiFe, NiCo alloys, metal models

1. Introduction

Electrodeposited metallic coatings are used mainly as layers protecting mechanic parts against corrosion. The wear protection is considerably less common. The difference between the corrosion and wear resistant coatings is first of all in thickness - while the first ones are usually thick not more than 10^{-6} m the latter may be even few mm thick. The other difference is properties. While the mechanical properties of anti-corrosive coatings are usually not much important, the wear resistant coatings must exhibit mechanical properties, i.e. hardness, strength etc. as good as possible.

These electrodeposits are deposited not only on new components to confer the required surface properties but also to restore the dimensions of parts which either have worn excessively in service or have been over-machined (renovation). A very important application is that of the production of free-standing bodies by electroplating onto mandrels capable of subsequent removal - electroforming.

2. Mandrel

The basic advantage of electroforming is that the appropriate mandrel can be produced at considerably lower expences that the needed shape [1]. Mandrel must be electrically conducting but need not be made from metal. Plastic mandrels are often used, being coated by some proper thin metal (like silver, or copper) layer after the final finishing has been made. The size of the electroformed shell is limited by the size of van and the performace of current rectifier. Obviously plastic mandrels are exclusively used in the case of big items, which can be even size of few m^2.

Mandrels can be temporary or permanent. Temporary mandrels can be melted (wax, low melting metallic alloys) or chemically solved (aluminium) after the process of deposition. This method is convenient in the case of shapes having negative angles so that the mandrel could not be separated. Of course, permanent mandrels are considerably more frequent, particularly of the production of a type should be repeated. Stainless steel is used, if high accuracy is needed. The advantage of electroforming is just the high reproduction accuracy, which can be as much as 2.10^{-9} m. The passivity of stainless steel is an advantage owing to easier separation of mandrel after the electrodeposition.

3. Electrodeposited metals

To the processes mostly used in electroforming belong [2,3]:

3.1 Copper - resistant to fretting corrosion, very good electrical conductivity but lower hardness of 40 to 160 HV and consequently lower strength. On the other hand copper deposits have generally low macrostress

3.2 Chromium - very hard 800-1000 HV but brittle, not resistant to shocks. Owing to low cathodic current efficiency difficult to produce very thick layers which are needed in electroforming. Environmental problems caused by toxicity of Cr^{VI} compounds.

3.3 Iron - inexpensive, hardness 150 - 350 HV, low corrosion resistance. Usually very high level of macrostress

3.4 Nickel - most commonly used in electroforming. Soft and ductile, good corrosion resistance. Hardness 180-400 HV. Deposits with zero macrostress can be achieved and so there is no limit to thickness.

3.4 Nickel alloys - if requirements on mechanical properties are higher, nickel alloys (most commonly with iron or cobalt) may substitute pure nickel. However, a risk of increase on macrostress occurs when an alloying element is codeposited with nickel.

4. Experimental procedure

Internal stress of electrodeposited NiFe and NiCo layers have been investigated by dilatometric method [4,5]. The method uses length changes of a prestressed tape, caused by macrostress in the layer growing during the electrolysis. The length changes have been registered by an inductive sensor connected with an amplifier and recorder. The functional (immersed) length of the annealed low-carbon steel tape, with dimensions of 0,1 x 10 mm was 175 mm. The plating cell was immersed in an ultrathermostat. Electrolyte was not stirred during the process. Electrolysis was carried out at temperature 50°C ± 0,5°C and pH = 4,0. Electrolyte was based on sulphates Ni^{2+} 0,95 M and Fe^{2+} 0,05 M, or Co^{2+} M and contained 0,4 M boric acid as a buffering agent and 0,1 M 5-sulphosalicylic acid as a complexing agent. An influence of additive EL (commercional name, OTB Berlin, Ltd.) on some properties of deposits was investigated. This additive does not contain sulphur, which might cause so called "sulphur embrittlement" in nickel electrodeposits [6].

5. Results and discussion

5.1 Nickel - iron system

The influence of EL concentration on internal stress at cathodic current density is shown in Fig.1. The deposits are rather stressed without EL presence (about 170 MPa). Internal stress decreases considerably with increasing EL content. The "zero level" is reached at the concentration of 250ml EL/l. If the content of EL is more incresed, the deposits exhibit compressive stress. This result is of great importance, because iron is usually cause of high tensile internal stress.

Fig.2 shows the influence of EL in microhardness of deposits. It is obvious that microhardness decreases with increasing EL content, what could be expected. At the "zero stress level" microhardness is still roughly 350 HV, which is distinctly more than at pure nickel.

Fig.1 Influence of EL concentration on internal stress

Fig.2 Influence of EL concentration on microhardness

5.2 Nickel - cobalt systém

The influence of EL concentration on macrostress is shown in Fig.3. The measurements were carried out at the cathodic current density 1 $A.dm^{-2}$. The difference between iron and cobalt system is obvious at the first sight. Internal stress is less than 100 MPa even at the absence of EL. With increasing EL concentration internal stress sinks rapidly. The "zero level" is reached at 15 ml EL/l which is 16 times less than at iron.

Fig.3 Influence of EL concentration on internal stress. Electrolyte NiCo, current density 1 $A.dm^{-2}$

The influence of cathodic current density on internal stress at the EL concentration 10 ml/l is presented in Fig.4. The area of compressive stress occurs round 2A.dm^{-2}.

Fig.4 Influence of cathodic current density on internal stress. Concentration of EL 10 ml/l

In conclusion a comparison between the NiFe and NiCo alloys can be done. Electrodeposited alloys broaden anyway the scale of properties of electrodeposits. In the case of nickel, which is the most common metal used for electroforming purposes, two alloying elements can come into consideration first of all. Iron as the less expensive one even cuts costs of the whole process, but the deposits are generally more stressed than the deposits of NiCo alloys. On the other hand, cobalt is even more expensive than nickel. The amount of the EL additive, which increases costs of the process, needed for keeping internal stress on a low level is more that ten times lower. Therefore, from the economical point of view no decision can be made. Some investigations comparing the properties of particular alloys would be needed in the future.

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