ADVANCED COATINGS FOR AUTOMOTIVE INDUSTRY FORMING DIES.

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ABSTRACT
The introduction of car body parts made of high strength sheets is increasing the number of problems during forming processes. PVD and CVD coatings have been obtaining the best results in stamping tools under very hard conditions. However, to obtain the best performance, some aspects have to be considered. The purpose of this paper is to summarize the fundamental aspects of these kind of coatings and the recommendations to obtain the optimal results in coated dies.

Keywords: HSS sheets, CVD, PVD.

1. INTRODUCTION
Local hardening, nitriding and hard chromium processes have been for many years successful surface processes for dies and punches in automotive industry. Especially in forming dies made of cast iron applied in so called «skin of the cars». The introduction of new materials with high strength values (450-1200 N/mm²) induces the application of new base materials and new coatings. These new coatings must increase the properties of the conventional coatings, which means hardness, adherence and friction coefficient. PVD and CVD coatings are nowadays obtaining the best results. However some questions have to be observed before deciding which kind of coating to apply. These questions refer to base material choice, surface preparation, sheet properties, coatings characteristics, dimensional tolerances allowed... All these points are in close relation and are conditioning factors for the final results. This paper presents the main questions referring to PVD and CVD coatings applied to forming dies. The knowledge in the stamping process, die manufacturing, heat treatment and coating application will provide the information needed to select the best coating.

2. HIGH TEMPERATURE PROCESSES: C.V.D. (CHEMICAL VAPOR DEPOSITION)
Thermal CVD coatings are usually based in titanium compounds. The process temperature is above 1000°C. The pieces are heated in an inert gas atmosphere before introducing the reactive gases. These gases are CH₄ to obtain carbides, N₂ for nitrides, Ar as inert gas and H₂ as a reductor gas. The most common metallic precursor is TiCl₄ liquid. It is gasified at 55 °C before the introduction in to the chamber. The process is carried out under low pressure conditions. This allows us to coat uniformly throughout the chamber. After coating (3-4 hours to 8-10 microns thickness) the pieces are cooled to below 1500°C (to avoid surface oxidation)
1000°C assure the best adhesion between layer and substrate due to the bi-directional diffusion effects on the substrate surface. Carbon is pumped out of the substrate and reacts with the reactive gases. This means smooth transition between the substrate and the layer is achieved.
The compounds obtained are TiC (3800HV), TiCN (3200 HV) and TiN (2200 HV) in mono or multilayer form.

At the end the steel lost its hardness through annealing temperature. It must be hardened and tempered. It depends on whether or not substrate distortion takes place. The substrate characteristics to avoid or minimize distortion are detailed in another chapter.

CVD coatings are specially recommended in the following applications:

- Forming dies, deep forming dies where the sheet thickness is more than 2 mm
- When during stamping processes there are peak and lamination effects in low strength sheets of over 2 mm thickness.
- High strength sheets (more than 450 N/mm²) and over 0.8 mm thickness.
- Stainless steel stamping processes.
- None permissible lubrication during forming processes.
- Forming processes of galvanic or electroplated sheets
- Forming processes which may cause surface heating on the dies and punches.

3. LOW TEMPERATURE PROCESSES: P.V.D. (PHYSICAL VAPOR DEPOSITION)

Hard coatings obtained by P.V.D. processes have been resolving wear problems increasing the hardness level and improving the friction coefficient enough to assure the length productivity of the die.

PVD techniques are based on the different kinds of evaporation systems. Under high vacuum conditions (10⁻⁵ mbar) the reactive metal or compound is evaporated and ionized. Ions react with the gases introduced in the reactor at low pressures and the compound is focused on the surface due to the bias applied between the pieces and the chamber wall. Hard thin films obtained by PVD process have advanced to improve hardness (AlTiN compounds) and friction coefficient (metal-carbon compounds). The main advantage of PVD coatings is the low temperature of process (500°C) At this temperature there is no distortion if the choice of substrate and heat treatment is correctly applied. Therefore the adherence is limited because at low temperatures there is no diffusion effects. The adherence values are enough if the working conditions are not severe. Some times CVD and PVD coatings can be combined in a die formed by different blocks, applying CVD or PVD coatings depending on working conditions.

PVD coatings are recommended in the following applications:

- Low strength and thin sheets
- Thin electroplated or galvanized sheets
• Poor lubricant conditions
• When the die surface is heated due to working conditions.

4. SUBSTRATE CHARACTERISTICS

Usually tools are made of steel. The kind of steels used in die manufacturing are named cold working steels. Most of them have the following characteristics (specially needed when the tool must be coated):

• High hardness after hardening and tempering (minimum 60 HRC)
• Hardening under gas pressure conditions (high alloyed steel especially high chromium content)
• Secondary hardness at temperatures above 500ºC

These characteristics assure less distortion during hardening processes, the possibility of keeping original size during the tempering process at high temperatures (480ºC-520ºC) maintaining high hardness values.

The steels widely used for tools and dies manufacturing are 1.2379 (German number) AISI D-2 steel, 1.2363 (German number) AISI 303 steel and high speed steels.

5. SURFACE PREPARATION

Surface preparation involves fine sand blasting, polishing and cleaning processes. Thin coatings tend to emulate the surface roughness. Surface defects have to be removed or minimized. Low friction coefficient can only be obtained if roughness is less than 1 Ra. This is the reason why working surface has to be blasted and polished to mirror sheen before and after coating (CVD and PVD). Sheet gliding on the die surface is possible with this finishing quality. Furthermore coating adherence can only be ensured with proper surface preparation.

5.1 Welding repairs

It is always better to coat new dies than older dies. Sometimes dies have to be repaired. If dies have to be repaired by welding process this must be carefully administered. The welding material has to present similar conditions to substrate material, to obtain the same properties after heat treatment (minimum 60 HRC) with the same level of distortion. The steps to repair by welding are:

• Heating the die to 400ºC
• Welding process with the recommended welding material
• Heating the die to 450ºC for 2-3 hours with subsequent cooling.
Die manufacturers are specialized in welding operations.

6. MANUFACTURING STEPS IN TOOLS AND DIES TO BE COATED

When a tool or die are designed previous to manufacture it is important to observe all the steps concerning heat treatment and coating. This will help avoid unnecessary re-adjustment (expensive works) and delay in delivery. These steps are resumed below.

- Choice of substrate material (Quality in chemical and structural composition: cast or forged steel)
- First machining
- Stress relieving at 600ºC
- Finishing
- Hardening in vacuum conditions
- Tempering at temperatures near 500ºC minimum twice. Hardness must be 60-58 HRC
- Assembling and adjusting the blocks
- Pre series of 5000-10000 stamped pieces for homologation
- Surface preparation, polishing and cleaning to coat
- CVD or PVD coating
- Second hardening and tempering under vacuum conditions (only after CVD coatings)
- Assembling and
- adjusting the blocks (This operation must be carried out by specialised operators)
- Press tests.

7. CONCLUSIONS

CVD and PVD coatings are successfully improving and resolving surface wear on tools and dies, especially in hard forming conditions. CVD coatings have obtained the best results in stamping sheets of more than 2 mm thickness and strength up to 400 N/mm². CVD has proved to be the best coating in high strength steels forming processes. CVD processes may cause distortion due the high temperature. Substrate material, surface preparation and assembling operations are very important phases to be observed during tools and die manufacturing. PVD and CVD coatings can be carried out on previously coated dies. The old coating must be removed prior to re coating. Damaged areas in dies can be carefully welded. PVD and CVD coatings are ensuring long life production, less maintenance operations, 70-90% on saving lubricant (environmentally friendly), in short economically recommended in high production dies.

8. REFERENCES

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