New Duplex Surface Treatment Dramatically Improves Die Life, Part Quality & Cost Savings

Loren Epler, President
Dynamic Surface Technologies
Canton, Michigan

Introduction

The use of Nitriding and Nitrocarburizing Surface Treatments as well as PVD & CVD Coatings such as CrN and CrC have been used for years to increase the life of Die Cast Tooling, but recently an advancement has been made to combine a DYNA-BLUE™ Ferritic Nitrocarburizing process with a layer of Chromium Carbonitride diffused into the steel. This Duplex Diffusion process is called DYNA-MAX/DST-Cr. This new process avoids the limitations of PDV and CVD coatings while imparting excellent mechanical properties needed to increase tool life, decrease buildup (soldering) and increase release properties to give better part quality, longer Tool life, less downtime/ cleanup and less scrap which represents huge savings.

This new technology represents a joint venture between Dynamic Surface Technologies, a Michigan Corporation with over 25 years experience in surface treating and HARD Technologies Pty Ltd of Australia, a metallurgical based R&D facility. This process is the outcome of years of research, testing, and real life case studies. This article will provide an overview of the properties of this new process compared to conventional surface treating/ coatings, how the process is applied as well as case studies that show dramatic improvement in tool life, cost effectiveness and part quality.

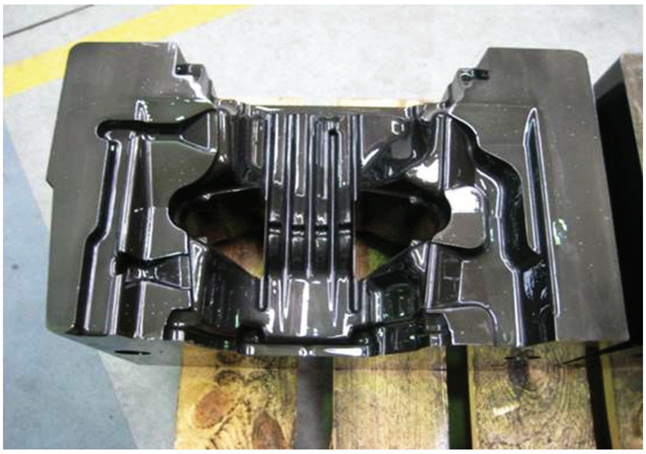

Figure 1 – Gear Carrier Housing with DST-Cr applied. (Courtesy of Long Minh Huynh-DST Technologies Pty, Ltd)

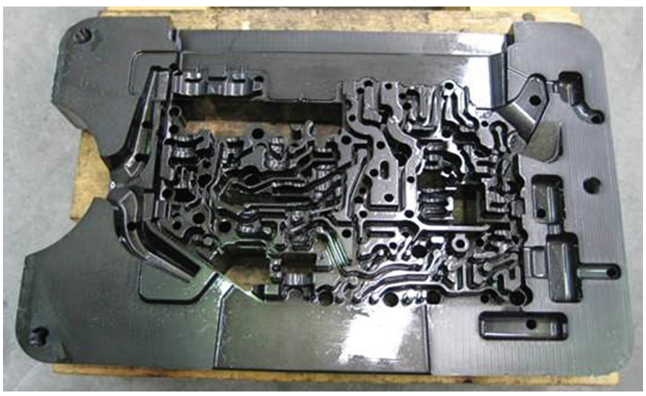

Figure 2 – Valve Body with DST-Cr applied. (Courtesy of Long Minh Huynh-DST Technologies Pty, Ltd)

What is the process and how is it applied?

Ferritic Nitrocarburizing is a low temperature, thermochemical (typically 950° - 1060 °F) diffusion process that yields two metallurgical characteristics:

1) An Epsilon Iron Carbonitride Compound layer that is composed of Nitrogen & Carbon[1]and has a hardness of up to 75HRC and

2) A nitrogen enriched diffusion zone[2] 60+ HRC that supports the compound zone.

The Duplex Diffusion process is accomplished with the addition of a Thermo Reactive Deposition (Cr) layer, which causes diffusion of nitrogen from the compound & diffusion zone towards the surface, which reacts with the alloy powder (N-2 +Cr) to form distinct layer of Cr that is diffused into the surface[3].

Both the Nitrocarburizing (stage 1) and Chromium Diffusion process (stage 2) utilize a Fluidized Bed Furnace. Fluidization is the term applied when making aluminum oxide

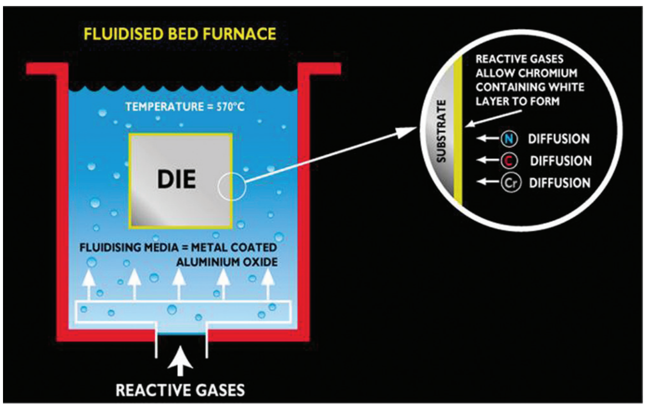

Figure 3 – Schematic of Fluidized Bed Furnace. (Courtesy of HARD Technologies)

particles react like a liquid[4] in a heat treating furnace. Process gases are introduced into the furnace through a diffusion plate, located in the bottom of the furnace. The gases are pressurized thus lifting and moving the aluminum oxide, scrubbing the part with fresh reactive gases and provides uniform heating + 2 °F, thereby ensuring consistent metallurgical properties with 6 times the thermal transfer of conventional nitriding furnaces. The process is not inhibited by part geometry or blind holes and provides uniformity of case depth on the entire part.

Microstructure

The Microphotograph shows the Chromium layer diffused into the steel 2.5-3 microns deep supported by a nitrogen rich diffusion zone, which is .005"-.007" deep. Because both the Nitrocarburizing process and Chromium diffusion process are diffused into the steel there are no problems with adhesion, brittleness, flaking, or peeling associated with PVD Coatings.

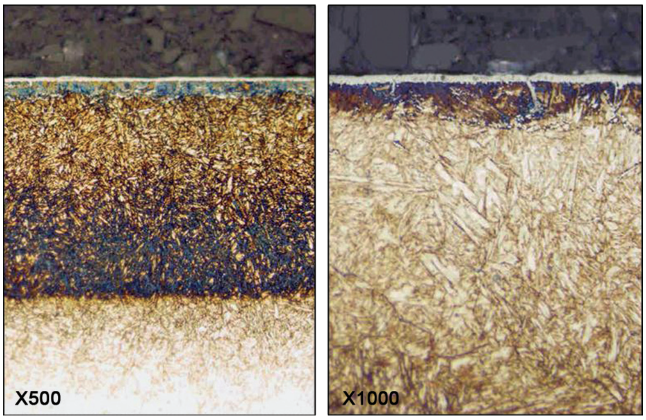

Figure 4 – Microstructure of DST-Cr. (Courtesy of HARD Technologies)

Hardness Testing of DST-Cr

Vickers hardness testing was conducted using a load of 10μN on the surface layer and a 25 g load beneath the surface layer to the core. The surface layer was determined to be 1520 Hv and a diffusion zone from 1050 to 650 Hv. This also revealed that the nitrocarburized diffusion layer was retained after the DST-Cr process with a gradual hardness transition down to the core. This deep diffusion layer provides good support for the hard Chromium layer. It is also evident that the original core hardness of the H-13 steel was maintained.

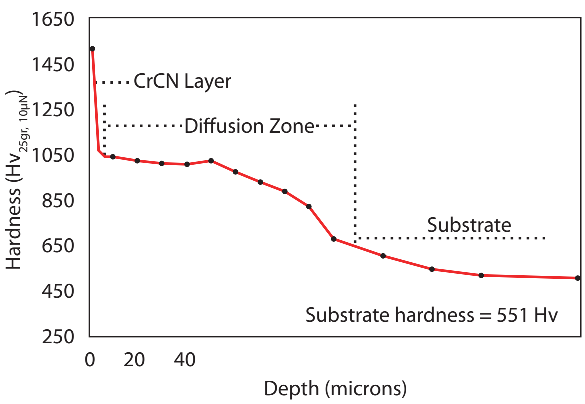

Figure 5 – Microhardness Profile.[5] (Courtesy of HARD Technologies)

Glow Discharge Optical Emission Spectrometry of DST-Cr

Quantitative depth profiling was performed using Glow Discharge Optical Emission Spectrometry. The GDOES revealed that the surface layer was rich in chromium (60%) and nitrogen at a total depth of 3 Microns.

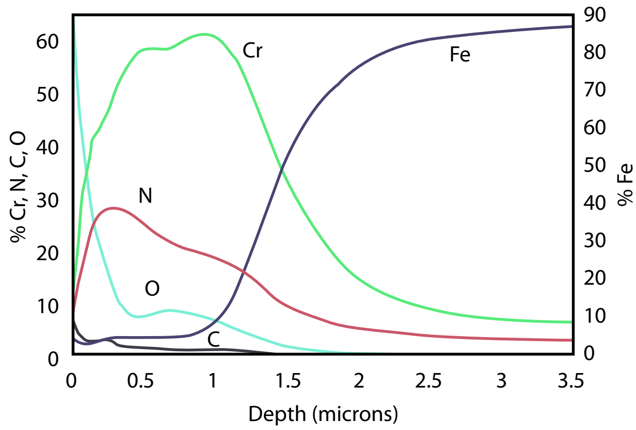

Figure 6 – Glow Discharge Optical Spectrometry of Chromium Layer[6] (Courtesy of HARD Technologies)

Pin on Disc "Coefficient of Friction Test" [7]

A Pin on Disk test was used to determine the coefficient of friction of untreated, Nitrocarburized and DST-Cr treated samples against 99.98% aluminum. A 1N load was used with .2 meter per second on an un-lubricated sample with Ra 0.2 ±0.04. The test revealed a coefficient of friction for untreated at an average of 1.1, Nitrocarburized at .2-.3, and DST-Cr at .1-.2

Performance Testing [8]

A tool performance study was done by a die cast facility (Mercury Marine) to provide real life test data of Ferritic Nitrocarburizing, DST-Cr and a PVD Chromium Nitride processes. This test revealed that the DST-Cr process had

Table 1 – Properties needed for Die Cast Die Performance.

Properties needed to increase die cast tool performance	Properties of DST-Cr
High Surface Hardness to Resist Wear & Erosion	1520 Hv (940 Hv is 68 HRC)
Resists Soldering	Chromium layer is an impervious surface layer to reduce soldering (attachment of Al)
Resistant to Heat Checking	Chromium layer has high compressive residual stresses that resist heat checking, cracking
Thermal Fatigue Resistance	Chromium layer resists thermal fatigue
Resistance to Thermal Softening	Chromium layer does not soften even at elevated temperatures
Resistance to Tool Chipping, Flaking, Peeling	Because the layer is diffused into the steel and not a coating, it does not flake, peel, etc.
Low Dimensional Variation - Die	The process is low temperature therefore no distortion
Good Release Properties	The Chromium layer provides excellent release properties
Able to be Repaired	No problem with weld repair or reapplying Chromium layer

the greatest increase in tool life. The test tool was a die cast core located near an end gate with an extreme amount of wear. The FNC process yielded 10,000 shots, PVD Chromium Nitride was 18,000 shots and the DYNA-MAX/ DST- Cr yielded 59,425.

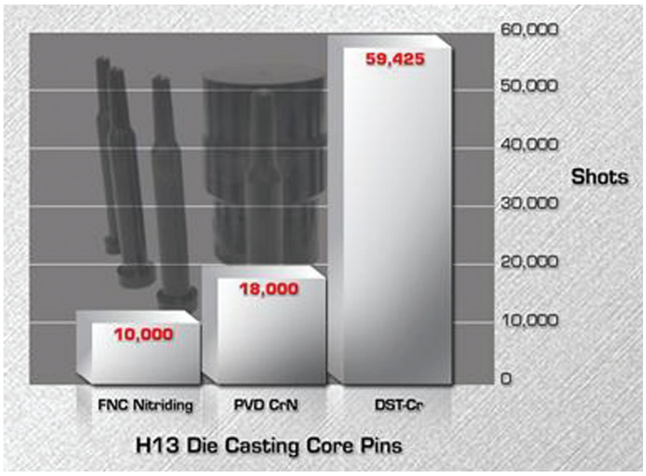

Figure 7 – Tool Performance Study.

High Pressure Diecasting

An untreated H-13 core pin experience sticking after 250 parts and required disassembling and cleaning daily.

A second core pin treated with DST-Cr maintained excellent surface finish even after 30,000 shots. The

Table 2 – Comparison of Surface Treatment/Coatings.

	Nitriding	Nitrocarburizing	PVD Coating CrN	CVD Coating TiCn	DYNA-MAX/DST-Cr
Thickness - microns	5-10	5-20	2-4	1-3	2-3
Typical Hardness Hv	700-1000	800-1200	1500+	1500+	1500+
Brittleness	Possible	No	Not typically	Not typically	No
Penetration of holes/pockets	No-line of sight	Yes with Fluidized Bed Furnace	No-line of sight	No-line of sight	Yes with Fluidized Bed Furnace
Resistance to flaking, peeling	No problem with flaking as this is a diffusion process	No problem with flaking as this is a diffusion process	Possible flaking if adherence problem	Possible flaking if adherence problem	No problem with flaking as this is a diffusion process
Dimensionally stable	Yes-low temperature process	Yes-low temperature process	Yes-low temperature process	No-this is a high temperature process	Yes-low temperature process
Weld repair	Problems with pin hole porosity	Can be welded with no porosity	After weld needs to be stripped and recoated	After weld needs to be stripped and recoated	Can be welded and reapplied with no stripping
Typical turn around time	5-7 days	1-2 days	5-7 days	5-7 days	2-3 days
Tool Life	Less than Nitrocarburize	2-10 times increase over Nitride	Good	Good	2-4 times increase over PVD, CVD Coatings

Figure 8 – Untreated Core Pin – 250 parts. (Courtesy of Long Minh Huynh-DST Technologies Pty, Ltd)

Figure 9 – DST-Cr Core Pin – 30,000 parts. (Courtesy of Long Minh Huynh-DST Technologies Pty, Ltd)

customer claims: wear, heat resistance and release properties of DST-Cr has significantly increased productivity, predictability and profitability.

Summary

The DYNA-MAX/DST-Cr process has shown substantial improvement over conventional nitriding, nitrocarburizing, and PVD coating without the problems of distortion, brittleness, flaking, adherence, welding that the other processes have exhibited. The DST-Cr process exhibited Tool Life 5 times longer than the Nitrocarburizing process and 3 times longer than PVD Chromium Nitride. The properties of the DYNA-MAX/DST-Cr are: High Hardness to provide wear and erosion resistance, an impervious Chromium layer to resist soldering, resist heat checking, thermal fatigue/softening, with no distortion, peeling or flaking (like PVD, CVD Coatings), increased coefficient of friction and excellent release, and is cost effective due to longer die life and less downtime. These properties are the reason this process has such a significant increase in Tool Life.

References

1. *Bell, Hanson T. "Gaseous Ferritic Nitrocarburizing" Metals Handbook 9th Edition Volume 4*
2. *Dawes, C. & Trantner, D.F. "Recent Developments in Surface Hardening Techniques, Metals Technology, Volume 5 August 1978*
3. *Fabijanic, D., Reynoldson, R, Kelly, G., Hodgson, P., "A New Low Temperature Duplex Surface Treatment*
4. *Reynoldson, R.W. "Controlled Atmosphere Fluidized Beds for the Heat Treatment of Metals, 1976*
5. *Fabijanic, D., Reynoldson, R, Kelly, G., Hodgson, P., "A New Low Temperature Duplex Surface Treatment*
6. *Fabijanic, D., Reynoldson, R, Kelly, G., Hodgson, P., "A New Low Temperature Duplex Surface Treatment*
7. *Reynoldson, Ray, HARD Technologies March 2006*
8. *Mercury Marine, November 2006*