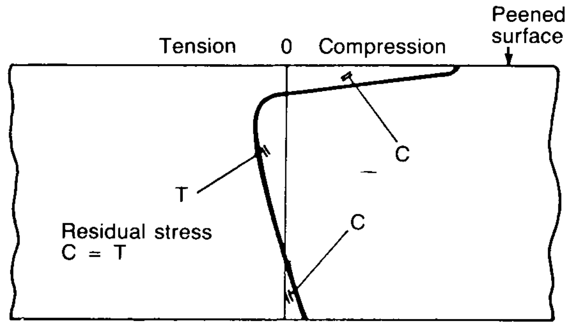
SECTION IX

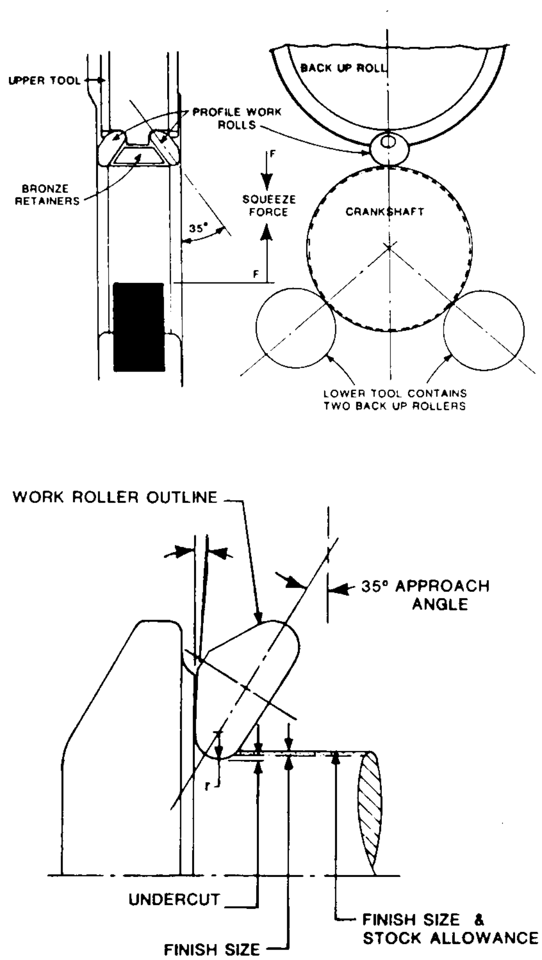
SURFACE TREATMENT

Figure 9.1



Distribution of stress in a shot-peened beam with no external load.

Figure 9.2



Schematic diagrams of tooling for undercut deep-fillet rolling of Ductile Iron crankshafts.

SURFACE TREATMENT

Introduction

Surface treatments are applied to castings for engineering, aesthetic and economic reasons. The surfaces of industrial castings may be treated to provide improved surface-related properties such as wear, fatigue and corrosion resistance. In castings used in consumer products, improved appearance is also an important objective of surface treatments. In many cases, surface treatment permits a casting to meet mutually exclusive design objectives. For example, the application of an abrasion-resistant coating will enable a Ductile Iron casting to be both wear resistant, a surface property, and impact resistant, a bulk property. However, regardless of the engineering and aesthetic objectives, the main reason for using surface-treated Ductile Iron castings is that they offer the most cost-effective means of meeting these objectives. Surface treatments commonly applied to Ductile Iron castings include: thermal and mechanical hardening treatments: the application of fused coatings to reduce friction and improve wear and corrosion resistance; the use of hot dipped metal coatings to improve appearance and corrosion resistance: the electrodeposition of metal coatings to increase corrosion and wear resistance and improve appearance and the application of diffusion coatings to increase resistance to wear, oxidation, and corrosion.

SECTION IX

THERMAL-MECHANICAL SURFACE HARDENING

Thermal surface hardening is a common and highly cost-effective method of improving the wear and fatigue resistance of Ductile Iron castings. Thermal hardening involves the rapid heating of the surface layer of a casting to produce a high carbon austenite which, upon removal of the heat source, is cooled sufficiently rapidly, either by self-quenching or the application of a quenching medium, to produce a martensitic structure. In addition to significantly increasing hardness, the formation of martensite creates compressive stresses in the surface layer, impeding the formation and propagation of cracks. Although slightly softer than hardened steel, the combination of a martensitic matrix and graphite nodules in surface hardened Ductile Iron can produce superior resistance to sliding wear. Flame, induction, and laser hardening are the most common methods used to thermally surface harden Ductile Iron castings.

Shot-Peening

Shot-peening hardens the surface of a Ductile Iron casting by the controlled impingement of spherical particles of hardened steel, ceramic or glass. This impingement produces a deformed, compressively stressed surface layer (Figure 9.1) having a depth and degree of stress that are controlled by peening parameters such as shot size and hardness, speed and angle of impingement and exposure time. For consistency of depth and hardness, shot peening should be mechanized and "Almen Strips" used to measure peening intensity. Shot-peening can significantly increase fatigue strength in both conventional (Figure 3.34) and austempered Ductile Irons (ADI) (Figures 4.17, 4.18, 4.35 and 4.36). Shot-peening is especially effective in improving the performance of ADI

Surfacing Materials	Classes	Application Methods	General Properties	Typical Uses
Ferrous Alloys, hardenable & austenitic	EFe, RFe5, ECI, RCI, EFeCr, RFeCr, EFeMn	Arc or Gas Welding	Hardenability increases with increase in carbon content. Austenitic types are hardenable by cold working.	Intermediate face for subsequent hard facing crushing equipment and abrasive applications. Metal to metal wear.
Cobalt Base	ECoCr, RCoCr	Arc or Gas Brazing	Corrosion and abrasion resistant. Hardness lower than ferrous alloys, but retained at elevated temperatures.	Valves and seats of internal combustion engines. Hot-working die facing and repair.
Carbides	WC, W_2C	Arc or Gas Welding	Maximum hardness and abrasion resistance. Brittleness dependent on matrix and backup metal.	Cutting and chopping of minerals and metals. Severely abrasive applications.
Copper Base	ECuZn, RCuZn, ECuSn, RCuSn, ECuAI, RCuAI	Arc or Gas Brazing	Corrosion resistant. Good antifriction properties. Excellent electrical conductivity.	Friction bearing surfaces. Moderate hardness for inlays on gear teeth.
Nickel Base	ENiCr, RNiCr	Arc or Gas Welding. Spraying	Heat and corrosion resistant. Fair hardness and impact resistance retained at elevated temperatures.	Hot gas and corrosion service. Suitable for hot-working surfaces that are to be machined.

Table 9.1 **Fusion coating materials, their properties and uses.**

Coating	Hardness	Elec. Res. Microhm-centimetre	Abrasion Resistance	Appearance		Thickness Mils	*Micrometres*	Characteristics and Uses
Aluminum	30-90 Vickers	2.8	Poor	White		0.25	*6.4*	Good thermal and heat resistance properties when diffused into base iron.
Cadmium	30-50 Vickers	7.5	Fair	Bright White		0.15-0.5	*3.8-12.7*	Pleasing appearance for indoor applications. Less likely to darken than zinc.
Chromium	900-1100 Vickers	14-66	Excellent	White - can be varied	(decorative) (hard)	0.01-0.06 0.05-12.0	*0.3-1.5* *1.3-304.8*	Excellent resistance to wear abrasion and corrosion. Low friction and high reflectance.
Cobalt	250-300 Knoop	7	Good	Gray		0.1-1.0	*2.5-25.4*	High hardness and reflectance.
Copper	41-220 Vickers	3-8	Poor	Bright Pink		0.2-2.0	*5.1-50.8*	High electrical and thermal conductivities. Used as undercoat for other electroplates.
Lead	5 BHN	10	Poor	Gray	(wear) (corrosion)	0.5-8.0 50	*12.7-203.2* *1270*	Resistant to many acids, hot corrosive gases, and atmospheres.
Nickel	140-500 Vickers	7.4-10.8	Good	White	(decorative) (wear)	0.1-1.5 5-20	*2.5-38.1* *127-508*	Resistant to a variety of chemicals and corrosive atmospheres. Used as undercoat for chromium.
Rhodium	400-800 BHN	4.7	Good	Bright White		0.001-1.00	*0.025-25.4*	High electrical conductance. Brilliant white appearance is tarnish and corrosion resistant.
Tin	5 BHN	11.5	Poor	Bright White		0.015-0.5	*0.38-12.7*	Corrosion resistant. Hygienic applications for good and dairy equipment.
Zinc	40-50 BHN	5.8	Poor	Matte Gray	(decorative) (corrosion)	0.1-0.5 0.5-2.0	*2.5-12.7* *12.7-50.8*	Easily applied. High corrosion resistance.

Table 9.2 **Electroplated coatings, their properties, characteristics and uses.**

because the resultant deformation transforms the stabilized austenite into martensite, producing both hardening and compressive stresses. In addition to increasing wear resistance and fatigue strength, shot-peening is also used to retard stress-corrosion cracking, relieve internal stresses, correct distortion and prepare surfaces for coating.

Surface Rolling

Surface rolling, like shot-peening, hardens the casting surface by the introduction of controlled deformation such as that exemplified by the fillet rolling of crankshafts (Figure 9.2). Like shot-peening, surface rolling can produce significant increases in the fatigue strength of conventional Ductile Iron and ADI components, especially those having unavoidable stress concentrations (Figure 3.35 and Table 3.3).

SECTION IX

SURFACE COATING

Fusion Coatings

Fusion coatings can be applied with any of the fusion welding processes used to repair and join Ductile Iron castings (see Section VIII) and also by flame, arc and plasma spraying processes. Table 9.1 summarizes the surfacing processes, properties and typical uses of the five major classes of fusion coating materials.

Electroplated Coatings

Electroplated coatings are frequently applied to Ductile Iron castings to provide special surface properties such as resistance to corrosion, wear and abrasion, special surface colour and reflectivity, and good general appearance. For some applications ductility and solderability are also important coating characteristics. Table 9.2 describes conventional electroplated coatings, their properties and typical uses.

Hot-Dipped Coatings

Hot-dip coatings are usually thicker than other coatings and are bonded firmly to the casting by a thin diffusion layer between the coating and casting. Table 9.3 lists the most common hot-dipped coatings, their structures and uses. The widely used process of hot-dip galvanizing produces the heaviest and most durable protective coating for iron castings. The substantial, uniform, and adherent coating of zinc provides effective protection against corrosion by acting as a barrier film against environmental corrosive attack and by sacrificial corrosion. Precautions should be taken to avoid the embrittlement of annealed ferritic castings by the galvanizing process (see page 3-55).

Diffusion Coatings

Diffusion coatings are applied by holding the castings at high temperature in intimate contact with the coating agent, which can be in one of four forms: powdered metal, volatilized metal or metallic salt, fused metal salts, or a gaseous atmosphere. The resultant diffusion processes alloy the surface layer of the casting to produce the desired mechanical and chemical properties. In diffusion coating the "coating" is not visible and is an integral part of the surface microstructure of the casting. Figure 9.4 lists the different types of diffusion coatings and describes their properties and uses. Figure 3.36 illustrates the significant increase in fatigue strength produced by the nitriding of a Ductile Iron casting.

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Type	Coating Structure	Thickness or Weight	Uses
Galvanizing	Outer layer of zinc over a base layer of an iron-zinc compound.	2 to 8 ounces per square foot *9 to 35 g/cm²*	Atmospheric corrosion resistance where non-staining corrosion products are desirable.
Tinning	Tin surface layer over an intermetallic tin-iron phase.	0.3 to 1.5 mils *7.6 to 38.1 μm*	Resistant to tarnishing in food service and non-industrial atmospheres. Intermetallic bond for bearings. Metallurgical bond for soldering.
Lead and Lead Tin	Mechanical bond of outer layer to substrate.	0.2 to 0.6 mils *5.1 to 15.2 μm*	High resistance to industrial atmospheric corrosion. Chemical process applications, especially with sulphuric and hydrochloric acids.
Aluminizing	Aluminum outer layer over an interfacial iron-aluminum layer.	2 to 4 mils *50.1 to 101.6 μm*	Corrosion and heat application up to 1000°F (540°C). Minimizes high temperature oxidation.

Table 9.3 **Summary of hot-dipped coatings, their structures and uses.**

Type	Coating Structure	Properties	Uses
Calorized	Metallic aluminum introduced into surface layer forming aluminum-iron alloy.	High temperature oxidation resistance.	Chemical process equipment, steam superheaters.
Chromized	Chromium carbide case formed on surface.	High hardness and wear resistance.	Combustion and mechanical equipment.
Cyanided Carbonitrided	Carbon-nitrogen compound formed by diffusion into surface.	Wear and thermal fatigue resistance.	Gears, cams, pawls, and engine heads.
Nickel-Phosphorous	Ammonium phosphate and nickel oxide products reduced and diffused.	Corrosion resistance comparable to austenitic irons. Poor wear resistance.	Chemical process pipe and fittings.
Nitrided	Nitrogen introduced into surface by contact of ammonia or other nitrogenous material.	Wear and corrosion resistance at elevated temperatures.	Same as for carbonitrided.
Sheradized	Zinc introduced into surface.	Corrosion resistance.	Atmospheric corrosion resistance.

Table 9.4 **Types of diffusion coatings, their characteristics and uses.**

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