

DEFECTS OF STEEL BILLETS AND METAL PRODUCTS

HANDBOOK-ATLAS

Defects of steel billets and metal products = Дефекты стальных заготовок и металлопродукции : handbook-atlas / [project manager and author : V. I. Gritsayenko] ; [the team of contributors : Z. A. Mikirova [et al.] ; under the general editorship of A. N. Savenok. — Minsk : ICC Minfina, 2019. — 287 p. УДК 669.019(035)

ББК 34

Чит. зал №1 — 5 экз.

The Handbook-Atlas has been developed on the basis of decades (1984-2018) of experience of the Byelorussian Steel Works. It contains the unique information on typical defects occurred at all process stages of the metallurgical and harware productions.

This Handbook-Atlas includes all defects ever observed on concast billets, concast blooms, rolled section steel, hot rolled square billets, mechanical-engineering discs, wire rod, hot rolled pipes, harware goods, hard-metal drawing die tools. It also addresses the causes of defects and measures to avoid them. The production processes of the main process stages of the works are described in brief; the core process equipment is listed herein.

This Handbook-Atlas is intended for technical & engineering employees and quality control departments at the iron and steel works as a practical guide for assessment of defects occurred at the intermediate process stages and in the finished products. It might be of interest to the specialists of the related enterprises, professors, students and Ph.D. candidates undertaking a course of metallurgical engineering. Also this Handbook-Atlas might be useful for consumers of the finished products of the Byelorussian Steel Works.



TABLE OF CONTENTS

NORMATIVE REFERENCES	14
INTRODUCTION	16
CHAPTER 1. STEEL QUALITY AND CLASSIFICATION OF DEFECTS	18
1.1. Classification of defects	18
1.2. Comprehensive strategy for quality of metallurgical products	21
CHAPTER 2. STEELMAKING	25
2.1. Melting, extra-furnace steel processing	26
2.2. Continuous steel casting	26
2.3. Processes of concast billet defect formation	29
CHAPTER 3. DEFECTS OF CONCAST BILLET	32
125×125 mm, 140×140 m, 250×300 mm, 300×400 mm in section, Ø200 mm	32
3.1. Shape defects	32
3.1.1. Swelling (crown)	
3.1.2. Concavity	33
3.1.3. Ovality	33
3.1.4. Longitudinal shrinkage depressions (scabs)	34
3.1.5. Rhomboidity	35
3.2. Surface defects	36
3.2.1. Non-metallic inclusions on the surface	36
3.2.2. Skin ripples	37
3.2.3. Longitudinal cracks	37
3.2.4. Transverse cracks	38
3.2.5. Reticular cracks	39
3.2.6. Belt	40
3.2.7. Mechanical defects (mark)	41
3.2.8. Folds	41
3.2.9. Pores	42
3.2.10. Metal bleeding	43
3.3. Internal defects	43
3.3.1. Centerline (axial) porosity	43
3.3.2. Segregation streaks and cracks	44
3.3.3. Edge point contamination	46
3.3.4. Ghost line (contour)	47
3.3.5. Centerline segregation	47
3.3.6. Irregular transgranular structure	49



	3.3.7. Pinhead blisters	
	3.3.8. Foreign metallic inclusions	50
	3.3.9. Non-metallic inclusions	51
	8.4. Classifier of defects of concast billet macrostructure (sulphur prints prepared by Baumann's nethod)	
	3.4.1. Centerline (axial) porosity	52
	3.4.2. Centerline segregation (axial chemical inhomogeneity)	53
	3.4.3 Segregation streaks and cracks (common, corner, axial)	
	3.4.4. Edge point contamination	60
	3.4.5. Ghost line (contour)	61
	3.4.6. Pinhead blisters	62
СН	APTER 4. ROLLED SECTION STEEL PRODUCTION	63
4	1. Process operations and characteristics of rolling mill 850	63
4	.2. Process operations and characteristics of small-section rolling mill 320	65
4	.3. Process operations and characteristics of rod mill 150	66
4	.4. Processes of formation of rolled section steel defects	68
	4.4.1. Billet defects	68
	4.4.2. Defects of section steel and wire rod	69
СН	APTER 5. ROLLED SECTION STEEL DEFECTS	. 71
5	5.1. Shape defects	. 71
	5.1.1. Ridge	. 71
	5.1.2. Abnormal sectional shape (oval)	. 72
	5.1.3. Apex angle underfilling	. 72
	5.1.4. Flat regions of the surface	. 73
	5.1.5 Die-rolled section underfilling	. 74
5	5.2. Surface defects	. 75
	5.2.1. Rolled crack	. 75
	5.2.2. Reticular rolled crack	. 77
	5.2.3. Rolled blister	. 79
	5.2.4. Rolled crust	. 81
	5.2.5. Rolled slag patch	. 82
	5.2.6. Small breaks	. 83
	5.2.7. Ingot hot tear	. 84
	5.2.8. Deformational tear	. 85
	5.2.9. Guide mark (scratch, score mark) inherited from concast billets	. 86
	5.2.10. Guide mark	. 89
	5.2.11. Dent	. 91
	5.2.12. Wrinkles	. 91



5.2.13. Rolling lap	92
5.2.14. Rolled scab	92
5.2.15. Fish scale	
5.2.16. Backfin	94
5.2.17. Roll marks	95
5.2.18. Scale pits	95
5.2.19. Stress crack	96
5.2.20. Rolled-in metal particles	97
5.2.21. Scuff marks	98
5.2.22. Rust spots	99
5.2.23. Rolled-in scale	99
5.2.24. Surface scale of non-conforming weight or composition	100
5.3. Internal defects	101
5.3.1. Flakes	
5.3.2. Structure inhomogeneity	102
5.3.3. Cast structure residue	103
5.3.4. Segregation streaks	
5.3.5. Foreign metallic inclusions	105
5.3.6. Centerline segregation	105
5.3.7. Grinding cracks	106
5.3.8. Delamination	107
5.3.9. Non-metallic inclusions	107
5.3.10. Pipe segregation	109
5.4. Structural defects of high-carbon wire rod (mill 150)	110
5.4.1. Structure of different graininess	110
5.4.2. Secondary sorbite in a surface layer	111
5.4.3. Troostite-martensite areas	112
5.4.4. Higher content of ferrite	112
5.4.5. Coarse pearlite	113
5.4.6. Cement carbide precipitation at the grain boundaries	113
5.4.7. Banding (secondary segregation)	114
5.4.8. Surface decarburization	115
CHAPTER 6. HOT-ROLLED PIPE MAKING	116
6.1. Basic operations of hot-rolled pipe making	
6.2. Main product mix of pipe rolling plant	
6.3. Process description of hot-rolled pipe making	119
6.3.1. Billet heating and pipe piercing	
6.3.2. Pipe rolling on continuous rolling mill, stretch-reducing mill and extractor	119



	6.3.3. Pipe prefinishing	. 120
	6.3.4. Pipe finishing and heat treatment	. 121
	6.4. Defect formation processes in the pipe making area	. 121
CH	APTER 7. DEFECTS OF HOT-ROLLED STEEL PIPES	. 123
	7.1. Shape defects	. 123
	7.1.1. Ridge	. 123
	7.1.2. Scab	. 124
	7.1.3. Cobble	. 126
	7.1.4. Polygonization	. 127
	7.1.5. Variation in wall thickness	. 127
	7.1.6. Unfinished section	. 128
	7.2. Pipe surface defects inherited from concast billet	. 129
	7.2.1. Steel-smelting slivers on blowholes and rolled blisters	. 129
	7.2.2. Steel-smelting slivers on hot and hot rolled cracks	. 131
	7.2.3. Steel-smelting slivers and bubbles on endogenous non-metallic inclusions	. 132
	7.2.4. Steel-smelting slivers and bubbles on exogenous non-metallic inclusions	. 133
	7.2.5. Steel-smelting slivers and delaminations on the rolled crust	. 134
	7.2.6. Steel-smelting slivers and delaminations on axial burning	. 136
	7.2.7. Steel-smelting slivers on segregation streaks and cracks	. 137
	7.3. Pipe surface defects of rolling origin	. 138
	7.3.1. Pipe-rolling lap	. 138
	7.3.2. Undercutting	. 139
	7.3.3. Guide mark	. 141
	7.3.4. Wrinkles	. 141
	7.3.5. Roll marks	. 142
	7.3.6. Mechanical damage	. 143
	7.3.7. Dent mark	. 144
	7.3.8. Pigeon hole	. 145
	7.3.9. Fish scale	. 146
	7.3.10. Backfin	. 147
	7.3.11. Tear	. 148
	7.3.12. Ragging marks	. 148
	7.3.13. Roll marks (from rolled-in scale)	. 149
	7.3.14. Foreign metallic inclusions	. 151
	7.4. Defects of pipe-rolling origin on the inner pipe surface	. 151
	7.4.1. Pipe-rolling slivers and bubbles.	. 151
	7.4.2. Ripple markings	. 152
	7.4.3. Wrinkles	. 153



7.4.4. Backfin	154
7.4.5. Foreign metallic inclusions	
7.4.6. Pipe-rolling crack	
7.4.7. Guide scratch	157
7.4.8. Guide mark	159
7.4.9. Dent mark	159
7.5 Surface finish defects	160
7.5.1. Scratch	160
7.5.2. Fin	161
7.5.3. Indentation	162
7.6. Heat treatment defects	163
7.6.1 Thermal crack	163
CHAPTER 8. HARWARE PRODUCTION	165
8.1. Production of steel cord, brass-plated hose wire and bronze-plated bead wire	167
8.2. Production of wire of different purpose and cold-deformed reinforcement in coils using mechanical method of scale removal	171
8.2.1. Manufacturing process of wire of different purpose	171
8.2.2. Manufacturing process of cold-worked deformed reinforcing steel bars	172
8.2.3. Manufacturing process of steel wire fibers	172
8.3. Main groups of defects of hardware production	173
8.3.1. Defects of steel cord, brass-plated hose wire and bronze-plated bead wire	173
8.3.2. Defects of cold-drawn deformed reinforcing steel bars	174
8.3.3. Defects of steel wire fibre	175
8.4. Inspection of defects of hardware production	175
CHAPTER 9. DEFECTS OF HARDWARE ITEMS	179
9.1 Defects of wire rod transportation, storage and preparation to drawing	179
9.1.1. Defects of wire rod transportation and storage	179
9.1.1.1. Surface contamination of wire rod bundle	179
9.1.1.2. Corrosion stains	179
9.1.1.3. Mechanical damages	180
9.1.2. Defects occurring at the stage of preparation of the wire rod surface to drawing	181
9.1.2.1. Underpickling	181
9.1.2.2. Presence of powdered sodium borate	182
9.2. Defects of cold-drawn wire	183
9.2.1. Surface defects inherited from wire rod	183
9.2.1.1. Surface defect in the area of rolled blister	183
9.2.1.2. Surface defect on rolled contamination	184
9.2.1.3. Rolled-in metal particles	185



	9.2.1.4. Surface defect due to foreign metallic macroinclusions	. 186
	9.2.1.5. Backfin on the wire surface	. 187
	9.2.1.6. Surface defect due to chemical inhomogeneity	. 188
	9.2.1.7. Surface defect due to mechanical damages of wire rod	. 189
	9.2.2. Internal defects inherited from wire rod	. 191
	9.2.2.1. Exogenous non-metallic inclusions	. 191
	9.2.2.2. Axial chemical inhomogeneity (segregation)	. 191
	9.2.2.3. Coarser-grained perlite	. 192
	9.2.3. Surface defects of wire occurring during drawing	. 193
	9.2.3.1. Guide mark	. 193
	9.2.3.2. Scuff marks (abrasions)	. 194
	9.2.3.3. Glossy surface	. 195
	9.2.3.4. Surface defects formed during wire drawing	. 195
	9.2.3.5. Surface stress cracks	. 196
	9.2.3.6. Surface defects in welding points	. 197
	9.2.3.7. Breakage due to increased tension stresses (contraction)	. 198
9.	3. Defects of patented and brass-plated wire bar	. 199
	9.3.1. Surface defects	. 199
	9.3.1.1. Surface defects on brass-plated wire inherited from wire rod	. 199
	9.3.1.2. Surface defects of drawing	. 200
	9.3.1.3. Guide marks	. 201
	9.3.1.4. Pits	. 202
	9.3.1.5. Burn from sparks	. 202
	9.3.1.6. Mechanical damage of brass coating	. 203
	9.3.2. Coating defects	. 204
	9.3.2.1. Peeling of brass coating	. 204
	9.3.2.2. Dark strips and spots	. 205
	9.3.2.3. Zinc strip	. 206
	9.3.2.4. Lead sticking	
	9.3.2.5. Sticking of aluminium oxide particles (sand)	. 208
	9.3.2.6. Brass sticking	. 209
	9.3.2.7. Carbon black contamination of the surface	. 210
	9.3.3. Defects of patented wire bar microstructure	. 210
	9.3.3.1. Inconsistent perlite structure	. 210
	9.3.3.2. Presence of divorced (globular) cementite	. 211
	9.3.3.3. Presence of upper bainite	
	9.3.3.4. Presence of structurally free ferrite	
	9.3.3.5. Surface decarburization	. 214



9.3.3.6. Surface overheating	215
9.3.3.7. Overheating with decarburization (stagnant end)	215
9.4. Surface defects of fine brass-plated wire	216
9.4.1. Wire defects	
9.4.1.1. Guide marks	216
9.4.1.2. Absence of coating on fine wire (gray wire)	217
9.4.1.3. Wire surface contamination	
9.4.1.4. Wire corrosion	218
9.5. Steel cord defects	219
9.5.1. Non-conformance of geometric parameters of steel cord	219
9.5.1.1. Steel cord diameter and linear density out of tolerance	219
9.5.1.2. Lay length out of specification	220
9.5.1.3. Loose lay	
9.5.1.4 Uneven coiling	221
9.5.1.5 Air cell	221
9.5.1.6. Macrowave	222
9.5.1.7. Microwave	223
9.5.1.8. Breakout of the core (central wire)	224
9.5.1.9. linversion	224
9.5.1.10. Knot	225
9.5.1.11. Crease mark	226
9.5.1.12. Out-of-straightness	227
9.5.1.13. High residual spinning	228
9.5.1.14. Non-spinning degree out of tolerance	228
9.5.1.15. Corrosion	229
9.5.2. Low-quality spooling of steel cord on the bobbin	230
9.6. Breakages during fine wire drawing and steel cord coiling	231
9.6.1. Breakages on the surface defects of wire	231
9.6.1.1. Breakages on the surface defects formed before the stage of brass plating	231
9.6.1.2 Breakages on the surface defects of fine drawing	232
9.6.1.3. Breakage on the hard alloy inclusions	233
9.6.1.4. Breakages on the surface inclusions of martensite (sparking)	233
9.6.2. Breakages due to internal defects of wire	234
9.6.2.1. Non-metallic inclusion	234
9.6.2.2. Breakages of axial crack type (cone-dimple)	235
9.6.3. Wire breakages due to higher external forces	238
9.6.3.1. Contraction during wire fracture of steel cord	238
9.6.3.2. Breakages of steel cord wires when twisting	239



9.6.4. Other breakages	239
9.6.4.1. Breakages on the surface defects of coiling	239
9.6.4.2. Breakages due to high strain hardening of wire (delamination)	240
9.6.4.3. Breakage due to low-quality welding on the fine drawing section	241
CHAPTER 10. PRODUCTION OF DRAWING DIE TOOL	242
10.1. Technique of drawing die tool making of hard alloys	242
10.2. Processes of defect formation during production and operation of the drawing die to	
alloys	
CHAPTER 11. DEFECTS OF DRAWING DIE TOOL	
11.1. Hard-alloy defects after sintering treatment	
11.1.1. Foreign inclusions	
11.1.2. Ring pores	
11.1.3. Visible porosity of type I	
11.1.4. Single pores	
11.1.5. Visible porosity of type II (structurally-free carbon)	
11.1.6. η–phase	
11.1.7 Uneven distribution of β-phase particles	254
This defect can be eliminated by replacement of the low-quality lot of powder mixture compliance with the sintering conditions.	-
11.1.8. Variation in grain size of α-phase	255
11.1.2. Slip cracks	256
11.1.3 Swell	256
11.2. Defects of hard alloy mechanical processing	257
11.2.1. Split of hard alloy insert	257
11.2.2. Transverse cracks	258
11.2.3. Inlet cone cleavage	
11.2.4. Outlet cone cleavage	260
11.2.5. Inadequate surface finish	261
11.2.6. Longitudinal cracks	261
11.2.7. Corrosion stains	262
11.3. Deviation of physical and mechanical properties of drawing die tools	
11.3.1. Low density	263
11.3.2. Discrepancy of coercive force value	264
11.3.3. Low hardness	
11.4. In-service defects of drawing die tool	
11.4.1. Cracks	
11.4.2. Longitudinal cracks	265
11.4.3. Transverse cracks	265
11.4.4. Breakout of a part of the hard alloy die blank	266



11.4.5. Destruction of outlet cone	267
11.4.6. Split of hard alloy insert	267
11.4.7. Full breakout of hard alloy insert	268
11.4.8. Striations	
11.4.9. Wear ring	269
11.4.10. One-sided working-out	
11.4.11. Pitting	271
11.4.12. Brass and scale sticking	272
11.4.13. Micropitting	272
11.4.14. Inadequate processing of the die exit	273
REFERENCES	274
References to Chapters 1–3	274
References to Chapters 4–5	276
References to Chapters 6–7	
References to Chapters 8–9	284
References to Chapters 10–11	