FORGING DESIGN HANDBOOK

Sponsored by the United States Air Force

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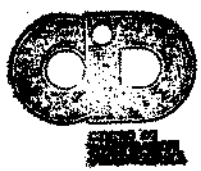

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Introduction vii

Trends in materials development. Importance of fracture mechanics in design. Importance of inspectability. Definitions. Synopsis of chapters.

Chapter 1. Material Selection 1

Material requirements. High-strength steel: melting; fatigue strength; toughness; stability; corrosion. Titanium alloys: airframe structural forgings; directionality of properties; fatigue strength; fracture toughness; beta forging; jet engine forgings; stability and corrosion. Aluminum alloys. Heat-resisting alloys.

Chapter 2. Material Control 15

Operation of material control: critical forgings; identification; routine production; combined specifications. Specifications for quality assurance: test plans; wrought structure and ductility; ductility and the amount of forging reduction; grain flow; grain size and microconstituents; fatigue strength; fatigue testing of full-size components; fracture toughness; room-temperature laboratory fatigue and fracture-toughness testing; stress corrosion; end-grain exposure; residual stress; protection against aggressive environments; hydrogen-stress cracking. Nondestructive inspection. Material control in manufacturing production: forging stock; forge processing; machine processing. Designer's check list for material control.

Chapter 3. Design Problems Involving Parting Line and Grain Flow 27

Grain flow and anisotropy. Parting line, forging plane, and flash. Parting line and seamless (flashless) cylindrical forgings: high-strength aluminum alloy cylindrical vessels; high-strength steel cylindrical vessels; stress corrosion in cylindrical vessels. Parting line, straight vs broken. Parting line and draft. Parting line and direction of grain and of loading. Parting line and forging process: flat forging vs extrusion vs cored forging; hammer vs press vs upsetter forging; ring gears. Designer's check list for placement of parting line. Examples 1 through 12.

Chapter 4. Design Problems Involving Draft 53

Types of draft: outside draft; inside draft; blend (or match) draft; natural (or design) draft; shift draft; back draft; no-draft; "bottom draft". Measurement of draft angle: vertical ram; horizontal ram. Amount of draft (degrees). Amount of draft (inches). Economical use of draft: design for minimum draft; design for draft with mechanical ejection; design for inherent draft; design for natural draft of round sections; design for shift draft; design for tilting the die impression; design for no-draft. Designer's check list for draft. Examples 13 through 21.

Chapter 5. Design Problems Involving Ribs and Bosses 71

Types of ribs and bosses; function, properties and producibility; design of ribs for strength and rigidity; design of ribs for fastening; design of ribs for special functions; design of combinations of ribs and bosses. Metal flow in the forging of ribs: forged vs extruded ribs; material properties vs forging process vs grain flow; dies for forging ribs; prevention of rib defects. Measurement of ribs and bosses. Design parameters for ribs and bosses: design vs parting line and grain flow; design vs placement of ribs; rib length and profile; sectional design and producibility; rib height, width, height-to-width ratio. Rib design data from actual forgings: design of ribs for producibility; design for producing $h:w$ = 15.5:1 in aluminum alloy; design for producing $h:w$ = 23:1 in aluminum alloy; design for producing $h:w$ = 6:1 in alloy A-286; design for producing an obliquely forged rib ($h:w$ = 17:1) in aluminum alloy; design for producing a rib preblocked as a web; design for producing a rib with improved parting-line location; design for producing ribs with close-tolerance contour and spacing. Designer's check list for ribs. Examples 22 through 28.

ners and fillets in metal flow: fillets for prevention of laps; corners and fillets for no-draft forging vs machined fillets. Design parameters derived from actual forgings: correlation of corner radius (R_c) and rib height (h); ratio of fillet and corner radii (R_f:R_c); correlation of fillet radii (R_f) and rib height (h); R_c and R_f vs forging alloy composition; R_c and R_f vs forging process; R_c and R_f vs net-forged or machined forgings; R_c and R_f vs draft; sizes suggested by users and producers. Designer's check list for corners and fillets. Examples 29 through 36.

Chapter 7. Design Problems Involving Webs 111

Unconfined and confined webs; functions of webs; functional web designs. Metal flow in the forging of webs: role of web thickness; avoiding web defects; reducing residual stress (stress relieving); producing thin webs; relieving web forging pressures. Suggested limits, and data from actual forgings, relating to minimum and actual thicknesses of webs: limits suggested by users and producers; correlation with width of web, W; correlation with W:h ratio; correlation with plan area; web-thickness data on actual forgings. Design of webs for producibility: design for producing flat webs, contoured webs, oblique webs; design for use of tilting; design for use of punchout, bead and taper; design for use of flat-back machining. Designer's check list for webs. Examples 37 through 45.

Chapter 8. Design Problems Involving Cavities and Holes 131

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Chapter 9. Design Problems Involving Flash and Trim 155

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Chapter 10. Dimensions and Tolerances 165

Dimensioning with tooling points and datum planes. Application of tolerances: finish allowances for machining (and for decarburization); draft allowance; length and width tolerances; die-wear tolerance; match tolerances; die-closure or thickness tolerances; straightness and flatness tolerances; radii tolerances; flash-extension tolerances; coining tolerances. Designer's check list for dimensions and tolerances.

Chapter 11. Processes and Equipment 170

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Chapter 12. Designing for Over-All Economy 177

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