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BOMBARDIER
Toronto Site
PROPRIETARY INFORMATION

PPS 35.09

PRODUCTION PROCESS STANDARD

REQUIREMENTS FOR TITANIUM ALLOY FORGINGS

Issue 4
- This standard supersedes PPS 35.09, Issue 3.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- Direct PPS related questions to christie.chung@aero.bombardier.com or (416) 375-7641.
- This PPS is effective as of the distribution date.

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Issue 4 - Summary of Changes (over the previous issue)

The following summaries are not detailed and are intended only to assist in alerting PPS users to changes which may affect them; refer to the applicable sections of this PPS for detailed procedure and requirements.

- Specified that this PPS is categorized as a controlled critical process according to PPS 13.39.
- Specified that all testing and evaluation specified herein must only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.
- Modified PCD requirements to be in-line with aluminum forging requirements.
- Specified production testing requirements within Table I as QAR cards are no longer applicable.
- Specified that first article forgings must be inspected for all the dimensions specified by the engineering drawing (i.e., 100% dimensional inspection) with all measurement results recorded and maintained on file. All production parts produced after the first article forging must be checked (e.g., using a suitable checking fixture) to ensure compliance with the engineering drawing limits.
- Specified where paragraph 6.2.1 visual defects are observed following FPI, reject part.
- Added requirement to refer to PPS 13.39 for additional personnel requirements.

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1 SCOPE

1.1 This Production Process Standard (PPS) specifies the requirements for titanium alloy die forgings.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS must be followed to ensure compliance with all applicable specifications. In general, if this PPS conflicts with the engineering drawing, follow the engineering drawing. The requirements specified in this PPS are necessary to fulfil the engineering design and reliability objectives.

1.1.2 Refer to PPS 13.26 for the subcontractor provisions applicable to this PPS.

1.1.3 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. do not supersede the procedure or requirements specified in this PPS.

2 HAZARDOUS MATERIALS

2.1 Before receipt at Bombardier Toronto, all materials must be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier Toronto Environment, Health and Safety Department.

3 REFERENCES

3.1 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.2 PPS 1.35 - Machining of Titanium Alloys.

3.3 PPS 13.26 - General Subcontractor Provisions.

3.4 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.5 PPS 15.01 - Part Marking.

3.6 PPS 20.03 - Fluorescent Penetrant Inspection.

3.7 PPS 30.14 - Heat Treatment of Titanium and Titanium Alloys.

3.8 PPS 31.09 - Cleaning of Titanium and Titanium Alloys.

3.9 LAB 011 - Test Piece - Standard Round, *Bombardier Toronto Laboratory Drawing*.

4 MATERIALS, EQUIPMENT AND FACILITIES

4.1 Materials

4.1.1 Titanium alloy as specified by the engineering drawing.

4.2 Equipment

4.2.1 The equipment used for production of titanium alloy forgings must be at the discretion of the forge house. It is the responsibility of the forge house to ensure that their equipment is capable of producing satisfactory forgings which meet the requirements of this PPS, the engineering drawing, and the applicable material specification.

4.3 Facilities

4.3.1 This PPS has been categorized as a Controlled Critical Process according to PPS 13.39 and as such only facilities specifically approved according to PPS 13.39 are authorized to perform titanium alloy die forging according to this PPS.

4.3.2 Bombardier subcontractors must direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier Aerospace facilities must direct requests for approval to the appropriate internal Quality Manager.

4.3.3 Facility approval must be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report must detail the materials and equipment to be used, the process sequence to be followed and the laboratory facilities used to show compliance with the requirements of this PPS. Any deviation from the procedure or requirements of this PPS must be detailed in the facility report. Based upon the facility report, Bombardier Toronto Engineering may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification must be prepared to demonstrate their capability. Once approved, no changes to subcontractor facilities may be made without prior written approval from Bombardier Aerospace Supplier Quality Management.

4.3.3.1 Unless otherwise specified by Bombardier Aerospace Supplier Quality Management, for approval of subcontractor facilities to utilize this PPS, completion of a test program and submission of suitable test samples representative of production parts is required. Test samples must meet the requirements specified in section 6.

4.3.3.2 All testing and evaluation specified herein must only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

5 PROCEDURE

5.1 General

5.1.1 For the purposes of this PPS, the term “MRB” (Material Review Board) must be considered to include Bombardier Toronto MRB and Bombardier Toronto delegated MRB.

5.1.2 For the purposes of this PPS, “LOT” is defined as a batch of parts of the same part number produced in a continuous working period from the same heat of material and heat treated in one furnace load.

5.1.3 For each forging, a Process Control Document (PCD) must be developed and maintained by the forging manufacturer. Once established and approved as specified herein, the PCD must be adhered to.

5.1.3.1 The PCD must define the overall manufacturing process including statistical process control, purchasing and acceptance of raw materials, processing equipment, manufacturing processes, process flow chart, batch/lot acceptance, packaging, shipping and quality control requirements for assuring consistent, uniform and compliant products. All specifications and test procedures employed during the process must also be listed and issue/date controlled on the PCD. All recorded data must be traceable to a batch/lot of material. The PCD must have a unique number relating to this specification and carry an issue/revision status. The PCD must be signed by the manufacturer, Bombardier Engineering and Bombardier Quality and must not be changed without prior written approval. The PCD and all production data must be available to any Bombardier Aerospace auditors when requested.

5.2 Forging

5.2.1 The procedure for the manufacture of forgings is at the discretion of the forge house. It is the responsibility of the forge house to ensure that their practices are capable of producing satisfactory forgings which meet the requirements of this PPS, the engineering drawing, and the applicable material specification. Record the optimum technique, once established, on a PCD. The process must be re-qualified if there is any technical changes (e.g., processing parameter, material, etc.) made to the Bombardier approved PCD. If unclear whether the change in question is technical in nature, contact Bombardier prior to implementing such change on production parts.

5.3 Heat Treatment

5.3.1 Unless otherwise specified by the engineering drawing, heat treatment of forgings must be carried out according to PPS 30.14. The applicable PCD must include heat treatment details. The Bombardier approved PCD must be adhered to.

5.3.2 All forgings must be heat treated to the condition shown in the final heat treatment column on the forging drawing.

6 REQUIREMENTS

6.1 Inspection Schedule

6.1.1 Except where otherwise specified by the engineering drawing, Inspect forgings according to the requirements of Table I.

TABLE I - INSPECTION SCHEDULE

INSPECTION	APPLICABLE SECTIONS	QUALIFICATION TESTING (Note 1)	PRODUCTION TESTING
Visual	section 6.2	Yes	100%
Dimensional	section 6.3	Yes	100%
Fluorescent Penetrant	section 6.4	Yes	100%
Ultrasonic	section 6.5	Not applicable	100%
Grain Flow	section 6.6	Yes	Not applicable
Mechanical Properties	section 6.7.1	Yes	Not applicable
	section 6.7.2	Not applicable	Two forged test coupons (Note 3) to be supplied with each lot of forgings when specified on the engineering drawing or purchase order or when the forgings are heat treated by a facility other than the supplier.
Hydrogen Content	section 6.8	Yes	One forging from each LOT
Metallographic Examination	section 6.9	Yes	One forging from each LOT

Note 1. Special inspection schedule requirements specified by the engineering drawing, if any, take precedence over the inspection schedule requirements specified herein.
Note 2. Qualification testing must be carried out for each new die or significantly reworked die. The supplier must submit one die forging sample to Bombardier Toronto for qualification and die approval.
Note 3. Forged test coupons must be of the same heat as the lot of forgings they represent and must be forged and heat treated together with the represented parts.

6.2 Visual Inspection

6.2.1 All Forgings must be of uniform quality and condition; free from blisters, fins, folds, seams, laps, cracks, segregation, spongy areas or other defects.

6.2.2 The surface finish of the forging must be a maximum of 125 RMS. Deep scratches, gouges or tool marks are not acceptable.

6.2.3 Blended flash areas that are not subject to subsequent machining, must be reasonably straight. Undercutting of the forging proper is not acceptable.

6.2.4 Failure of the qualification sample forging to meet the visual requirements must be considered cause for corrective action by the subcontractor (e.g., die rework) and submission of another forging for qualification re-test.

6.2.5 Consider any production forging which fails to meet the visual inspection requirements as unacceptable and refer to MRB for disposition. If the unacceptable forging is part of a lot, subject each forging in the lot to visual inspection. Accept forgings meeting the requirements and refer all forgings not meeting the requirements to MRB for disposition.

6.3 Dimensional Inspection

6.3.1 Ensure that forgings conform to the dimensional requirements of the engineering drawing. First article forgings must be inspected for all the dimensions specified by the engineering drawing (i.e., 100% dimensional inspection) with all measurement results recorded and maintained on file. All production parts produced after the first article forging must be checked (e.g., using a suitable checking fixture) to ensure compliance with the engineering drawing limits.

6.3.1.1 Failure of the qualification sample forging to meet the dimensional requirements must be considered cause for corrective action by the vendor (e.g, die rework) and submission of another forging for qualification re-test.

6.3.1.2 Consider any production forging which fails to meet the dimensional requirements as unacceptable and refer to MRB for disposition. If the unacceptable forging is part of a lot, subject each forging in the lot to dimensional inspection. Accept forgings meeting the requirements and refer all forgings not meeting the requirements to MRB for disposition.

6.4 Fluorescent Penetrant Inspection

6.4.1 Forgings must be fluorescent penetrant inspected, where required, according to PPS 20.03. Evidence of any defects specified in paragraph 6.2.1 must be cause for rejection.

6.4.1.1 For fluorescent penetrant inspected qualification sample forgings, evidence of defects must be cause for corrective action by the vendor and submission of another forging for qualification re-test.

6.4.1.2 For fluorescent penetrant inspected production forgings, evidence of defects must be cause to refer the forging to MRB for disposition. If the unacceptable forging is part of a lot, subject each forging in the lot to fluorescent penetrant inspection. Accept forgings without defects and refer all forgings with defects to MRB for disposition.

6.5 Ultrasonic Inspection

6.5.1 Forgings which are to be ultrasonically inspected must meet the requirements of the engineering drawing. Consider any production forging which fails to meet the ultrasonic inspection requirements as unacceptable and refer to MRB for disposition. If the unacceptable forging is part of a lot, subject each forging in the lot to ultrasonic inspection. Accept forgings meeting the requirements and refer all forgings not meeting the requirements to MRB for disposition.

6.6 Grain Flow

6.6.1 The qualification forging sample must be sectioned and etched and the grain flow pattern must be examined by a laboratory as specified in paragraph 4.3.3.2. The location of the cross-section must be as specified on the engineering drawing or must be as such to represent the principal sections of the forgings. The grain flow pattern must not show any sharply re-entrant flow lines or any discontinuities in the grain flow, other than at the forging parting line. If the grain flow is found to be satisfactory, retain the sample forging or a photograph as a quality standard.

6.6.2 Failure of the qualification forging sample to meet the grain flow requirements must be considered cause for corrective action by the subcontractor and submission of another forging for qualification re-test.

6.7 Mechanical Properties

6.7.1 Qualification Testing

6.7.1.1 Perform qualification testing using two LAB 011 tensile test specimens. If possible, prepare the test specimens from the qualification forging sectioned for grain flow determination according to section 6.6. If it is impractical to prepare the tensile specimens from the sectioned forging, use an additional forging for preparation of the test specimens.

- Test specimens must conform to the dimensions specified on Bombardier Toronto Laboratory Drawing LAB 011, selecting the largest specimen possible.
- Unless otherwise specified, test specimens must be taken with the axis transverse to the forging flow lines from the areas designated by Stress Engineering.
- If the forging drawing shows cross-hatches areas, with minimum mechanical properties referenced to the cross-hatched areas, the tensile test specimen must be cut from each of these areas.

6.7.1.2 Mechanical properties of the test specimens must meet the minimum mechanical properties stated on the engineering drawing. If the engineering drawing does not specify the mechanical properties required, the mechanical properties of the test specimens must meet the minimum mechanical properties specified in Table II.

6.7.1.3 Failure of the qualification sample forging to meet the mechanical properties must be considered cause for corrective action by the vendor and submission of another forging for qualification re-test.

6.7.2 Production Testing

6.7.2.1 One of the forged test coupons specified in Table I must be machined to dimensions of the largest possible LAB 011 test specimen. Mechanical properties of the machined test coupon must meet the minimum mechanical properties stated on the engineering drawing. If the engineering drawing does not specify the mechanical properties required, the mechanical properties of the test specimens must meet the minimum mechanical properties specified in Table II. When the forgings are to undergo further heat treatment, heat treat the test coupons from the remaining forgings of the lot. When the forgings are not to undergo further heat treatment, suitably identify the test coupons and retain.

6.7.2.1.1 Failure of a test coupon to meet the mechanical property requirements must be cause for the rejection of the represented lot of forgings. If a lot of forgings which has been rejected is to be re-heat treated, the test coupons for the other forgings in the lot must be re-heat treated with the forgings and one of these test coupons must be re-submitted for mechanical property testing. Failure of the second test coupon must be cause for the lot to be referred to MRB for disposition.

TABLE II - MECHANICAL PROPERTIES (Note 1)

ALLOY	SECTION AS HEAT TREATED		MINIMUM TENSILE STRENGTH	MINIMUM YIELD STRENGTH 0.2% OFFSET	MINIMUM ELONGATION IN 4D	MINIMUM REDUCTION IN AREA
	THICKNESS	WIDTH				
ANNEALED OR SOLUTION TREATED						
Ti-6Al-4V	≤ 3,000"	≤ 3,000"	130,000 psi	120,000 psi	10%	20% (T) 25% (L)
SOLUTION TREATED AND AGED						
Ti-6Al-4V	≤ 0.500"	0.501" - 8.000"	160,000 psi	150,000 psi	10%	15%
	0.501" - 1.000"	1.001" - 4.000"	155,000 psi	145,000 psi	10%	15%
		4.001" - 8.000"	150,000 psi	140,000 psi	10%	15%
	1.001" - 1.500"	1.501" - 4.000"	150,000 psi	140,000 psi	10%	15%
		4.001" - 8.000"	145,000 psi	135,000 psi	10%	15%
	1.501" - 2.000"	2.001" - 4.000"	145,000 psi	135,000 psi	10%	15%
		4.001" - 8.000"	140,000 psi	130,000 psi	10%	15%
	2.001" - 3.000"	3.001" - 8.000"	135,000 psi	125,000 psi	8%	15%
	3.001" - 4.000"	4.001" - 8.000"	130,000 psi	120,000 psi	6%	15%

Note1. Any specific requirements specified by the engineering drawing regarding mechanical properties take precedence over the requirements specified in this table.

6.8 Hydrogen Content

6.8.1 A sample for hydrogen content determination must be removed from a suitable area of the forging. The sample must be approximately a 1/4" cube, cut off using a hand hacksaw. The maximum acceptable hydrogen content is 150 ppm.

6.8.1.1 Failure of the qualification sample forging to meet the hydrogen content requirements must be considered cause for corrective action by the vendor and submission of another forging for qualification re-test.

6.8.1.2 Failure of a production forging to meet the hydrogen content requirement must be cause for the scrapping of the represented lot.

6.9 Metallographic Examination

6.9.1 Remove (cut) a sample for metallographic examination from a suitable area of the forging using a hand hacksaw. Examine the microstructure of the sample for the correct heat treatment condition and the absence of alpha case.

6.9.1.1 Failure of the qualification sample forging to meet the metallographic examination requirements must be considered cause for corrective action by the vendor and submission of another forging for qualification re-test.

6.9.1.2 Failure of a production forging to meet the metallographic examination requirements must be cause for the represented lot to be referred to MRB for disposition.

7 SAFETY PRECAUTIONS

7.1 Safety precautions applicable to the materials and procedures specified herein must be defined by the subcontractor performing the work for Bombardier Toronto.

8 PERSONNEL REQUIREMENTS

8.1 This PPS has been categorized as a Controlled Critical Process according to PPS 13.39. Refer to PPS 13.39 for personnel requirements.

9 SPECIAL POINTS TO NOTE

9.1 Take care to prevent titanium from coming in contact with chlorinated hydro-carbons. When cleaning is required, the procedures specified in PPS 31.09 must be followed.

9.2 Samples for hydrogen content and metallographic examination must be cut from the forging using a hand hacksaw.

9.3 Carry out machining of test samples according to PPS 1.35.

9.4 Reports (i.e., including micro-section and metallographic reports) must be furnished by the supplier with each shipment of forgings, certifying physical properties, microstructure and chemical composition for each lot, together with other pertinent data as required by the P/O and the applicable engineering drawings.

9.5 Except as noted in paragraph 9.6, the use of temporary or permanent marking or layout materials is strictly prohibited except where all traces of these materials would be removed by subsequent machining or trimming to size.

9.6 Each forging, bag of forgings, or bundle of forgings, depending on size, must be part marked according to PPS 15.01.