MERITOR
2135 West Maple Road
Troy, MI 48084-7121

Process Specification

Specification: 1-1
Revision Date: 01/10/2014
Revision Level: C

FORGING

1.0 GENERAL SPECIFICATION:

All the requirements for the general specifications apply unless superseded by the requirements within this specification.

2.0 SCOPE:

This specification covers the general hot forging process requirements.

3.0 PROCESS REQUIREMENTS:

3.1 Material Certifications:

The forging supplier shall be responsible for verification that the steel mill certifications meet the requirements of Meritor B-1 and any other appropriate Material Specification that may apply. If information supplied is not conforming or complete then an approved deviation is required prior to forging production components.

3.2 Steel Bar Quality:

The forging supplier shall visually inspect each bar (either at receiving inspection and/or on shearing or cutting) and assure that it is free from bar defects that might affect part quality. The individual Material Specification and/or Material Specification B-1 lists the acceptance criteria.

3.3 Heat Lot Control:

Heat lot control and identity must be maintained. Mixing of heat lots prior to forging is not permitted. When heat codes are required either by Meritor or the control plan of the supplier they shall follow Meritor specifications. The heat code can be used only for the specific heat lot of steel. Heat lot control is required for all parts that will be normalized, annealed, quench and tempered, carburized or induction hardened.

3.4 Multiple Forging Billet Control:

The forging supplier will control the process of making the multiple (mults) forging billets (either through cutting or shearing) to assure that the edge conditions do not produce laps or forging discontinuities. The size and weight of mults must be controlled for consistent grain flow and fill of the forging shape. For hot precision forgings each mult

must be weighed. Weights must be within the controlled range documented within the control plan.

3.5 Heating Practices:

Heating practices must minimize decarburization, grain growth, and surface oxidation. Grain boundary oxidation, incipient melting / burning of the grains is not permitted.

Mult temperatures must be continuously monitored upon exiting the furnace/induction heater. Suitable controls must be in place to guarantee that over-heated billets are scrapped. Under heated billets and billets which had reached the forging temperature range but not forged may be re-processed. Furnace heated billets can be reheated once; induction heated billets can be re-heated up to two times after initial heating, provided the initial heating process did not exceed the approved billet / mults heating temperature. All re-heated billets shall cool to ambient temperature prior to re-heating. Records of billet / mult re-heating are to be maintained, for each heat lot, at the supplier. It is recommended to mechanically descale the billets / mults prior to re-heating.

Total decarburization (Free Ferrite, Type 1 per SAE J419-1983) shall be avoided and the decarburized layer shall not adversely affect the subsequent heat treatment (hardness and microstructure, etc.) or final product performance.

The control plan must address heating time, heat input, re-heating/rework process interruptions and reaction plan to handle product in the heating system.

3.6 Forging Temperature:

The minimum forging temperature must be above the recrystallization temperature for the specific chemical composition specified and must be adequately held to ensure that any micro-alloy constituents are put into solution before being cooled from the forging temperature. This temperature will vary depending upon the chemical composition and the type of heating equipment utilized. For induction heating the “aim” for surface to core temperature variation is less than 80°F, the maximum variation is not to exceed 100°F, unless the process is intentionally designed using non-isothermal forging conditions. This temperature variation limit applies to the condition just before forging. Non-isothermal conditions require prior approval of Meritor Materials Engineering – Troy and such approval must be obtained prior to tools being made.

The maximum billet temperature is limited to 2300°F for steel parts. This is to be considered the over temperature high limit, thus actual nominal forging temperature must be below 2300°F. All billets that exceed the upper billet heating temperature of 2300°F are scrap and cannot be re-heated.

A forging process utilizing temperatures and ranges other than those listed above may be acceptable provided that the forging supplier provides all data and process controls to demonstrate the heating and forging processes will not cause overheating or burning as defined within this specification. The billet temperature shall not exceed 2350°F. All billets that exceed the upper billet heating temperature of 2350°F are scrap and cannot be re-heated. This allowance is material grade and part specific; the temperatures and process controls are to be reviewed and approved by Meritor Materials Engineering.

3.7 Forging Die Control:

Forging dies should be designed using computer aided design codes that permit simulation of the forging process. When possible, these should be submitted as part of the technical review for consideration.

Forging dies shall be numbered and re-sink/major reworks shall be monitored to confirm that no significant change in any dimension has occurred. Should a major change occur in any dimension, a new PPAP with grain flow must be submitted to Meritor for review.

3.8 Press Setup:

3.8.1 Forging:

Forging tonnage, process time and load rates shall be documented. Significant changes in die design, tonnage, type of equipment, placement of mult, will require a new PPAP submission.

3.8.2 Trim:

Trim press tonnage shall be documented. Trim and flash allowances shall be within the tolerances of the dimensions of the part unless otherwise noted on the print.

3.9 Cooling:

Cooling rates should be sufficiently uniform to assure consistent microstructures throughout.

3.10 Controlled Cooling:

Parts requiring controlled cooling must have a detailed controlled cooling control plan that reflects the requirements of CQI-9 for the appropriate microstructural development.

3.11 Defects:

Defects that adversely affect product performance (i.e., folds, laps, non-fill, cold shuts, splits, internal ruptures) are not permitted. Die mismatch and flash should be minimized.

Forgings shall be clean and free of flash, excess lube, rust, scale and any other conditions that detrimentally affect the handling, machining, heat treatment or performance of the product.

Excessive handling marks are not permitted, and subject for rejection. Light surface dings and marks may be permitted providing that they don't affect the form, functionality and performance of the part and the surface indications are within the dimensional tolerances.

Adequate inspection procedures shall be employed to detect non-conforming product. First piece inspection of products from the production process must be thoroughly examined.

Any changes to the tooling and/or the process will require a new PPAP sample submission.

4.0 METALLURGICAL REQUIREMENTS:

4.1 Grain Flow:

Macro etching the components to evaluate the grain flow shall be done in accordance to ASTM E381-01 (2012). The grain flow throughout the product must be continuous and uninterrupted. Grain flow shall not have abrupt changes in direction that could constitute potential laps and / or folds. A consistent grain flow must be maintained around high stress areas, fillets and radii. End grains are not permitted in these areas. The grain flow must be approved by Meritor Materials Engineering – Troy. Any changes to the tooling and/or the process will require a new PPAP sample

submission. The general forging layout chart 5-36658 shall provide an example of grain flow for specific applications.

4.2 Surface Discontinuities:

Fluorescent Magnetic Particle Inspection (FMPI), Fluorescent Liquid Penetrant Inspection (FPI), or other non-destructive test inspection methods shall be utilized to demonstrate that the forging process is stable and is not prone to laps, folds, splits, wrinkles, and/or cracks.

Visual inspection should also be utilized to demonstrate that the forging process is not prone to performance impeding imperfections such as surface handling, die marks, gouges, dents, scrapes and tears.

4.3 Grain Size:

Grain size shall be determined in accordance with ASTM E112-12 (2012).

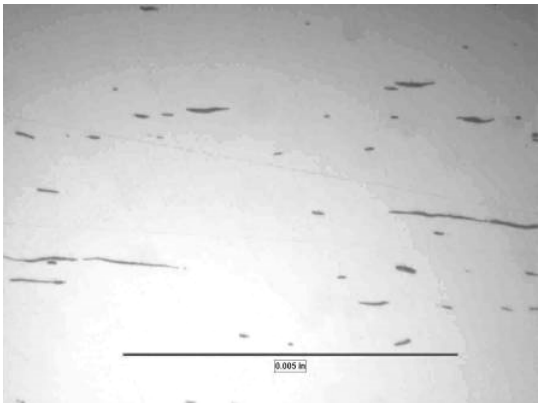
Finished forged parts shall exhibit an as forged grain size of ASTM 3 and finer, unless otherwise approved by Meritor Materials Engineering – Troy.

Forgings that require control cooling shall exhibit an as forged grain size of ASTM 3 and finer, unless otherwise approved by Meritor Materials Engineering – Troy.

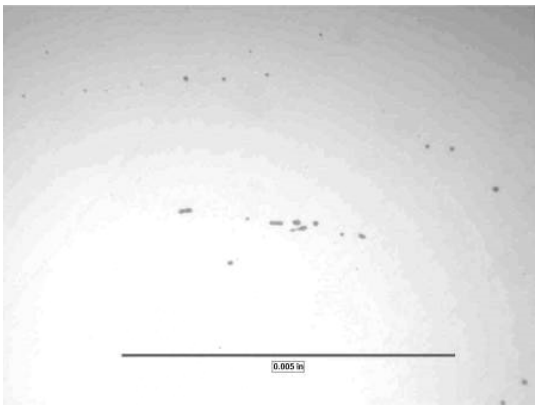
The above grain size requirement does not apply for forgings utilizing SAE 11XX series and SAE 12XX series grades of material, provided the requirements of Section 4.4 Incipient Melting are compliant. The maximum grain size is to be communicated and approved during the Technical Review and on the supplier’s control plan.

4.4 Incipient Melting:

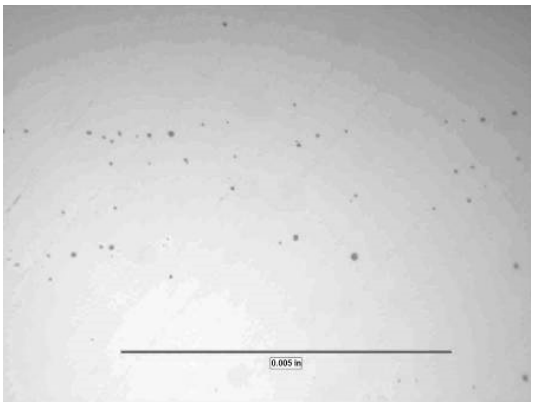
Incipient Melting / burning of the grains, on the forged components, is not permitted. The manganese sulfide inclusion stringers shall not exhibit any indication of grain boundary triple point (junction of multiple grains), which would indicate localized melting of the steel matrix. Inclusion ratings of 0 through 2 (balling) are acceptable. Ratings of 3 (triple points) through 5 (grain boundary liquation) are un-acceptable. The photographs below illustrate the rating criteria.



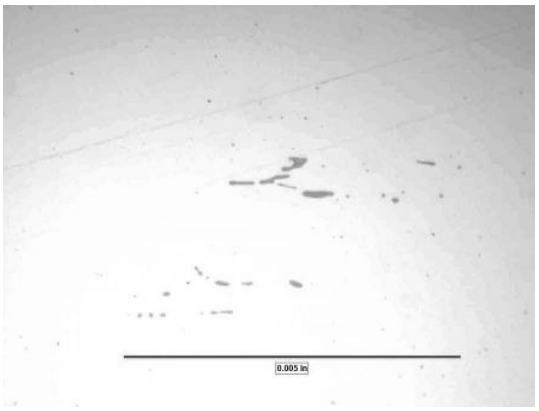
Rating 0 - no change to inclusions



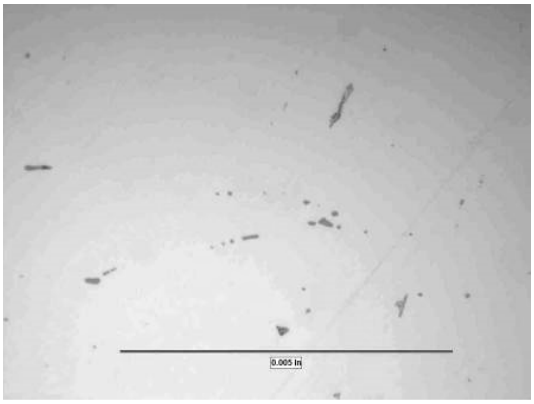
Rating 1 - necking of inclusions



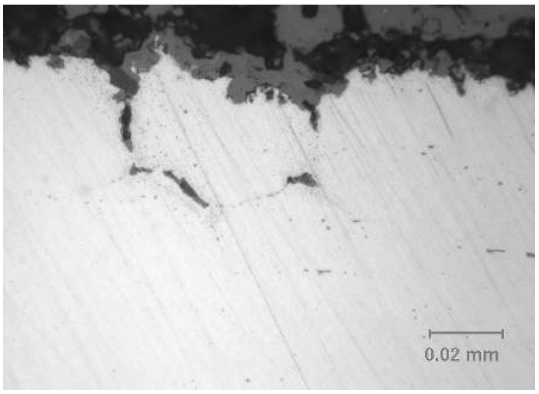
Rating 2 - balling of inclusions



Rating 3 - inclusions observed at grain boundary triple points



Rating 4 - inclusions observed intermittent around grain boundaries



Rating 5 - inclusions connected around grain boundaries

5.0 PROCESS CAPABILITY:

In accordance with the general specifications listed above, suppliers are responsible for demonstrating process capability on the following:

Billet Heating Temperatures
Grain Boundary/Inclusion Analysis
Decarburization
Grain Size
Grain Flow
Heat Treat capabilities (As required)

6.0 METALLURGICAL PPAP SUBMISSION REQUIREMENTS:

6.1 For all PPAP's, Internal (Meritor manufacturing plants) and External (supplier), the following is required:

i) Metallurgically complete PFMEA's.
ii) Metallurgically complete control plans.
iii) Completed capability studies on the metallurgical requirements listed within Section 5.0 and the print specifications (ie PS-1 – destructive study {families of components may exist and this needs to be worked out on a case by case basis – Typically done in a Pre-Award}).

6.2 Metallurgical PPAP sample submissions, Materials Engineering requires:

1 – piece as forged.
1 – piece after thermal processing, if thermal processing is required.
1 – materials testing and inspection results to the specifications listed on the print, including grain flow analysis, grain size, and microstructure (Section 5.0).

7.0 REFERENCE SPECIFICATIONS:

Industry Affiliation	Standard Number and revision Date	Title of Standard
Meritor	B-1	General Wrought Steel Standard
Meritor	1	Control of Heat Treating Processes, Furnaces, and Auxiliary Equipment
Meritor	5-36658	Forging Grain Flow Chart
ASTM	E112-12 (2012)	Standard Test Methods for Determining Average Grain Size
ASTM	E381-01 (2012)	Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
SAE	J419 (1983)	Methods of Measuring Decarburization
AIAG	CQI-9 (2011)	Special Process: Heat Treatment System Assessment

Date	Change
01/10/2014 Level C Request 30932-32	1) Removed line about control plan approval prior to purchasing of controlled cooling equipment in Section 3.10 Controlled Cooling. 2) Added grain size exemption for SAE 11XX and SAE 12XX grades in Section 4.3 Grain Size. 3) Tabularized Section 7.0 Reference Specifications. 4) Added "..temperatures to be continuously monitored.." to Section 3.5 Heating Practices.
05/03/2013 Level B Request 30272-164	Clarified billet re-heating requirements in section 3.5. Added details on billet heating in section 3.6, Added section 3.6.1. Clarified handling damage in section 3.11. Clarified visual inspection in section 4.2. Clarified inclusion / incipient melting ratings and added photographs to section 4.4. Added revision levels to the reference specifications in section 7.0.
06/03/2011 Level A Request 30272-134	Issued

Approved By: S. Doyle Jr.
Director – Materials Engineering