International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 9, pp 266-271, September-2024

https://doi.org/10.47001/IRJIET/2024.809031

# The Manufacturing Processes of Airbus A320 Landing Gear Bhushings Using Reverse Engineering Methods

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*Abstract* - **The aviation sector is currently enjoying fast growth, as seen by the manufacture of 8,650 Airbus A320 aircraft. One critical component is the landing gear bushing (P/N 201160616), which provides safety and performance during takeoff and landing. PT. GMF AeroAsiaTbk is having difficulty obtaining these bushings due to low stock, configuration changes, and delivery delays. To address this, PT. GMF AeroAsiaTbk, through PMA Holder GMF Aero Asia, intends to produce bushings independently under the Parts Manufacturing Approval procedure outlined in CASR Part 21 Sub-Part K, with DGCA monitoring. Reverse engineering approaches are utilized to overcome technical information restrictions, allowing high-quality bushings to be produced. The research goals are to collect dimensional and material data, develop optimal production methods, and understand the electroplating process on bushings. The reverse engineering procedure entails taking measurements with a vernier calliper and a Coordinate Measuring Machine (CMM) as well as reviewing the Component Maintenance Manual. Preparation, fabrication, inspection, packing, and marking are all part of the production process. Bright cadmium electroplating is used to prevent corrosion and enhance appearance. The findings are expected to improve production efficiency, decrease downtime, and ensure the availability of dependable spare parts.**

***Keywords:*** Bushings, landing gear, Airbus A320, reverse engineering, electroplating.

## I. INTRODUCTION

In terms of aircraft maintenance, especially on performance components such as landing gear bushings, companies must ensure the availability of high-quality spare parts to maintain aircraft reliability and safety [1]. Therefore, PT. GMF AeroAsiaTbk, as a leading provider of aircraft maintenance, repair, and overhaul services, has a great responsibility to ensure the availability of spare parts, especially in this critical component landing gear bushings for operators both nationally and internationally during the replacement of spare parts.

However, in the field, the company is often faced with obstacles stemming from the availability of parts, differences in configuration, and shipping delays [12]. These conditions encouraged PT. GMF AeroAsia to use the Parts Manufacturing Approval method under the supervision of the Deputy General of Civil Aviation (DGCA) and guided by CASR 21 Sub-Part K to be able to independently produce spare parts, in this case, Airbus A320 landing gear bushings, by Reverse Engineering under the responsibility of GMF PMA Holder [9].

The reverse engineering method is used to provide solutions to the main challenges faced, namely the availability of technical information provided by landing gear bushing manufacturing companies [5]. With the use of this method, it is expected to produce products of the same quality or even better, increase production efficiency, reduce downtime, and ensure the availability of reliable spare parts and following standards [8].

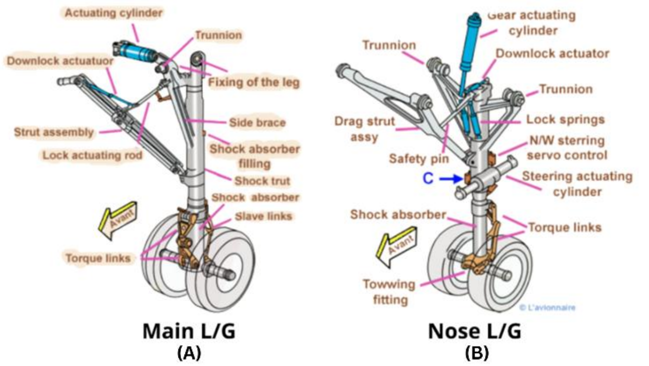


**Figure 1 : Airbus A320 Landing Gear**

The landing gear of the Airbus A320 aircraft in Figure 1 is a system consisting of wheels, tires, brake systems, struts (support pillars), and other devices that support the aircraft

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during the takeoff, landing, and taxiing phases of the runway. The landing gear system has an important role in ensuring the safety, comfort, and performance of the aircraft during flight operations. Every shaft connection and hole in the aircraft landing gear system has bearings that are used as a damper from shock during take-off and landing conditions, protecting shafts and holes from deformation due to wear and also ensuring the connection between holes and straight and concentric shafts [1]. These components are called bushings, as shown in Figure 2.

**Figure 2: Landing Gear Bushings Airbus A320**

Bushing components have various types, divided based on the basic material used and the type of geometry owned by the bushing itself [12]. Various types of bushings based on the base material include metal bushings commonly used in heavy loading [6], plastic bushings that have light loads and corrosion resistance [10], and composite bushings, which have the characteristics of wear resistance and low friction [3]. Various types of bushings based on geometric shapes include self-lubricating bushings that have special geometry and coating to create a slippery surface and minimal lubrication [11], cylindrical bushing, which is the simplest form of the bushing in the form of a shell [2], and flanged bushing, which has a collar at one end to minimize movement and support, thus increasing retention and stability [2].

The bushings on the landing gear of the Airbus A320 family aircraft with a configuration of one nose landing gear and two main landing gear have a total of 110 bushings, with a division of 56 bushings on the Main Landing Gear (MLG) and 54 bushings on the Nose Landing Gear (NLG). The dominant bushing type is the metal self-lubricating flanged bushing.

The research was conducted at PT GMF AeroAsiaTbk, especially at GMF PMA Holder, which focused on the process of making landing gear bushing prototypes on Airbus A320 aircraft, in this case on landing gear bushings located on the Airbus A/C main landing gear set using reverse engineering methods. The reverse engineering object used was the landing gear bushing of the existing A320 aircraft.

## II. METHODOLOGY

Technical specification data collection was available by the manufacturer, and bushing observations were carried out on the WS-01 Landing Gear Shop unit. The data was then processed and tidied up to prepare for the next process, namely direct measurement with the Mitutoyo Absolute Digimatic Vernier Calliper and verified using the Romer Absolute Arm RA7 coordinate measuring machine in inch units with an accuracy of 0,003 inches. The data obtained and verified will be compared with those available in the aircraft maintenance module and related literature studies. Then, the dimension data that has been received is converted into 3D modelling using Solidworks2023 software, and technical drawings are made. The basic material used based on information from the literature is AMS 4640 Nickel-Aluminum Bronze. The bushing manufacturing process goes through several machining stages, namely cutting, milling, turning, and CNC machining. The finishing stage is carried out by electroplating bright cadmium coating.

AMS 4640 material is an alloy that has high strength with mechanical characteristics above the average of brass nickel-aluminium alloys on the market; it is obtained from a special manufacturing process carried out. The physical and mechanical properties of AMS 4640 can be seen in Table 1.

**Table 1: The Physical and Mechanical Properties of AMS 4640**

| Mechanical and Physical Properties | Unit | Nominal Values | | |
|---|---|---|---|---|
| Dia. | mm | Ø ≤ 25.4 | Ø ≤ 25.4- 50.8 | Ø ≤ 25.4 |
| Tensile Strenght | MPa | 814 | 793 | 772 |
| Yield Strenght | MPa | 517 | 448 | 420 |
| Elongation | % | 18 | 18 | 20 |
| Brinell Hardness | HBW | 228 | 217 | 212 |
| Rockwell Hardness | HRB | 98 | 96 | 96 |
| Reduction of Area | % | 15 | 20 | 20 |
| Compressive Strenght | MPa | 1034 | 1000 | 965 |
| Shear Strenght | MPa | 483 | 476 | 448 |
| Modulus Elastisitas | GPa | 117 | 117 | 117 |
| Charpy | J | 11.3 | 11.3 | 11.3 |

 

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| | | | | |
|---|---|---|---|---|
| Izod | J | 13.6 | 13.6 | 13.6 |
| Fatigue ($10^9$ Cyc) | MPa | 262 | 255 | 255 |
| Densitas | g/cm | | 7.53 | |
| Koef. Ekspansi | $10^{-6}$/K | | 16.2 | |
| Kond. Elektrik | m/Ω.mm$^2$ | | 5 | |
| Panas Spesiifik | J/g.K | | 0.45 | |
| Kond. Termal | W/m.K | | 46 | |

The nominal composition of the alloy AMS 4640(Aluminum-Nickel Bronze) in Table 2 is as follows:

**Table 2: Nominal Elements Compositions Value AMS 4640**

| Elements | | Compositions (%) |
|---|---|---|
| Aluminum | (Al) | 10 % |
| Iron | (Fe) | 2.5 % |
| Nickel | (Ni) | 5.0 % |
| Manganese | (Mn) | 1.0 % |
| Copper | (Cu) | Balance |
| Other | | Max 0.5 % |

The machining tools and measuring instruments used during the landing gear bushing prototyping process can be seen in Table 3.

**Table 3: Tool Used in Manufacturing Process**

| Tool Name | Type | Manufacturer | Function |
|---|---|---|---|
| Bandsaw Machine | H-550 EII | AMADA | Cutting |
| Lathe Machine | SC-200 | PINACHO | Turning |
| CNC Turning Machine | L 250 | TATUNG OKUMA | Turning, Finishing |
| Milling Machine | F-3 | ACIERA | Milling |
| Alkaline Clean Tank | - | PTI | Electroplating |
| Bright Cadmium Tank | - | PTI | Electroplating |
| Brightening Tank | - | PTI | Electroplating |
| Vernier Caliper | Absolute Digimatic | Mitutoyo | Measuring |
| Coordinate Measuring Machine | RA7 | Hexagon | Measuring |
| Gauge Thickness | PosiTector 6000 | DeFelsko | Measuring |

## III. RESULTS AND DISCUSSIONS

### 3.1 Comparison of Measurement Results

In the reverse engineering process, the measurement stage goes through three processes, namely measurement with a vernier calliper and measurement verification with a coordinate measuring machine, and then the two measurement results are compared to aircraft maintenance modules and related literature. The comparison data can be seen in Table 4.

**Table 4: Comparison of Bushing Measurement Result**

| No. | Parameter | Value (mm) | | |
|---|---|---|---|---|
| | | Vernier Caliper | Coordinate Measuring Machine | Component Maintenance Manual |
| 1. | Inner Diameter | 31.86 | 31.91 | 31.82–31.86 |
| 2. | Outer Diameter | 35.94 | 35.99 | 35.94–35.97 |
| 3. | Flange Diameter | 41.98 | 42.01 | - |
| 4. | Length | 24.96 | 2.51 | - |
| 5. | Flange Thickness | 2.46 | 25.43 | - |
| 6. | Chamfer | 45° x 0.78 | 45° x 0.73 | - |
| 7. | Radius | 0.52 | 0.56 | - |
| 8. | Groove | | | |
| | - Groove Widht | 3.88 | 4.36 | - |
| | - Groove depth | 0.38 | 0.39 | - |

### 3.2 3D Modeling and Engineering Drawing

The modelling process is carried out using Solidworks 2020 software, with detailed modelling results can be seen in Figure 3.

*International Research Journal of Innovations in Engineering and Technology (IRJIET)*

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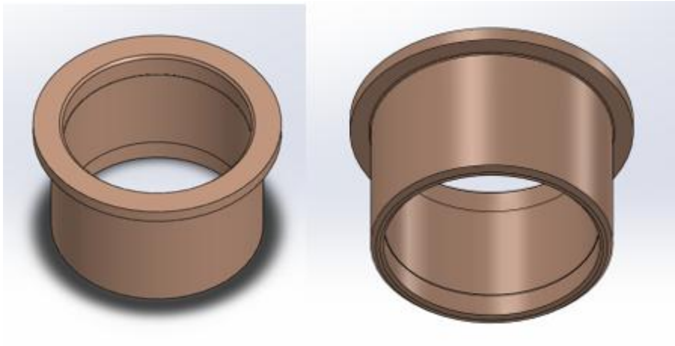

**Figure 3: 3D Modeling of *Landing Gear Bushings***

A simple technical drawing of a bushing 3D model can be seen in Figure 4.

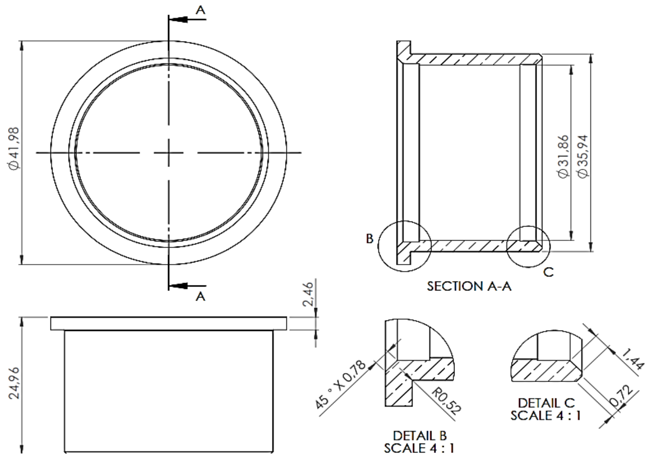


**Figure 4: Engineering Drawing *Bushing Landing Gear***

### 3.3 Landing Gear Bushing Manufacturing Process

The production stage of the Airbus A320 landing gear bushing is divided into two main stages, the bushing production preparation stage which includes material preparation to the readiness of production documents, and the production stage, which includes machining, coating, and inspection processes.

The preparation step carried out in the bushing manufacturing process is to read the process sheet and pay attention to SOPs and K3. In the preparation stage, the initial material that is still in the form of a billet rod with a diameter of 2 inches will be inspected and marked according to the required length, which is 1.5 inches.

The fabrication stages carried out in making bushings include cutting AMS 4640 billet rods according to the needs of the length with a band saw machine, turning the workpiece according to the production drawings using a CNC turning machine, finishing processes on post-production bushing products, cadmium bright coating by the method of electroplating, and the last is the stage of inspection of finished products and packaging.

### 3.4 Machining Process Parameters

The machining parameters used in the machining process are shown in Table 5.

**Table 5: Machining Parameters**

| No | Parameter | Value |
|---|---|---|
| A | Bandsaw Machine | |
| | Feedrate | 7 $^{mm}/_{min}$ |
| | Cutting Speed | 20 $^{m}/_{min}$ |
| B | CNC Turning Machine | |
| | Spindle Speed | 225 rpm |
| | Cutting Speed | 16.25 mm/m |
| | Feed Rate | 31.5 mm/min |
| | Depth of Cut | 3 mm |
| | Material Removal Rate | 1535.6 $mm^3/m$ |
| C | Milling Machine | |
| | Spindle Speed | 375 rpm |
| | Cutting Speed | 34.15 m/min |
| | Feed Rate | 52.5 mm/min |
| | Depth of Cut | 0.5 mm |
| | Material Removal Rate | 896.43 $mm^3/m$ |
| D | Lathe Machine | |
| | Spindle Speed | 375 rpm |
| | Cutting Speed | 24.72 mm/m |
| | Feed Rate | 52.5 mm/m |
| | Depth of Cut | 1 mm |
| | Material Removal Rate | 1297.8 $mm^3/m$ |
| E | Electroplating | |
| | Water Temp. | $\leq 38^{o}C$ |
| | Cathodic Current | 2,1–2,6 $A/dm^3$ |

### 3.5 Cadmium Bright Electroplating Results

The electroplating process is carried out in-house at TCW's workshop, specifically involving the application of Cadmium Bright plating. The process begins with the preparation of the workpiece, which is tied to a stand and then immersed in an alkaline clean tank for 10 minutes. Next, the workpiece is immersed in the Cadmium Bright tank for 2 minutes while swinging up and down. In the cadmium plating process, a chemical reaction occurs that is characterized by the formation of foam on the bushing and a change in colour from orange copper to silvery white, which indicates the success of the process. The coating thickness is verified using gauge thickness with a minimum value of 0.58 microns. A comparison can be seen in Figure 5 between gilded and unplated bushings. The purpose of this process is to create a corrosion-resistant coating and smooth surface on the bushing, making it easier to install.

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**Figure 5: Bushing Differences after the Electroplating Process**

### 3.6 Bushing Product Comparison

After going through all the processes from observation to finishing, it takes 9 working hours to produce the final product of PMA Bushings. This product is then compared with *bushings* made by overseas manufacturers to be able to evaluate their disadvantages and advantages. The evaluation results are shown in Table 6.

**Table 6: Final Product Evaluation**

| Comparison Parameter | Bushing made by PMA GMF AeroAsia | Bushing made by another country |
|---|---|---|
| Product Dimension | The dimensions are appropriate but still need further adjustment. | The dimensions are appropriate and in the existing tolerance number. |
| Materials | The material used is AMS 4640 standard bushing material. | The materials used are kept secret but comply with Airbus standards. |
| Visual | The appearance of the bushing becomes white due to the cadmium coating. | The appearance of the bushing is bright yellow, like brass metal. |
| Surface Roughness | Surface roughness has not been tested. | It is not stated, and testing has not been carried out. |
| Cost | Estimated efficiency of 40%. | Fluctuating due to unbalanced supply and demand. |

It can also be seen the comparison of measurements between the main dimensions in the production drawing with the products of *landing gear bushings* in Table 7.

**Table 7: Comparison of Measurements between the Main Dimensions in the Production Drawing**

| No | Parameter | Value (mm) | | Difference (Result - Main) (mm) |
|---|---|---|---|---|
| | | Production Result | Main Dimension | |
| 1. | Inner Diameter | 31.82 | 31.86 | + 0.04 |
| 2. | Outer Diameter | 36.00 | 35.94 | + 0.06 |
| 3. | Flange Diameter | 42.08 | 41.98 | + 0.10 |
| 4. | Length | 25.42 | 24.96 | + 0.46 |
| 5. | Flange Thickness | 2.62 | 2.46 | + 0.16 |
| 6. | Chamfer | $45^o$ x 0.94 | $45^o$ x 0.78 | + 0.16 |
| 7. | Radius | 0.68 | 0.52 | +0.16 |
| 8. | Groove | | | |
| | - Groove Width | 3.98 | 3.88 | + 0.10 |
| | - Groove Depth | 0.54 | 0.38 | + 0.16 |

## IV. CONCLUSION

The bushing *reverse engineering stage* is carried out by measuring with a vernier calliper tool and diversification with a Coordinate Measuring Machine tool and aircraft maintenance module. 3D Modeling and Engineering Drawing using Solidworks 2020. The process of making landing gear bushings through Part Manufacturing Approval Holding PT. GMF AeroAsiaTbk with the Reverse Engineering method includes five stages: preparation, fabrication, inspection, electroplating, and packing and marking. Corrosion prevention of bushing parts is carried out by bright cadmium plating type, which also improves surface aesthetics. The electroplating process includes preparation, use of an alkaline clean solution, rinsing, dyeing, and checking with gauge thickness.

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**Citation of this Article:**

Norman Iskandar, Muhammad Ferdiansyah, M. Amirullah Akbar, & Sulardjaka. (2024). The Manufacturing Processes of Airbus A320 Landing Gear Bhushings Using Reverse Engineering Methods. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 8(9), 266-271. Article DOI https://doi.org/10.47001/IRJIET/2024.809031

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