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Application of DFMA in lock band service modification of ATB-I3 building machine

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Abstract: The locking mechanism on the band service, known as the lock band service, is used to move materials to the tire-making machine. A building machine is a device that assembles components into partially finished or green tires. The components are tread, which acts as the tire tread, band/ply, which are fabric sheets coated in rubber, and bead wire. Subsequently, the materials are put together on the drum-mounted construction machine. The ATB-I3 machine has the largest downtime owing to a band service fault, with 840 minutes in January 2024, and is the problem with the highest downtime in section A2. The cause of the excessive downtime in the band service is an issue with the band service lock system, namely the pneumatic movement lock mechanism on the band service component. As a result, adjustments must be made by altering the lock band service's design. After that, a weld joint strength analysis is performed to make sure the modification can be safely put into practice. To obtain the optimal modification design, the DFMA method is employed. With the use of the DFMA approach, the updated design—which had a design efficiency value of 4.23% to 4.31% before—was improved. The welding connection in the updated design is safe to use since, according to the results of the welding connection calculation, the lock band service holder has a maximum welding load of 294,645.08 N whereas the actual welding load is 147,928 N. The reduction in service band downtime was tested with this improvement. Following the implementation of the update in March 2024, the amount of downtime resulting from damage to the band service dropped by 445 minutes, or 52.97%, to 395 minutes.

Keywords: Modification; building machine; DFMA; pneumatic

1. INTRODUCTION

One of the machines used in the tire production process is the construction machine. The end product is known as a Green Tire (GT), which indicates that the tire is not yet done and needs to go through a curing procedure to become a tire [1]. The locking mechanism on the band service, known as the lock band service, transfers material on the building tire machine. Bead wire, band/ply, a rubber-coated fabric sheet, and tread—which function as the tire tread—are the parts. After that, the material is put together on the drum-shaped construction machine. Band service is used in the process of moving the band material to the drum. The most frequent cause of downtime is band service issues, with the ATB-I3 machine seeing the most downtime as a result of these issues. Downtime is the amount of time wasted when a machine is being repaired, preventing it from being used[2]. Band servicing issues caused 840 minutes of downtime for the ATB-I3 machine in January 2024. The cause of the high band service downtime is pneumatic issues with the lock band service system, namely the movement locking system on the band service component. The lock band service cylinder holding bolt is broken, and the lock band service cylinder is damaged from direct contact with the lock hole and is unable to sustain the force of the lock band. These machine factors are the cause of the lock band service issue.

The effectiveness of machine changes to minimize downtime caused by damage to the pud body ply station on the building machine has been the subject of previous studies. By switching from using bushings as roll conveyor bearings to using bearings, the roll conveyor design employed in this study was able to successfully reduce pud body ply damage. Nevertheless, the study did not examine the strength of the joints in the modified components; instead, it focused solely on the reduction in downtime following modification. Ascertaining the maximum tensile strength value of the connection when receiving loads until the connection breaks requires computing the strength of welded joints in modifications [3][4].

To get the optimal design, it is required to modify the pneumatic lock band service system's design using the DFMA approach in light of these issues. The goal of the update is to improve system performance. Additionally, to make sure the design is safe to apply to the machine, the strength of the welded joints in the design is analyzed.

2. METHOD

To get the best outcomes from adjustments, it's critical to create a plan before beginning. By altering the locking design, the author of this modification conceptualizes the construction of a pneumatic lock band service modification. When using the prior design, the pneumatic cylinder would lock straight into a vertical position, which would harm the cylinder itself. The pneumatic cylinder is positioned horizontally to create the redesigned design. To prevent the pneumatic cylinder from coming into direct contact, a locking plate is added and pushed by the cylinder with the use of a linear guideway. Then, to get effective design outcomes, apply the DFMA method to the design [5]. The ATB-I3 device was used for this study, which ran from January to March of 2024. Some steps must be completed throughout the research process for this study to be conducted. As seen in Figure 1, these steps can be shown in a flow chart.

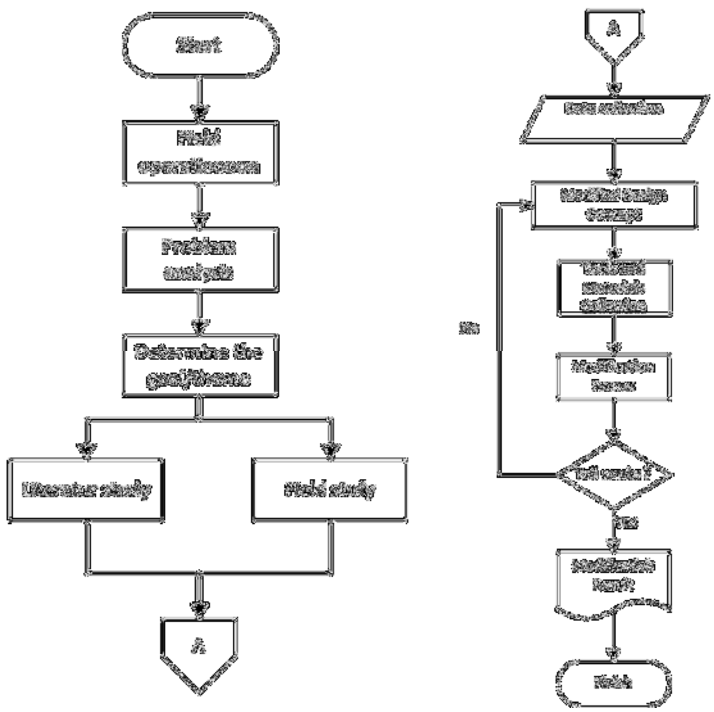

Figure 1. Modification flow diagram.

The research's flow chart, shown in Figure 1 begins with field observations to identify the circumstances and issues that are present there. Subsequently, the investigator examines the current issues to ascertain the origin of the problem. Researchers to ascertain the goals that need to be met. To develop a modified design that can be used to solve issues, information from literature reviews and field investigations is gathered. The best efficient design is then determined by analyzing the redesigned design idea using the DFMA approach, and its safety is ensured through weld joint strength analysis [6][7]. Subsequently, the machine might be equipped with an altered design. The researcher extracts the modification outcomes from the problem formulation, which is addressed by data processing and testing before machine application.

Data collection stages

The data collection stages carried out in this modification are as follows:

Direct research

To gather the supporting information required for the final project, field investigations are conducted as part of direct research to ascertain the actual conditions in the tire manufacturing production process. There are various methods for gathering data, including:

a) Primary Data: Through interviews and firsthand inspections of the tire manufacturing process, information on lock band service damage can be obtained, as well as the mechanism by which the damage may arise.
b) Secondary Data: Not being physically present in the field, this data collection involves examining corporate records, namely the band service outage data that engineering has input.

Literature study

To obtain some references from several articles, journals, and theses from research that has been done and is unquestionably relevant to the theme to be addressed, a literature study is conducted at this stage of data collecting.

Machine working system

The machine continues to function in the same manner as it did before the modification process being carried out. The lock cylinder's design has changed. Instead of using the piston axle to lock the lock band service vertically as it did previously, the horizontal cylinder position design pushes the lock plate to lock the lock band service. To improve the precision of the locking, the author incorporates a linear guideway as the base for the locking plate, which is driven by a pneumatic cylinder. To effectively detect the position of the pneumatic cylinder without making physical or mechanical touch, the red switch sensor is replaced with an inductive proximity sensor and a trigger plate [8].

3. RESULTS AND DISCUSSION

Design before modification

Before making changes to the device, researchers observed the lock band service design. Subsequently, as Figure 2 illustrates, a 3D drawing was created to facilitate the analysis of the prior design. This is an image of the lock band service's parts before alteration.

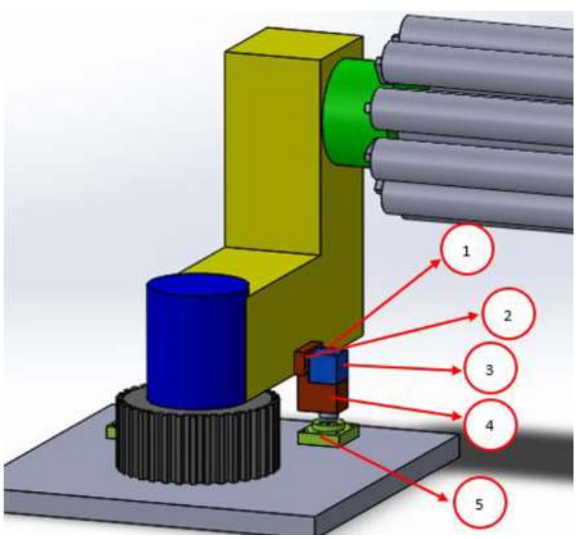

Figure 2. Design before modification.

Modification design before DFMA

By altering the pneumatic cylinder's locking mechanism, the lock band service modification's design [9]. To provide more stable locking, the prior mechanism that locked vertically was modified to lock horizontally with the aid of a locking plate and linear guideway. Without physical or mechanical

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touch, the proximity sensor is utilized to detect if the locking plate is locking [10]. An overview of the lock band service modification design, as seen in Figure 3 is provided below.

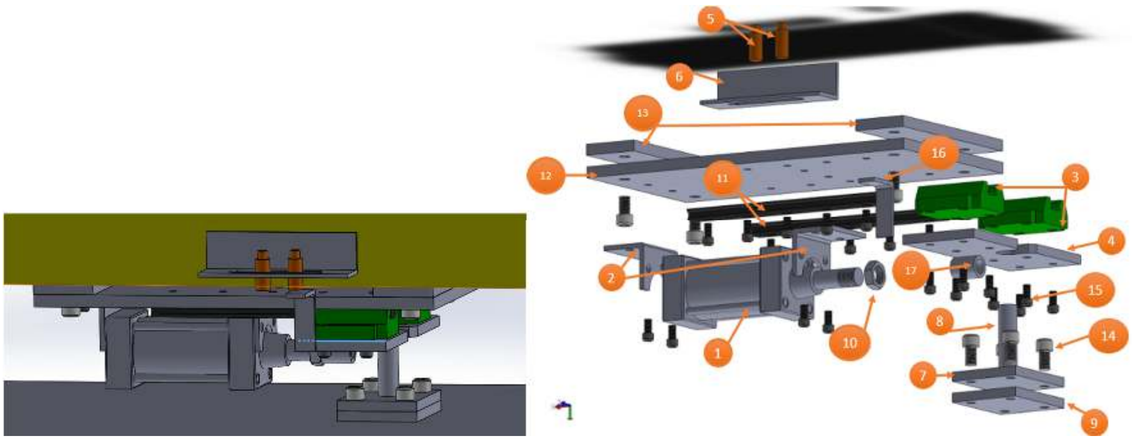

Figure 3. Modified design concept before DFMA.

Description:

1. Pneumatic cylinder
2. Pneumatic cylinder holder
3. Linear guideway
4. Locking plate
5. Proximity sensor
6. Proximity mount
7. Locking pin plate
8. Locking pin ass
9. The base of washer pin plate
10. M20 nut
11. Linear guideway rail
12. Base plate
13. Seat base plate
14. Bolts M10 x 20
15. Bolts M8 x 15
16. Plate trigger proximity
17. Ass thread locking plate

Analysis of the modification design concept

The DFMA approach is a technique used to assess product designs that consider how simple the manufacturing and assembly processes will be [11]. To find the value of the design efficiency index, the modification design process requires the completion of the DFA Design for Assembly (DFA) study [12]. DFA seeks to simplify products to make them easier to assemble and require less time to complete [13]. The orientation and movement of components (handling) and the attaching of one component to another or a group of other components (insertion and fastening) are often the two key aspects that affect the manual assembly process [14]. The time needed to assemble a product will be determined by the two parameters mentioned above.

A matrix table was created by compiling the values of various combinations of the aforementioned requirements, which were obtained through experimentation [15]. The total time needed for assembly can then be estimated after estimating the values of all components using manual handling and manual insertion matrices. This allows for the calculation of the design efficiency index value, as shown in Table 1 below.

Table 1. Manual assembly handling analysis modified design.

Item Name	Number of Item	Manual Handling Code	Handling Time per Item' s	Manual Insertion Code	Insertion Time per item' s	Total Operation time' s	Min Part' s	Description
1. Pneumatic cylinder	1	00	1,13	06	5,5	6,63	1	*Add and screw fasten*
2. Pneumatic cylinder holder	2	20	1,8	06	5,5	14,6	1	*Add and screw fasten*
3. Linear guideway	2	00	1,13	06	5,5	13,26	1	*Add and screw fasten*
4. Locking plate	1	90	2	06	5,5	7,5	1	*Add and Screw fasten*
5. Proximity sensor	2	00	1,13	06	5,5	13,26	1	*Add and screw fasten*
6. Proximity mount	1	20	1,8	06	5,5	7,3	0	*Add and welding*
7. Locking pin plate	1	00	1,13	06	5,5	6,63	0	*Add and welding*
8. Locking pin ass	1	10	1,5	06	5,5	7	1	*Add and welding*
9. The base of washer pin plate	1	00	1,13	06	5,5	6,63	0	*Add and welding*
10. M20 nut	1	00	1,13	38	6	7,13	1	*Add and screw fasten*
11. Linear guideway rail	2	20	1,8	06	5,5	14,6	1	*Add and screw fasten*
12. Base plate	1	95	4	06	5,5	9,5	1	*Add and screw fasten*
13. Seat base plate	2	00	1,13	96	12	26,26	0	*Add and Welding*
14. Bolts M10 x 20	10	1	1,43	38	6	74,3	1	*Add and screw fasten*
15. Bolts M8 x 15	22	1	1,43	38	6	163,46	1	*Add and screw fasten*
16. Plate trigger proximity	1	30	1,95	96	12	13,95	0	*Add and Welding*
17. Ass threading locking plate	1	00	1,13	96	12	13,13	0	*Add and Welding*
Total	**52**					**405,14**	**11**	

Theoretically, using equation (1), the efficiency of the lock band service alteration design assembly can be determined as follows:

$$E_{ma} = \frac{N_{min} . t_a}{t_{ma}} \quad (1)$$

Description:
E_{ma} = Index of design efficiency
N_{min} = Theoretical minimum number of components
T_a = Fastest time to assemble a component (ideal = 3 seconds)

The following are the findings of the application of DFA analysis to the computation of the improved lock band service design's assembly efficiency using equation (1):

$$E_{ma} = \frac{11.52.3}{405,14} \tag{1}$$

$$E_{ma} = \frac{1716}{405,14}$$

$$E_{ma} = 4,23\ \%$$

3.1. Modified Design Improvements

With the design efficiency of the lock band service modification calculated from Table 1, component design changes may be identified with the DFMA approach to improve manufacturing and assembly efficiency. Component removal, combining, and reduction are possible ways to improve DFA. The component improvements are shown in Table 2. Figure 4. shows the design outcomes upon improvement. While Table 3 displays the findings of the analysis of manual assembly handling.

Table 2. Lock band service modification design improvements.

No Part	Nama Part	Figure	Improvement Plan
6	Proximity mount		Combined with base plate
13	Seat base plate		Combined with base plate
16	Plate Trigger Proximity		Combined with locking plate
4	Locking plate		Combined with plate trigger proximity
9	Base of washer pin plate		Combine with locking pin plate
7	Locking pin plate		Combine with a base of washer pin plate

Redesigning the design is possible after evaluating enhancements to the lock band service modification design and taking Table 2 into consideration. As seen in Figure 4 this design innovation combines several components while reducing the total number of components.

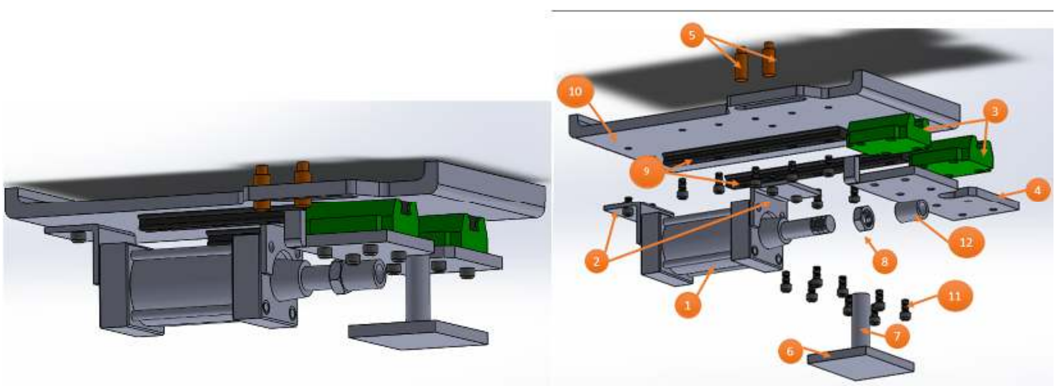

Figure 4. Modified design after repair.

Table 3. Analysis of manual assembly handling modified design after improvement.

Item Name	Number of Item	Manual Handling Code	Handling Time per Item' s	Manual Insertion Code	Insertion Time per item' s	Total Operation time' s	Min Part' s	Description
1. Pneumatic cylinder	1	00	1,13	06	5,5	6,63	1	*Add and screw fasten*
2. Pneumatic cylinder holder	2	20	1,8	06	5,5	14,6	1	*Add and screw fasten*
3. Linear guideway	2	00	1,13	06	5,5	13,26	1	*add down and screw Fasten*
4. Locking plate	1	90	2	06	5,5	7,5	1	*Add and Screw Fasten*
5. Proximity sensor	2	00	1,13	06	5,5	13,26	1	*Add and screw fasten*
6. Locking pin plate	1	00	1,13	06	5,5	6,63	1	*Add and Welding*
7. Locking pin ass	1	10	1,5	06	5,5	7	1	*Add and Fasten Screw*
8. Nut M20	1	00	1,13	38	6	7,13	1	*Add and screw fasten*
9. Linear guideway rail	2	20	1,8	06	5,5	14,6	1	*Add and screw fasten*
10.Base plate	1	95	4	96	12	16	1	*Add and welding*
11.Bolts M8 x 15	22	01	1,43	38	6	163,46	1	*Add and screw fasten*
12.Ass threading locking plate	1	00	1,13	96	12	13,13	0	*Add and screw fasten*
Total	**37**					**283,2**	**11**	

The calculation of assembly efficiency of the lock band service modification design can theoretically be calculated using equation (1) as follows:

$$E_{ma} = \frac{11.37.3}{283{,}2} \quad (1)$$

$$E_{ma} = \frac{1221}{283{,}2}$$

$$E_{ma} = 4{,}31\ \%$$

Calculation of the strength of welded joints on mounting plates with machine bases

The technique of combining multiple metal or non-metal components is called welding. It is done by melting a portion of the base metal and filler metal, either under pressure or not, and either way, it creates a continuous connection [16].

Calculation of allowable tensile stress

Utilizing an RB-26 E-6013 electrode with a tensile stress of 60 Ksi, or 427.47 N/mm2, the mounting plate connection is welded. Thus, the division of σt by the factor of safety (FOS) yields the permitted tensile stress (σ_(allowable)) in welded joints. The factor of safety (FOS) for steel material under a fixed load is 4. Thus, it can be computed as follows using equation (2):

$$\sigma_{ijin} = \frac{\sigma_t}{FS} \tag{2}$$

$$\sigma_{\text{ijin}} = \frac{427{,}47\ \text{N/mm}^2}{4} = 106{,}86\ \text{N/mm}^2$$

Strength of welded joint of a mounting plate with machine base

To calculate the maximum load for double filet welding, you can use equation (3) as follows:

$$\text{P} = 2 \times 0{,}707 \times \text{s} \times 1 \times \sigma_{\text{ijin}} \tag{3}$$

$$\text{P} = 2 \times 0{,}707 \times 6\ \text{mm} \times 205\ \text{mm} \times 106{,}86\ \text{N/mm}^2$$

$$\text{P} = 294.645{,}08\ \text{N}$$

Description:

P = Maximum load on welding
s = Welding width
1 = Welding length
σ_{ijin} = Allowable tensile stress

The changed components' total load of 147,928 N is received in this welded connection, and the maximum welding load is 294,645.08 N. Thus, it may be concluded that the welded joint is secure because of the maximum P > P component.

Analysis of modification results

With 52 components overall, the design efficiency value before to improvement was 4.23% after the redesigned design was analyzed using the DFMA approach. Then, with a total of 37 components, the design was improved to the point where the design efficiency value rose to 4.31%. The lock band service mounting plate's welded joint strength is calculated, and it receives a welding load of 147.928 N, with a maximum welding load of 294,645.08 N. Because the maximum P is greater than the component's P, the welded joint is deemed safe for usage. To reduce the ATB-I3 engine's downtime, modification testing was performed in February 2024 by applying a changed design to the engine, as seen in Figure 5.

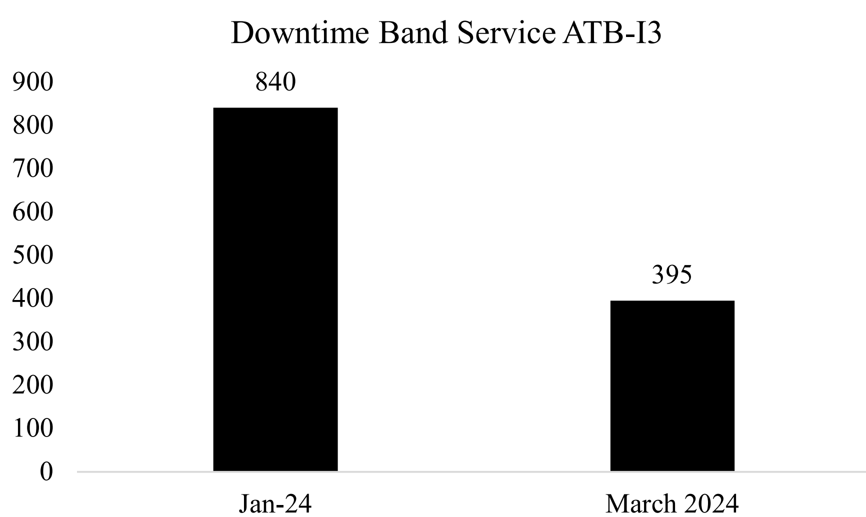

Figure 5. Downtime band service data on ATB-I3 engine problems after modification.

Figure 5 illustrates that in January 2024, there ware 840 minutes of downtime before the change, and in March 2024, there ware 395 minutes following the modification. Thus, upon adjustment, the ATB-I3 engine's downtime problem service band dropped by 47%. This lock band service system modification has been successful in lowering the amount of machine downtime.

4. CONCLUSION

The research concludes that the lock band service modification design, which consists of 52 components, has a design efficiency value of 4.23% before DFMA repairs are performed. It was possible to reduce the number of components to 37 and raise design efficiency to 4.31% after DFMA upgrades. Aside from that, the maximum load P > P component led to the analytical calculations' findings regarding the strength of the welded junction between the mounting plate and the machine base being deemed safe. The total load of the changed components it supports is 147,928 N, while the maximum load that the welded joint can carry is 294,645.08 N. The ATB-I3 machine underwent modifications in February 2024, and by March 2024, the amount of downtime brought on by service band damage had dropped from 840 minutes to 395 minutes.

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