Design and Fabrication of Grooving Fixture for Brake Pads Production Line

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Abstract. In manufacturing industries, the quality of the parts produced and the customer satisfaction is very important. The confirmation to the specifications demanded by the customers and delivering the demanded parts in right quantity at right time is very much essential to satisfy the customers so that the customer-manufacturer relationship can be maintained. This project deals with improving the quality, productivity and reducing lead time for manufacturing of brake pads. Of all the other problems faced by a brake pad manufacturing company, the bottleneck region where the production flow is affected was found to be in the finishing line. The reason for this bottleneck was observed to be the increased setting time in grooving machine. The increase in setting time is due to different setting procedures followed by the operators to obtain an important parameter called thickness under groove in the brake pads. A time study was done and the feasible solution was identified to be a combined fixture which can accommodate variety of parts and also meet the specification of the different parts. Therefore, a combined fixture was designed for high volume parts and the testing was done. As a result, the setting time was reduced to a greater extent and also the productivity was improved with better quality.

Keywords: Productivity, Lead time, Brake pad, Fixture design, Grooving, Time study.

1. Introduction

Rane Brake Linings (RBL) limited, a brake lining manufacturer currently has a huge list of products on offer and will also be able to engineer, test and develop new friction products as per the customer demand. The current product types that are being produced are

1. Commercial Vehicle Brake Lining
2. Passenger Vehicle Brake Lining
3. Passenger Vehicle Disc Pads
4. Clutch facings
5. Railway brakes

Each of the above product families has their own number of products of different sizes, shapes and grade of materials. All of the above products could be manufactured to supply the Original Equipment Manufacturers or as Replacement parts. The Disc and pad module (DPM) has a major part in the RBLs output and is the module in the factory with a greater number of processes. RBL produces disc pads for passenger vehicles like cars, commercial vehicles like trucks and busses and for special purpose applications as required.

ICAMDMS 2024, February 23-24, Coimbatore, India
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DOI 10.4108/eai.23-2-2024.2346954

1.1 Functions Of Brake Pads

Brake pads are a component of disc brakes used in automobiles and other applications. These are the most important component in a braking system. Generally, there are two brake pads contained in a brake caliper. The main function of these brake pads is to stop the vehicle by converting kinetic energy to thermal energy through friction. When the brakes are applied, the caliper clamps or squeezes the two pads together onto the spinning rotor to slow or stop the vehicle. When a brake pad heats up due to contact with rotor, it transfers small amount of its friction material onto the disc, leaving a dull gray coating on it. The pad and the disc (now having the friction material) stick to each other, providing the friction that stops the vehicle.

To have the required properties that it can withstand the high temperature and have less wear rate, brake pads are generally made by composite materials [1]. In this work, the manufacturing of brake pads is done by powder metallurgical process. Brake pads are composed of steel backing plates with friction material bound to the surface facing the disc brake rotor. The brake pad with the friction material is shown in Fig. 1.

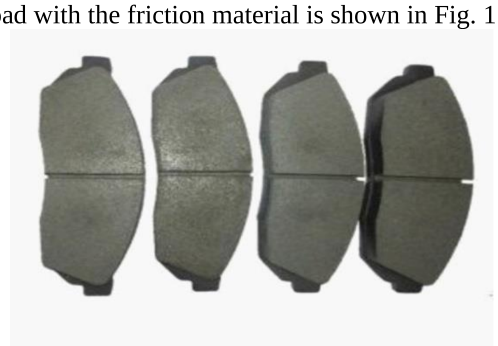

Fig. 1 Brake pads

The major processes that are involved in the production of disc pads are shown in the flow diagram (Fig. 2).

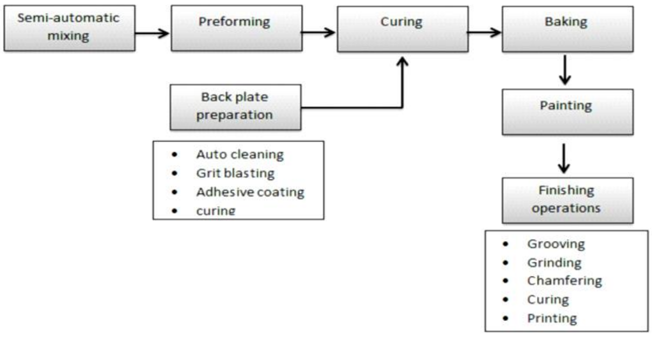

Fig. 2 Process flow diagram of brake pads

1.2. Processing Steps Involved In Finishing Of Brake Pads

- Grooving

The pads that pass the inspection are sent to grooving station. In this process the friction material in the pads are grooved at the specified place (either at the center of the pad or at an offset) as per the requirements. This work mainly deals with the effect of this grooving operation on the quality and productivity of the pads by using an appropriate fixture. The Fig. 3 shows the grooving machine on which the pads are processed [2].

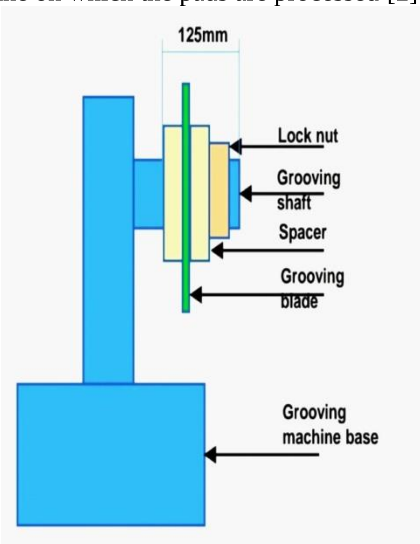

Fig. 3 Grooving machine

- Final Grinding

The grooved pads are then set to a surface grinding machine and the friction surface is ground using industrial diamond coated grinding wheels to the required thickness.

- Chamfering

Some varieties require chamfering on the edges of the pad to the required dimensions. Chamfering is done in place of grooving as both of them are used to dissipate heat. The usage of either chamfer or groove is based on the design given by the customer.

- Heat Searing

This is the process in which some specified pads are kept in an oven at comparatively higher temperatures and for a very short time to further enhance the properties. This process is done only if the customer demands.

- Final Inspection

The finished pads are inspected physically by trained and experienced personnel and the pads with any defects are rejected or the ones with acceptable defects are sent to be reworked [3,4].

- Printing and Packing

The inspected pads are printed with the information about the batch of produce (Date, shift, mix etc). The printed pads are then packed to be dispatched [5,6].

In order to facilitate the above mentioned grooving process, a fixture is used to accelerate the production [7]. The Fig. 4 shows the existing fixture that is used for locating the brake pad for grooving operation.

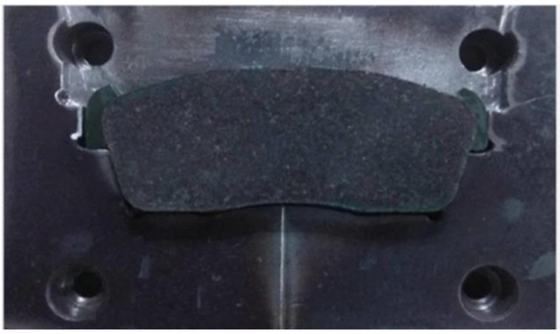

Fig. 4 Existing fixture

The critical part processing of brake pad is the finishing operation where every dimension is specified by the customers has to be ensured. This finishing operation (grooving, grinding and chamfering) is important for the efficiency of the brake pad to function. Braking system in all vehicles must work in good condition to make sure the safety of passengers.

Various literature are reviewed in order to reduce the production time by designing proper fixture for the assembly process. Shailesh et al. [8] has reviewed various methods for clamping and locating various work pieces in a fixture to reduce the cycle time by reducing the loading and unloading times. In the paper, the possible optimal design and methodology to achieve the required productivity and to reduce the setting time is suggested. As a result, the efficiency and reliability of the fixture design has enhanced by the system and the result of fixture design has made more reasonable.

Kumar et al. [9] has designed and analyzed a modular jig to reduce the machining time and cost of winding cone. The optimum design involves four phases namely: research, design, machining and implementation. The design phase was based on the Design for Six Sigma (DFSS) methodology for the fixture. The proposed design was verified and analyzed using VSM and SWO and was able to increase the number of parts per cycle. The results showed that the use of modular fixture has added a benefit of using the one base structure for machining different products.

Bejlegaard et al. [10] proposed a generic architecture design methodology for the design of reconfigurable fixtures. A method developed for reconfigurable manufacturing systems design has been adapted for the design of reconfigurable fixtures. Each step of the methodology reveals a number of relevant tools to support each step. In order to evaluate, the methodology is applied to an industrial case and a 3D model was developed and simulated. The results showed that the fixture can be reconfigured for different product components.

Nithyanandhan et al. [11] proposed various methods and alterations in disk pad module to improve the module productivity. The area study was selected and was evaluated based on work study technique which brings out the processes to be improved. The results and conclusions showed that the bottlenecks which causes the reduced productivity was in the finishing line that tend to consume more time and various suggestions were given to improve the line by modifying the process with low cost.

Hui et al. [12] designed a flexible fixture to reduce the manufacturing cost and improve the production efficiency. In the paper, the design of flexible clamping platform is studied and the application is showed in a case study with control system. When comparing with the simulated results, it was found that the flexible fixture with the follow up support has higher accuracy.

Hatam et al. [13] proposed an algorithm for finite element simulation of wear employing Archard's wear equation. To evaluate the accuracy, experiments were conducted and the results were compared. It is shown that the contact area is more likely to be affected by back plate thickness while the worn mass is more sensitive.

Biswas et al. [14] proposed a model for work study which is highly effective in terms of improving the productivity in a company. This methodology involves time and motion study for all the activities of manufacturing a product. In the paper, the above techniques were employed to manage the inventories and other resources including man to improve productivity. The results concluded that work study could be used to improve productivity by enabling logical layout for facilities and uninterrupted flow of materials which would reduce cost and time.

From the literatures it is understood that, of all the required properties that are needed to produce a brake pad, a parameter called thickness under groove (TUG) is an important parameter. Groove is one which is provided in the brake pads to allow heat that is created during braking action to dissipate easily without interfering with the braking. Also the groove indicates that the pad cannot be used beyond the grooved thickness. According to the customer, there can be one groove or multi groove or no groove. The pads with no grooves will have chamfer on the edges or even both (groove and chamfer). Therefore, it is very much important to maintain the TUG, avoid the groove offset issues and to obtain consistent output at a minimum time. To obtain this parameter, the best way is to provide a fixture that would make the work simple and also meet the standards.

2. Methodology

The Fig. 5 shows the parts of the grooving machine and the dimensions of the components used for placing the brake pad according to the specification. The problem identified is that the operator has to adjust the height of the grooving wheel in order to obtain the specified thickness under groove parameter. Each time adjusting the wheel would not provide the desired value consistently. Initially, the fixture base plate shown in Fig. 5 was used with varying height according to the specification of the various pads. Now, the height of the base plate is fixed to be 30 mm so that it would not be changed every time while the setting is changed. As the base plate height is fixed, the required difference in height is brought in the fixture plate. The dimension of fixture plate is fixed based on the specifications of the brake pads.

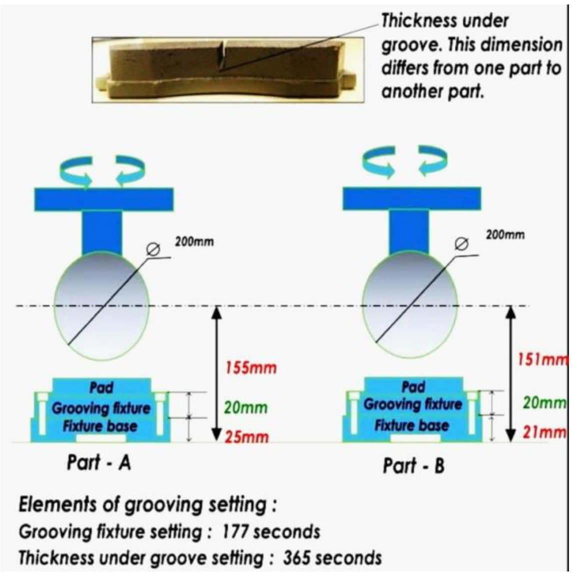

Fig. 5 Element dimensions in grooving machine

Thickness under groove setting contributes 56% of overall setup time and every day 15 settings are done. Also based on the demand from the marketing department, it was known that the number of parts that has to be packed per shift is 7500. Due to various problems in the finishing line, the actual parts being packed by end of the shift is not meeting the demand.

2.1. Feasible Solution

The fixture is a special tool for holding a work piece in proper position during manufacturing operation. Frequent checking, positioning, individual marking and non-uniform quality in manufacturing process are eliminated by fixture which increases the productivity and reduces the operation time.

To locate and immobilize work pieces for machining, inspection, assembly or other operations, fixtures are used. A fixture consists of a set of locators and clamps. The locators are used to determine the position and orientation of a work piece, whereas clamps exert clamping force so that the work piece is pressed firmly against locators. In this work, the clamps are not required as the work piece is unloaded by the force of the grooving wheel itself. The aim of this work is to reduce the setting time involved in fixing the pads. Here, only the operator loads the work piece and once the operation is complete, the piece will be thrown out to the collecting area which is then taken for next operation.

The total number of settings for a month and the setting time per setting data was observed and is shown in Table 1. The elemental time study for setting the current fixture was also done and it was taken for various parts. The Table 2 shows the elemental time for setting which was observed on an average for the variety of parts.

Table 1. Number Of Setting and Setting Time In Grooving Machine

Process	**Number of setting**	**Average no. of setting/shift**	**Setting time/setting**
Grooving	192	6.4	602 sec

Table 2. Elemental Time Study for Grooving Operation

Sl.no	***Operation***	***Activities***	***Timing (Sec)***	***Type***
1	Grooving	Getting grooving parts from plan board	3	NVA
2		Pick up the tools	10	NVA
3		Remove the old fixture from the grooving base fixture	143	NVA
4		Put old fixture in the rack	10	NVA
5		Pick the selected fixture from rack	12	NVA
6		Fix the grooving fixture	140	NVA
7		Adjust the grooving height based on spec	124	VA
8		Getting approval from QA line inspector	160	NVA
Total			602	

In the Table 2, NVA and VA are the non-value adding and value adding operations as in the case of grooving machine. Fig. 6 shows the VA and NVA components in sec.

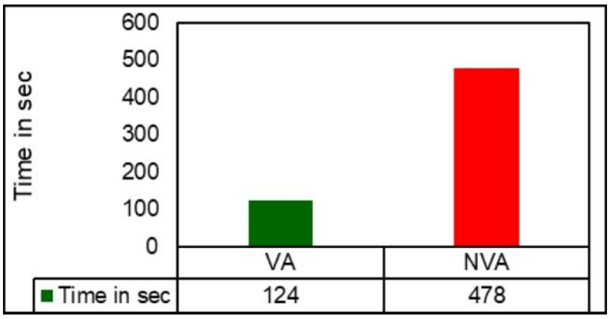

Fig. 6 Value adding and Non-value adding component time

The required specification of the parts for designing the fixture are total pad length and thickness under groove and is shown in Table 3 for the selected high volume parts.

Table 3. Specifications of the Parts

VARIETY	TOTAL PAD LENGTH (in mm)	THICKNESS UNDER GROOVE (in mm)
800 CC	119.2	7.40-7.90
Versa	108.6	6.20-6.40
ALTO	100	7.00-7.30
Wagon R	100	7.00-7.30
Maruthi 800 cc	119.2	7.40-7.90
Maximo	119.4	7.30-7.70
Etios	123.05	6.40-6.80
Tavera	127	6.90-7.20
Bolero (plain & pin)	129.25	9.40-9.80
Brezza	137.1	7.40-7.90
Innova	146.5	7.40-7.80

2.2. Modelling Of Grooving Fixture

Based on the data collected and the constraints of the machine, a fixture has been designed. The fixture shown in Fig. 7 is modeled using Solid Works 2016.This fixture is not provided with the clamping mechanism as the process is designed in such a way that the work piece will be unloaded automatically on the effect of the pneumatic force given for the linear movement of the fixture set up. The profile on the fixture is designed based on the shape and dimensions of the brake pads. The slots in the fixture are provided to accommodate the pins on the back-plate of the pad.

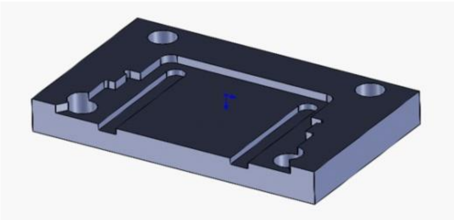

Fig. 7. Newly Modeled fixture

The Fig. 8 is a fixture that can accommodate six part varieties. These parts are grouped based on the volume and their total pad length.

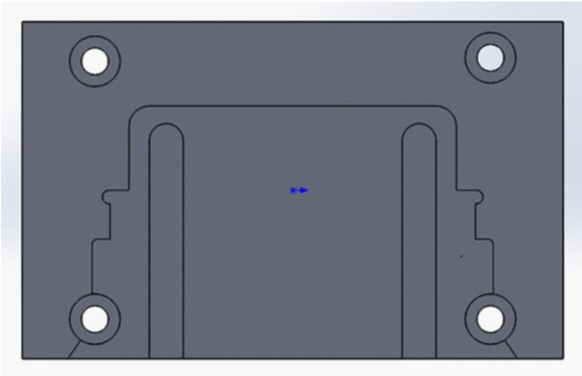

Fig. 8 Fixture designed which can be used for 6 parts

The Fig. 9 shows the assembly of the grooving fixture with the component (brake pad). The fixture is assembled to the base plate with the help of bolts (6 mm) and the base plate is assembled with a sliding bracket. For the linear motion of this base plate with fixture, a main shaft is connected at the center which is driven by a pneumatic source.

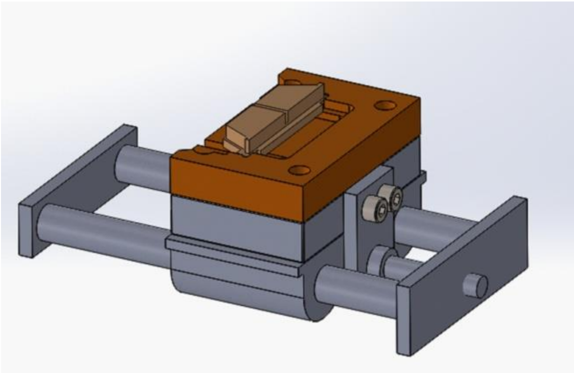

Fig. 9 Assembly of fixture with pad

The components of the fixture assembly are,
1. Brake pad 2.Fixture 3.Base plate 4. Main shaft 5.Sliding Bracket

3. Results and Discussions

3.1. Analysis Of The Fixture Using Ansys

The fixture that has been modeled is analyzed now using ANSYS 18.1. The material of the fixture selected is mild steel. The fixture is subjected to two forces i.e., the tangential force that is getting transferred through the pads from the grooving wheel and the force transferred to the bolts from the pneumatic piston. These two forces are acting in the opposite direction. The following gives the amount of force obtained from the pneumatic arm and the tangential force from the wheel [15].

Force Calculations

Pneumatic Arm Force
Bore = 0.5mm
Pressure = 4 bar = 400000 N/mm²
Force = Pressure x Area
= 400000 x л x 0.025
= **785 N** (80.02 Kg)
Grooving wheel - Tangential Force
Mass = 0.35kg
Radius = 0.1m
Speed,N = 1440 RPM
Angular velocity, ω = (2 x л x N) / 60
= 150.72 rad/sec
Tangential velocity = ω x r
= 150.71 x 0.1
= 15.07 m/sec
Power = Force x (Tangential velocity of Blade + Tangential velocity of pad)

$$P = F_t (v_w + v_p) \quad (1)$$

Tangential velocity of work piece = 0
Rated Motor Power = 3Hp (2237w)
Substituting in above equation (1)
2237 = F x (15.07 + 0)
Tangential Force = **148.44N** (15.13kg)

The model geometry is selected in ANSYS software and the material EN31 is chosen. The mesh selected for the body is fine mesh [16]. For static structural analysis, the base of the fixture is made fixed. The load is given in the form of force i.e., the tangential force 148.44 N acting on the vertical plane along the contour of the fixture where the pad comes in contact with the fixture. The pneumatic load of 785 N is given to the bolts. The solution obtained is for the equivalent (von-mises) stress and total deformation [17]. The analysis is made for the existing fixture that was used before and for the newly designed fixture. When force is applied, the maximum and minimum amount of deformation and stress values are obtained for existing and new fixtures are shown in Fig 10, Fig. 11, Fig. 12 and Fig. 13.

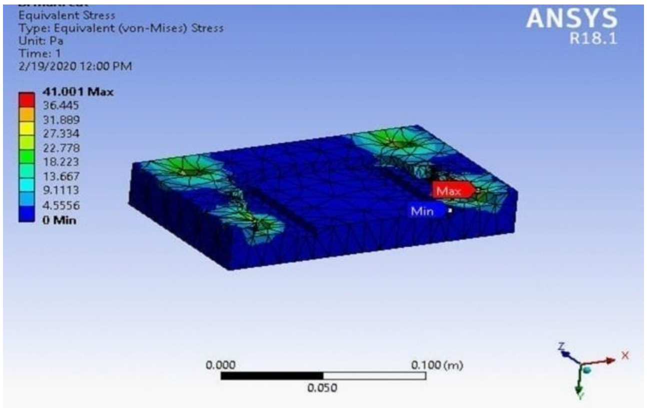

Fig. 10 Equivalent stress of existing fixture

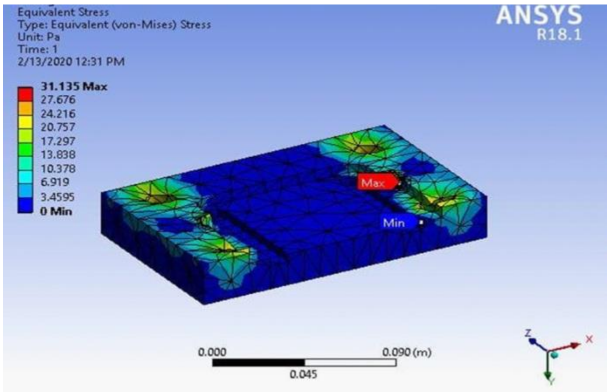

Fig. 11 Equivalent stress of newly designed fixture

The induced stresses for both the existing fixture and the newly designed fixture are 41 MPa and 31 MPa. The stress level induced are reduced to 24% with the newly designed fixture.

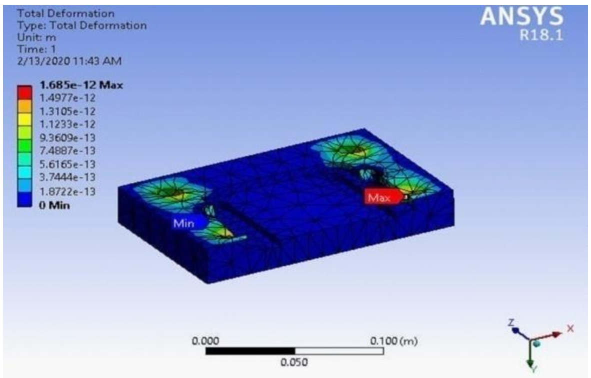

Fig. 12 Total deformation of existing fixture

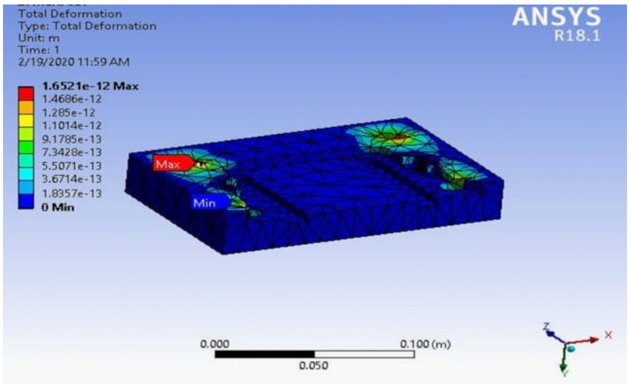

Fig. 13 Total deformation of newly designed fixture

Very minimal deformation is observed on the newly designed fixture for the applied load.

From the analysis, it is observed that the stress induced and the deformation is very much reduced in the newly designed fixture and they are within the allowable limit [18].

3.2. Fabrication of Grooving Fixture

After designing and analysis, the fixture was fabricated using EN 31(High carbon alloy steel). The fixture is manufactured by conventional machining process. The raw material chosen for fabrication was in the form of a rectangular block where the following operations were performed.

- Face milling
- Drilling
- Boring
- End milling
- Slotting

Fig. 14 shows the fixture fabricated using above mentioned process.

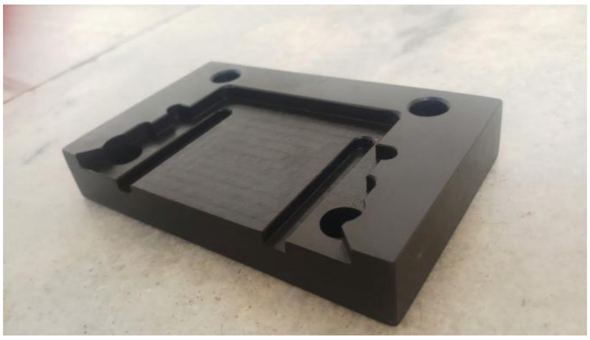

Fig. 14 Fabricated fixture

After the completion of fabrication, the fixture was taken for testing in the grooving machine. The fixture is assembled to the base plate and the element time taken to complete the setting according to the specification was noted. This observation is made for all the variety of brake pads for which this fixture has been designed. The element time taken after using the combined fixture as shown in the Table 4

Table 4. Element Time Taken After Using Newly Designed Grooving Fixture

Sl.no	Operation	Activities	Timing (sec)
1	Grooving	Getting grooving parts from plan board	3
2		Pick up the tools	10
3		Remove the old fixture from the grooving base fixture	120
4		Put old fixture in the rack	10
5		Pick the selected fixture from rack	10
6		Fix the grooving fixture	102
7		Adjust the grooving height based on spec	15
8		Getting approval from QA line inspector	30
Total			300

The results show the improvement in the finishing line after using the grooving fixture. There are three finishing lines, each with a maximum capacity of 2500 parts per shift. The testing was done for line 2 and the capacity of the line 2 was observed to be 2291 parts per shift initially. The use of combined fixture has resulted in the reduction of the total setting time taken per setting by about 50% as shown in Fig. 15. Therefore, this has improved the capacity of the line 2 to 2810 parts per shift which is shown in Fig. 16.

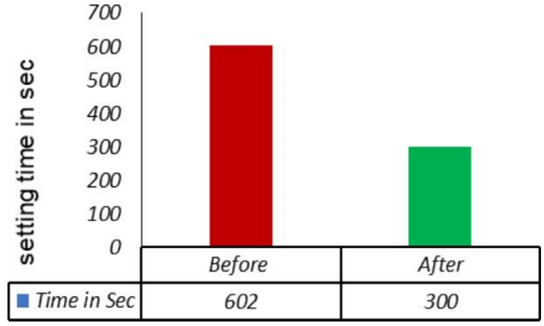

Fig 15 Setting time in sec

Fig 16 Capacity of line 2

Fig. 17 shows that the setting time taken before using the combined fixture was 1800 sec for about 6 settings per shift. By using this combined fixture, it was observed that the setting time is reduced to 600 sec as it doesn't require such number of settings and can be used to groove different parts with one setting. Considering one change of setting for the combined fixture, the below graph was plotted.

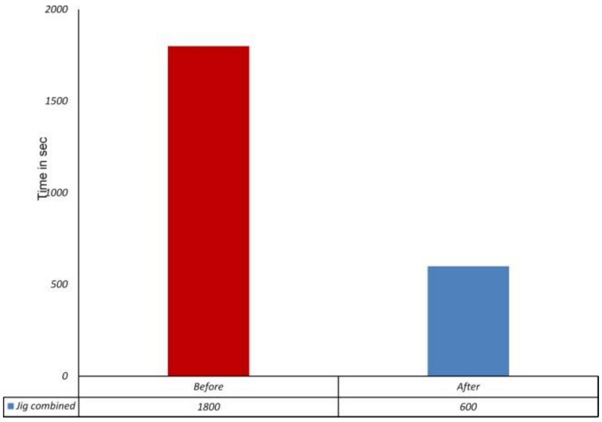

Fig 17 Setting time with combined fixture

As a result from the above graphs, it is clearly known that the setting time has been reduced to a greater extent and also the productivity is improved by using the combined fixture. As the combined fixture is used for more than one variety of parts, the number of settings is minimized and therefore, the time is reduced. Here, the non-value adding wheel adjustments can be eliminated. This is an effective way to minimize the complexity in setting the fixture on the base plate which also reduces worker fatigue.

4. Conclusion

The combined fixture that was used for the six varieties (800 cc, Maruthi 800 cc, Alto, Wagon R, Versa, A star) is proved to be an efficient way to reduce the number of settings and improve the productivity.
Thus, usage of this combined fixture has eliminated the adjustments made in the grooving wheel to obtain the specified thickness under groove, which contributed to the excess setting time to achieve the desired specification of each variety. The height of the grooving wheel was kept constant and the required TUG is achieved by using this fixture.

Since the operations are done manually, the proposed solution given was sufficient to improve the productivity. This newly designed fixture also automates the production process where there are large special requirements.

Acknowledgement. The authors express their sincere thanks to the Rane Brake Linings (RBL) limited, Chennai for providing the necessary support and infrastructure to carry out this work.

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