BRAKE LINING PROCESS ANALYSIS

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Abstract - ***To map the flow of manufacturing of the product and machining of the components and to eliminate the problems faced during production of brake lining such as delamination, surface crack, re-work of the lining material, excessive tool wear and also to eliminate the human error occurring at the mixing process. Due to the human error the product gets rejected in batches and the company faces a rejection in masses and faces an irreversible loss of the composite mixture and it amounts to lakhs. In this project we tried to analyse the major causes of rejection of the brake lining material produced and also to find the deviations present in the already pre-defined and pre-applied process in the company. We have further discussed the methodology to prevent the human error occurring by semi-automation of the product and also to prevent the fly loss occurring at the mixing unit.***

Key Words: Brake lining, Process analysis, Friction material, Automation, mechanical properties, structural analysis.

1. INTRODUCTION

Our team is doing the project work at one of Rane group of companies, Rane Brake Lining (RBL) at its plant located at Ambattur Industrial Estate, Chennai. It is a tire 2 supplier company and the company manufactures the brake lining friction material. Brake linings are the consumable surfaces in brake systems, such as drum brakes and disc brakes used in transport vehicles. Brake linings were invented by Bertha Benz (the wife of Karl Benz; Karl invented the first patented automobile) during her historic first long-distance car trip in the world in August 1888. The first asbestos brake linings were developed in 1908 by Herbert Frood.[1] Although Frood was the first to implement the use of asbestos brake linings, the heat dissipation properties of the fibres were tested by various scientists, including well known materials chemist Dr Gwilym Price, who did most of his research and testing from Cambridge, United Kingdom and various Cambridge-funded institutes. Brake linings are composed of a relatively soft but tough and heat-resistant material with a high coefficient of dynamic friction (and ideally an identical coefficient of static friction) typically mounted to a solid metal backing using high-temperature adhesives or rivets. The complete assembly (including lining and backing) is then often called a brake pad or brake shoe. The dynamic friction coefficient "μ" for most standard brake pads is usually in the range of 0.35 to 0.42. This means that a force of 1000 Newtons on the pad will give a resulting brake force close to 400 Newtons. There are some racing pads that have a very high μ of 0.55 to 0.62 with excellent high-temperature behaviour. These pads have high iron content and will usually outperform any other pad used with iron discs. Unfortunately, nothing comes for free, and these high μ pads wear fast and also wear down the discs at a rather fast rate. However, they are a very cost-effective alternative to more exotic/expensive materials.

2. FUNCTION OF BRAKE LINING

Since the lining is the portion of the braking system which converts the vehicle's kinetic energy into heat, the lining must be capable of surviving high temperatures without excessive wear (leading to frequent replacement) or outgassing (which causes brake fade, a decrease in the stopping power of the brake).

Due to its efficacy, chrysotile asbestos was often a component in brake linings. However, studies such as a 1989 National Institutes of Health item showed an uncommonly high proportion of brake mechanics were afflicted with pleural and peritoneal mesothelioma, both of which are linked to chrysotile and asbestos exposure.[2] Public health authorities generally recommend against inhaling brake dust,[3] chrysotile has been banned in many developed countries, such as Australia in late 2003,[4] and chrysotile has been progressively replaced in most brake linings and pads by other fibres such as the synthetic aramids.

3. BREAK LINING PROCESS FLOW

The different processes involved in the brake lining process are as given in (fig1).First is the mixing process followed by the preforming and curing which is then followed by baking and finishing. Only after all these the testes are taken.

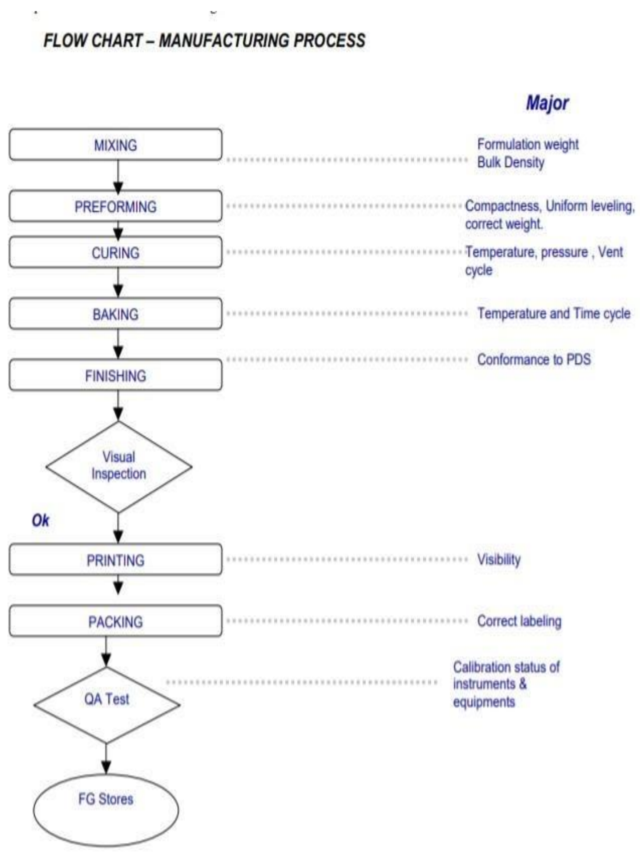


Fig-1: Brake lining process flow.

3.1. Mixing

This process involves the mixing of raw materials viz., Resins and fibres in the proportion already determined for the each product. Friction materials are combined with various materials which are required to be mixed up before production. And any error in this process affects the entire production unit and also the brake lining manufactured using it.

3.2. Preforming

Preforming is a process to level the mixture obtained from the "mixing" process thereby giving compactness to the product. The input derived from the mixing process is verified for its weightage and is treated in the preforming machine. This process actually gives shape to the product.

3.3. Curing

Again, brake pads are put under high temperature to strengthen and ensure they can perform under extreme conditions. The Input from the Preforming process is treated in the curing machine at a very high pressure and temperature to make the product intact. In this process, the curing machine hardens the product received from performing process in the same shape. The hardening process is done with proper time gaps as per the Vent Cycle. After curing process, the output is transferred to the Baking process.

3.4. Baking

In this process, the cured material is baked before passing on to the finishing stage of the product. Roll-lining brake material for typical application in passenger cars usually consists of continuously compressing the wet mixture between rolls and then baking the compressed mixture at about 300° F. to 350° F. for a period of about 10 to 15 hours.

3.5. Finishing

The baked product is bifurcated into the required pieces. Further, the product is sent for grinding, grooving, riveting etc. Once these processes are complete, the finished product is sent for visual inspection. . After visual inspection, the part name is printed on the product and sent for packing process. Simultaneously the sample is also sent for Quality assurance analysis and after certification by the Quality department, the product is moved to the finished goods stores.

3.6. Visual inspection

Visual Inspection, used in maintenance of facilities, mean inspection of equipment and structures using either or all of raw human senses such as vision, hearing, touch and smell and/or any non-specialized inspection equipment

3.7. Printing and Packaging

Packaging is the science, art and technology of enclosing or protecting products for distribution, storage, sale, and use. Packaging also refers to the process of designing, evaluating, and producing packages. Packaging can be described as a coordinated system of preparing goods for transport, warehousing, logistics, sale, and end use. Packaging contains, protects, preserves, transports, informs, and sells. [5]

4. PROCESS EVALVATION

When we considered all the process and started evaluating it one by one we came to the following conclusion. The process like preforming baking and finishing, we concluded that they were all fine and did not need any changes in them after five weeks of observation. But meanwhile we saw major deviations in the mixing and curing process that we have discussed further in the report.

4.1. Curing process evaluation and planning

When we first started the evaluation of the curing process we found out that the temperature of the curing process was way below than the allowable temperature. (Table -1)

Table -1: Table of temperature data collected from curing process

LOADS	units	Actual min	Actual max	CAVITY 1	CAVITY 2	CAVITY 3	CAVITY 4	CAVITY 5	CAVITY 6	CAVITY 7	CAVITY 8	CAVITY 9	CAVITY 1(	V.PRESSURE	H.PRESSURE
1	°c	150	160	140	141	142	147	148	136	135	140	139	128	90-100	200-205
2	°c	150	160	150	144	144	142	137	135	143	140	138	134	90-100	200-215
3	°c	150	160	147	142	144	150	146	156	147	145	140	127	90-100	210-220
4	°c	150	160	131	140	136	145	148	148	146	140	137	131	90-100	200-205
5	°c	150	160	129	137	145	137	153	141	138	141	140	128	90-100	200-215
6	°c	150	160	135	139	142	146	148	152	146	141	128	130	90-100	210-220
7	°c	150	160	146	131	130	130	138	147	138	135	130	121	90-100	210-220
8	°c	150	160	147	144	140	152	142	162	158	149	140	129	90-101	210-221
9	°c	150	160	132	133	137	135	131	152	147	137	131	125	90-102	210-222
10	°c	150	160	147	143	144	137	148	152	145	143	134	127	90-103	210-223
11	°c	150	160	147	140	142	147	146	149	142	136	132	132	90-104	210-224
12	°c	150	160	148	143	142	146	143	149	144	142	136	129	90-105	210-225
13	°c	150	160	154	141	138	145	147	146	134	136	134	130	90-100	200-220
14	°c	150	160	152	138	136	141	135	136	129	130	131	129	90-105	200-220
			Average	143.214	139.714	140.143	142.857	143.571	147.214	142.286	139.643	135	128.571		

Then after plotting the scatter chart (Chart -1) we understood that the issue was with the calibration of the temperature feedback sensor and not with the capacity of the heating coil or the temperature distribution of the material. Due to this error there were a lot of delamination issues and many of the manufactured parts were rejected

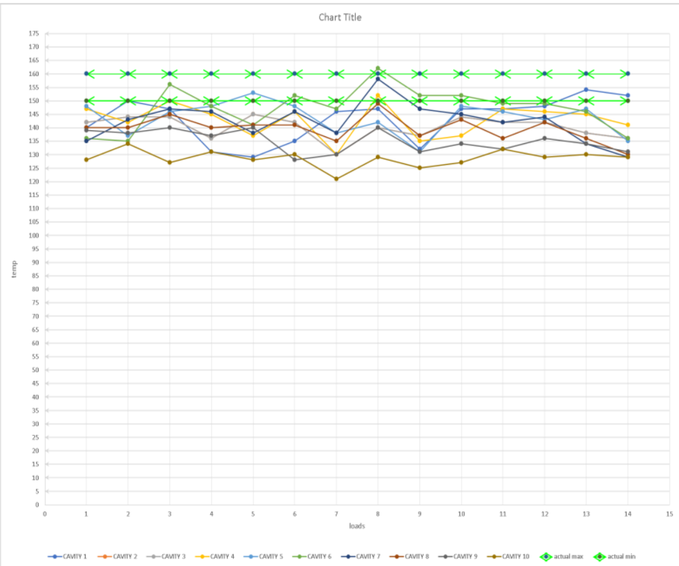


Chart -1: Image of the scatter chart of the temperature distribution

The fluorescent green line in the top and bottom represents the upper and lower limit of the allowable temperature and the different colored lines represents the different cavity temperature at different cycles and from this data it can be considered that there was a considerable error in the cavity temperature.

When we evaluated the deviation in the pressure applied then we found out that the pressure was deviated a little bit but that was affecting the product considerably

Table -2: pressure data collected from the curing process

LOADS	V.PRESSURE(bars)				H.PRESSURE(bars)			
S.no	Actual(min)	Therotical(min)	Actual(max)	Therotical(max)	Actual(min)	Therotical(min)	Actual(max)	Therotical(max)
1	90	98.066	100	117.68	200	218.688	205	245.166
2	90	98.066	100	117.68	200	218.688	215	245.166
3	90	98.066	100	117.68	210	218.688	220	245.166
4	90	98.066	100	117.68	200	218.688	205	245.166
5	90	98.066	100	117.68	200	218.688	215	245.166
6	90	98.066	100	117.68	210	218.688	220	245.166
7	90	98.066	100	117.68	210	218.688	220	245.166
8	90	98.066	101	117.68	210	218.688	221	245.166
9	90	98.066	102	117.68	210	218.688	222	245.166
10	90	98.066	103	117.68	210	218.688	221	245.166
11	90	98.066	104	117.68	210	218.688	224	245.166
12	90	98.066	105	117.68	210	218.688	225	245.166
13	90	98.066	100	117.68	200	218.688	220	245.166
14	90	98.066	105	117.68	200	218.688	220	245.166

From the diagram (Table -2) we can say that there is a pressure deviation and it is less than the allowable minimum pressure.

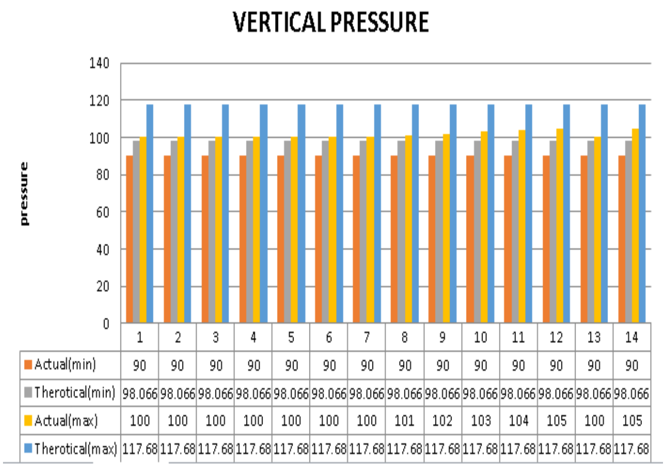
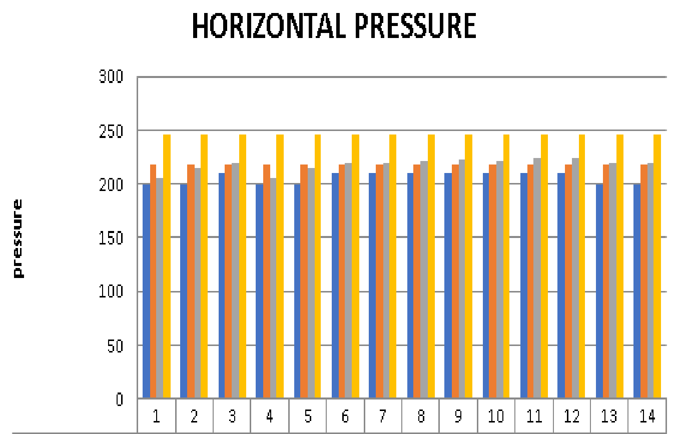


Chart -2: vertical pressure

In the image (Chart-2) it has the comparison of the theoretical pressure value represented by grey for minimum pressure and blue for maximum pressure and actual pressure value represented by red for minimum and orange for maximum The same scale is applied for the horizontal pressure chart too (Chart-3).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Actual(min)	200	200	210	200	200	210	210	210	210	210	210	210	200	200
Therotical(min)	218.7	218.7	218.7	218.7	218.7	218.7	218.7	218.7	218.7	218.7	218.7	218.7	218.7	218.7
Actual(max)	205	215	220	205	215	220	220	221	222	221	224	225	220	220
Therotical(max)	245.2	245.2	245.2	245.2	245.2	245.2	245.2	245.2	245.2	245.2	245.2	245.2	245.2	245.2

Chart-3: the chart for horizontal pressure

4.2. Mixing process evaluation and planning

When the process was further traced back then we found human error occurring at the mixing unit due to the confusion of requirements of different grades and different compositions this error did not take place regularly but once it takes place it causes a major loss in the company. This is due to the fact that the mixture composition almost contributes to the entire process flow and a simple mistake in the composition can affect the production of the brake lining.so we tried to semi automate the mixing process

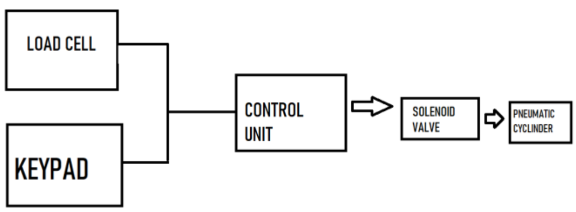


Fig-1: Image showing the logic behind the automation of the mixing unit

The logic behind the automation is very simple and straight forward, a load cell is a force transducer. As shown in (Fig. 1). It converts a force such as tension, compression, pressure, or torque into an electrical signal that can be measured and standardized. As the force applied to the load cell increases, the electrical signal changes proportionally and a keypad is used to input the grade running on the plant and the final signal is given to the control unit, the control unit decides whether or not to allow the material in or not by checking the material weight on the load cell and then finally if the weight matches the preprogramed material grade weight then it opens the door. For example lets us consider Brake lining material 1.Which is formed by mixing the following ingredients A, B, C, D. Let's us take a situation in which the person who is working on the mixing chamber has to load MATERIAL "A" for about 10kg due to his negligence or atmospheric factor the material amount is increased or decreased by some amount for example instead of 10kg the worker has measured 12kg or 8kg in this case the actual value of 10kg is not achieved. This error will be portrayed in final result such as material loss, life time of brake is decreased. To eliminate this error we are going to use a door powered by pneumatic cylinder which is controlled by control unit. This way we can completely avoid the human error occurring in the mixing unit.

5. RESULTS AND DISCUSSION

After applying the proposed plan we finally got favourable results and the rejection of the parts was reduced to a considerable extent .The results for the different process were obtained as follows.

5.1 Curing process results

After altering the feedback sensors output we thought that the temperature and the pressure were going to be fine but there were some error in the heating coil due to the repeated use of the heating coil the heat output varied from the required output so the company had to change the heating coil completely. After doing all these and some slight alterations in the hydraulic pistons providing the vertical and horizontal pressure the obtained values matched exactly within the limits of the temperature which was given to us by the company's Research and development unit. The pressure values also were within the range.

5.2. Mixing unit Semi automation results

We used a double acting pneumatic cylinder as shown in the (fig -2) by using 5/2 solenoid valve for controlling the cylinder the calculations are given below

Load calculation:

$v = 1000 \times 570 \times 10$

$= 570.00$ mm^3

Assuming density of material for design purpose:

ie: $e = 2700$ kg/m^3

$m = e \times v$

$= 0.0057 \times 2700$

= 15. 39 kg

To select the pneumatic cylinder:

Pressure - 2 bars/ 1 bar

Force - 145N

Area - ?

2 bar = 200000 N/m^2

F = P × A

A' = F/P

= 300/200000

= 1.5 × 10^ (-3) m^2

A" = F/P

= 300/100000

= 3 × 10^ (-3) m^2

d = 0.0437 m

d' = 43.7 mm

A = 3 × 10^ (-3) m^2

r' = 0.030

d = 0.061803

d"= 61.803 mm

r" = 0.02 mm

= 21.48 mm

d"= 42.96 mm (for 1 bar)

Only model found :

Airmax - 1 m - 651000

d = 65 mm (bore diameter)

r = 32.5 mm

A = 3318.30 mm^2

= 0.0033183 m^2

Pmax = 200000 N/m^2

Pemax = 200000 × 0.0033

=663.66 N

Where:

A' =area of the cylinder for 2 bar.

A'' =area of the cylinder for 1 bar.

d'= bore diameter of the cylinder for 2 bar.

d''=bore diameter of the cylinder for 1bar.

P= pressure of fluid.

M=mass of the component.

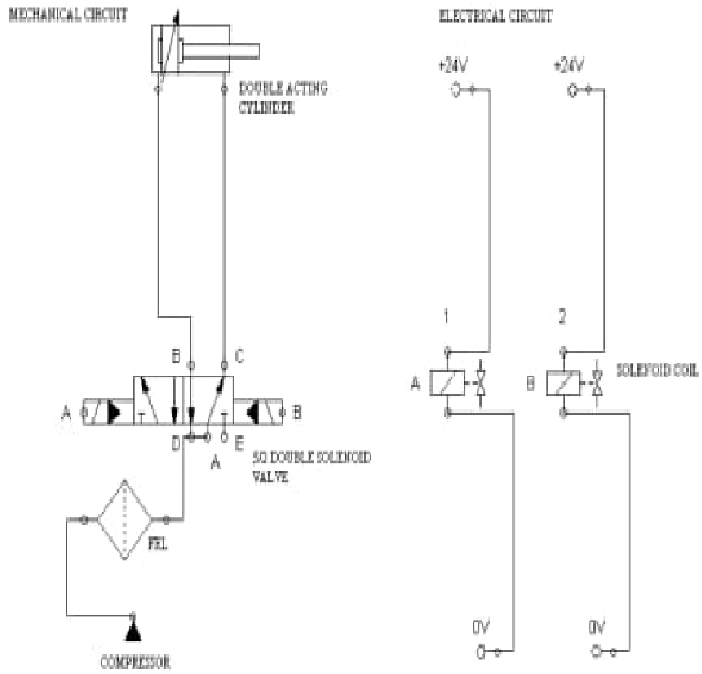


Fig 2:- Double acting pneumatic cylinder with 5/2 solenoid valve.

After implementing the automation with the help of the control unit along with the interface of 5/2 solenoid valve we did the analysis for both the door and the railings for the sliding door using FEA software

(a)Ansys software:

ANSYS,Inc. is an engineering simulation software (computer-aided engineering, or CAE) Developer headquartered south of Pittsburgh in The South pointe business park in Cecil Township, Pennsylvania, United States. One of its most Significant products is Ansys CFD, a proprietary Computational fluid dynamics (CFD) program.

Simulation Technology: Structural Mechanics, Static Structural analysis etc.

(b)Material Used:

- Aluminium alloy
- Structural steel

(c)Analysis of the door:

We did the analysis of the door by assuming that it has to withstand the force caused by accidentally hitting the door by the operator with the weight of the maximum density material that is nearly equal to 150kg and then also it should be able to withstand the sudden impact force. In order to test this we assumed intermittent loading for a particular time as shown in (Fig. -3) where the x-axis represents the time and the y-axis represents the load acting.

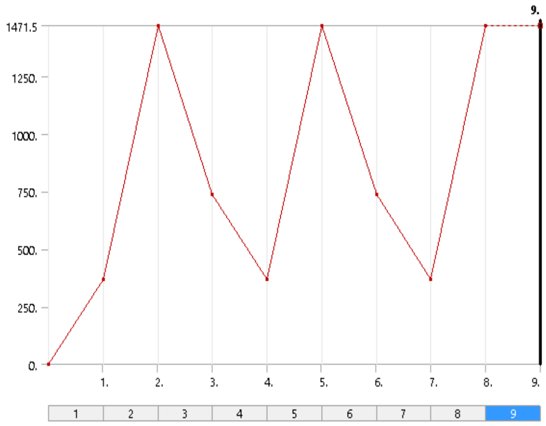


Chart-4: Intermittent loading of the component

The door had a dimension of about 1000mm*570mm*10mm. This was given to us as a requirement by the company and we were allowed only to change the material to withstand various loading. We had to select the material as a light weight and highly durable material and we choose aluminium alloy as our first choice after performing analysis on the aluminium alloy we landed on the following results. (Table-3) shows the properties of the door.

Table-3: Table showing the properties of door.

Properties	
Volume	5.7e-003 m^3
Mass	15.39 kg
Scale Factor Value	1.

We selected a node size of 5.7374e-002 m and total nodes of 1403 were used for both the static structural analysis and von mises stress analysis. For that we got a maximum deflection of about 5.3989e-010 m which is shown in (Chart-5) and the animation of the door is shown in the (Fig -3). The results for the von mises equivalent stress got a maximum stress of

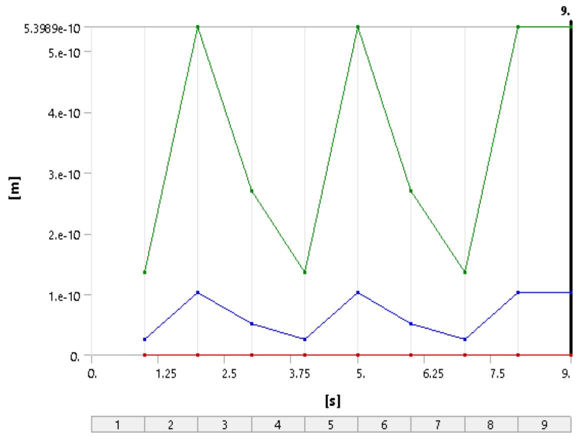


Chart-5:Image showing the total deformation formed.

About 657.44pa and the results for the intermittent loading are shown in the (Chart-6)

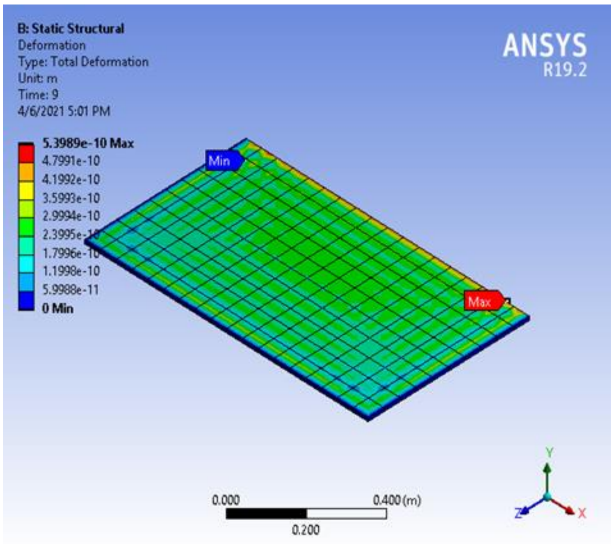


Fig 3- Image showing the deformation animation of the door

The image shows the stress formed due to the varying load acting on it where the red line shows the minimum stress formed and the blue line represents the average stress formed on it and the green line représtents the maximum stress acting on it The various stress formed are shown below.(Table4)

Table -4: various stress formed on the door.

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	4.5794e-006	657.44	336.8
2.	1.8317e-005	2629.7	1347.2
3.	9.1587e-006	1314.9	673.59
4.	4.5794e-006	657.44	336.8

5.	1.8317e-005	2629.7	1347.2
6.	9.1587e-006	1314.9	673.59
7.	4.5794e-006	657.44	336.8
8.	1.8317e-005	2629.7	1347.2
9.			

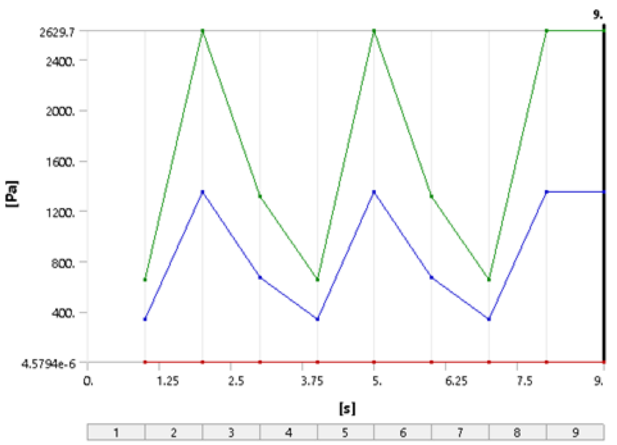


Chart-6 Comparison of stress developed with time

The maximum stress formed on the material is way less than the yield strength of the aluminium alloy and the stress formed is within the elastic limit of the material and when the load acting is removed the material gets back to its original dimensions without any plastic deformations at all. The animation of the stress formed on the door is shown below (Fig -4).

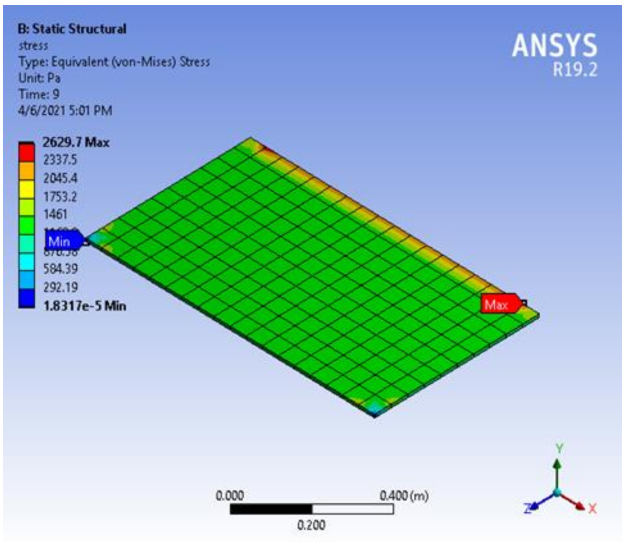


Fig -4: Image of the stress formed on the door

(d)Analysis of the guideways:

We did the analysis of the guide ways assuming it to be a simply supported beam and we choose structural steel as a material for it because of its hardness and cheapness. It had its support on both the extreme ends and there were no supports on the centre we took the node size to be 2.e-002 m and we had total of 2028 nodes. We did the static structural analysis and the von mises equivalent stress for the guide ways assuming the load to be 300N that is the weight of the door after including the Factor of safety 2.For that we got a maximum deformation of 1.278e-004m from the static stress analysis. The analysis animation is shown in the (Fig. -5)

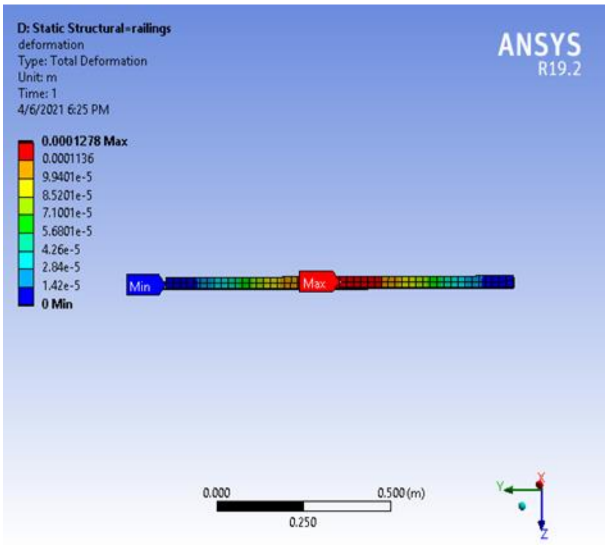


Fig. -5: animation of the deformation of guideways.

From the von mises stress equivalent we got a maximum stress of 1.3131e+007pa for the maximum load acing on it but the maximum stress is still less than the yield stress of the material and therefore even when there is ssome deformation on the guideways it still lies in the elastic limit of the material and once the load is taken away from it then there is no plastic deformation and the material falls back to its original shape and size. The image of the guideways von mises equivalent force is given in (Fig.-6).

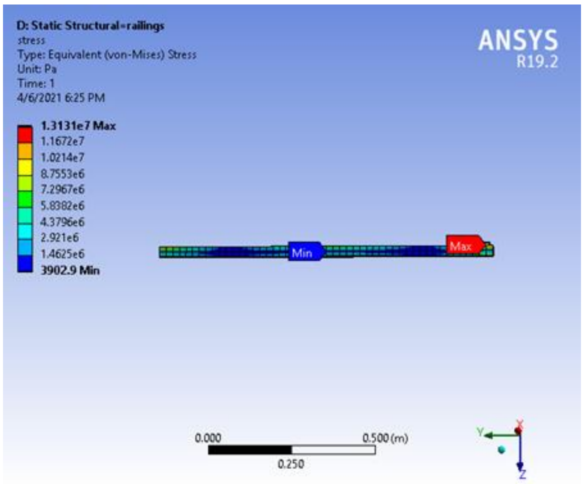


Fig. -6: image showing the stress formation on the guideways

6. CONCLUSIONS

The complete process analysis was done and it was implemented in the manufacturing unit of brake lining friction material. Mostly the issue was caused by only two of those processes and they were the mixing and curing process. The curing process had deviations in the sensitivity of the feedback sensor and its heating coil had its heating capacity lower than the given value. Whereas in case of the mixing unit there was a human error and the absence of testing after the mixing was the main cause of the part rejection. To prevent the human error, we semi-automated the mixing process and we achieved it by checking the weight of the additive and controlling the input by controlling the weight of the additive of the mix. Thus we did a process analysis on the brake lining manufacturing unit and we reduced the number of parts and batches rejected and made the company's manufacturing line profitable.

ACKNOWLEDGEMENT

We would like to give our sincere regards to Rane brakes Pvt. ltd.

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