DESIGN AND DEVELOPMENT OF BRAKE PEDAL AND DRUM FOR MULTIUTILITY FARM VEHICLE

Kunal Taksande[1], Pawan Maske[2], Dr. Arvind Chel[3]

[1,2,3]Department of Mechanical Engineering,
[1]UG Student, DIEMS, Aurangabad
[2]UG Student, MGM's Jawaharlal Nehru Engg. College, Aurangabad
[3]Associate Professor, MGM's Jawaharlal Nehru Engg. College, Aurangabad

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Abstract - *Brake system is the most significant safety aspect of any vehicle. Its main function is to slow down the vehicle and bring it to complete rest. This work aims to provide comprehensive calculations of drum brake for a multiutility agriculture vehicle. A notable advancement in design of brake pedal is changeable leverage ratio for increasing or decreasing the transmitted force to the tandem master cylinder as per requirement. AISI 1018 material is used to fabricate the brake pedal. A latch is provided to connect both the brake pedals. Brake pedal is designed in Creo 3.0 and analysis of the brake pedal is done in Ansys for optimizing the design.*

***Key Words:** Brake Pedal, Pedal Ratio, Drum brakes, adjustment for TMC force, brake fluid.*

1. Introduction:

Multi utility agriculture vehicle (MAV) is a multipurpose vehicle which can be used for a number of applications such as ploughing the field, carrying a trolley, harvesting crops with appropriate attachments. Hence the braking system is expected to perform in extreme conditions. This works contemplates the design procedure with calculations for MAV. Moreover, the effort applied by the driver on the brake pedal should be more for maximum braking efficiency, in order to increase the comfort and ensure proper functioning [1]. Recent trends in mechatronics show that with the use of electronic components, the braking system efficiency has increased exponentially, but on the other side the cost of these components then increases [2]. Brake and Fuel efficiency are affected by the weight of the vehicle; advancements in use of materials to reduce overall vehicle weight is in demand, which will reduce the emissions [3]The slot facilitated at the back side of the pedal is to connect both the pedals and hence both the wheels can be stopped. This vehicle is subjected to perform in field; hence the steering system should be optimum. To support the steering system, a latch is given to disintegrate both the pedal, thus if one brake is applied, the other wheel rotates and provides turning effect. Hence to counter such problem a brake pedal was designed in 3D modelling software Creo 3.0 followed by its Analysis. Thus, the brake pedal was optimized until absolute results were obtained.

2. Design of drum brake and its components:

The design of drum brake components like brake pedal, Tandem master cylinder, drum brake has been narrated in following subsections. Specification of brake fluid and evaluation of coefficient of friction of tyre are given below:

2.1 Brake Pedal:

The brake pedal is a device used to actuate the brakes of any automobile vehicle. Hence it is expected that the brake pedal must be durable and must have low weight. From elementary statics, the force increase will be equal to the driver's applied force multiplied by the lever ratio of the brake pedal assembly. The design of the brake pedal is discussed in detail. The brake pedal assembly is shown in Fig.1.

Figure-1 Brake pedal assembly

The force output of the brake pedal assembly (F_{bp}, N) can be determined as follows:

F_{bp} = the force output of the brake pedal assembly (N)

F_d = the force applied on pedal pad by the driver (kg)

L_1 = the distance from the brake pedal arm pivot to the output rod clevis attachment (m)

L_2 = the distance from the brake pedal arm pivot to the brake pedal pad (m)

g= acceleration due to gravity (m/s^2)

F_{bp}= F_d * [$L_1 \div L_2$]* g

   = 30 * (10÷1) * 9.81

F_{bp} = 2943 N

2.2 Tandem Master Cylinder

Assuming incompressible liquids and infinitely rigid hydraulic vessels, the pressure generated by the tandem master cylinder (as shown in Figure-2) is calculated as follows:

Figure-2 Tandem master cylinder

$P_{mc} = F_{bp} \div A_{mc}$

$= 2943 \div [(\pi \div 4) * (d)^2]$

$= 2943 \div [(\pi \div 4) * (19.05 * 10^{-3})^2]$

$P_{mc} = 103.7 * 10^5$ N/m^2

P_{mc} = the hydraulic pressure generated by the master cylinder.
d= diameter of master cylinder piston from OEM (19.05 mm)
A_{mc} = the effective area of the master cylinder hydraulic piston

2.3 Drum brake

OEM parts are used for calculations, to maintain the standards. The two shoes of the break drum are shown in figure-3. The torque calculations are given for both rear wheels as follows.

Figure-3 Drum brake

$P_d = P_{mc}$ x 0.8 = 103.7 x 10^5 x 0.8

P_d= 82.96 x10^5 N/mm^2

Where, P_d = Pressure on drum (N/m^2)

P_{mc} = Pressure on Master Cylinder

$F_d = P_d$ x A= 82.96 x 10^5 x(0.12 x0.03)

= 29865.6 N

T = F_d x r x µ =29865.6 x 0.1 x 0.35

T = 1045.296 N

Where, r = Radius of drum

µ=co-efficient of friction

For torque on both tyres,

T_{total} = T x 2 = 1045.296 x 2 = 2090.592 N

2.4 Brake Fluid

Brake fluids are hydraulic fluids that are used in hydraulic brakes. These incompressible fluids are used to transfer the pressure to the drum pads. The brake fluid used is Department of Transportation 3 (DOT) [2]. The properties of DOT 3 brake fluid are given in the Table-1.

Table -1 Properties of DOT 3

Property	Corresponding value
Viscosity	1500 mm/s
Dry boiling point °C	205
Wet Boiling Point °C	140
Primary constituent	Glycol ether

2.5 Tyre

Assuming that there is adequate friction between the tyre and the road, the tyre will develop slip in order to react the torque found in the rotating assembly [5].

$F_{tyre} = [T_r \div R_{tyre}]$

$F_{1\ tyre} = [1045.296 \div 0.4]$ = 2613.24N

$F_{2\ tyre} = F_{1\ tyre}$ = 2613.24N

$F_{total} = F_{1\ tyre} + F_{2\ tyre}$ = 5226.48 N

Where, T_{total} = the total braking force reacted between the vehicle and the ground (assuming adequate traction exists).

The deceleration of the vehicle is calculated by

$a_v = F_{total} \div m_v$ = 5226.48÷450

a_v = 11.6144m/s^2

Where, m_v is mass of vehicle = 460Kg

The stopping distance of the vehicle is given by

$SD_v = [V_v^2 \div (a_v \times 2)] = [(4.16)^2 \div (11.6 \times 2)]$

SD_v = 0.74 m

V_v = Initial velocity of the vehicle = 15kmph = 4.16m/s

The stopping time is calculated by

$t^2 = SD_v \div [0.5 \times a_v]$

$t^2 = 0.74 \div [0.5 \times 11.6]$

t = 0.12 sec.

3. Design and Analysis of Brake Pedal

3.1 Modelling of brake pedal

A model of brake pedal was designed in 3d modelling software Creo 3.0 considering constraints and parameters and then analysis of the pedal was done in Ansys Software. The mechanical advantage (leverage ratio) that can be obtained are 12:1, 7.2:1 and 5.14:1 by changing the tandem master cylinder connection. Figure-4 depicts the drafting of the Brake pedal.
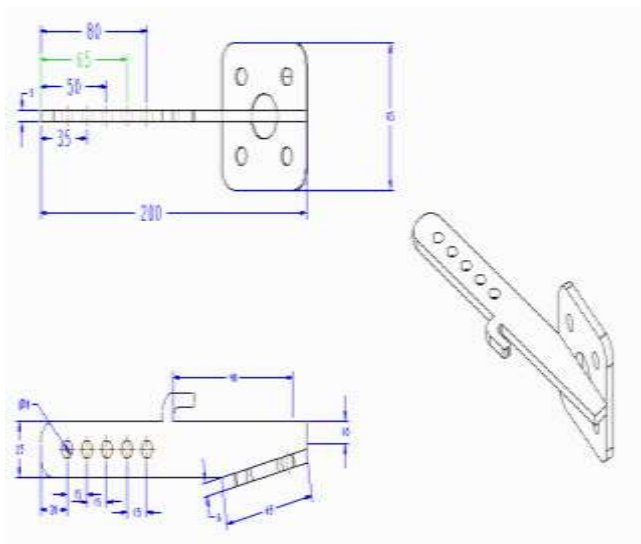

Figure-4 Drafting of the brake pedal

3.2 Material Selection

The brakes are expected to work in extreme condition, hence must have high Fatigue strength. AISI-1018 was used as a pedal material. Properties of AISI 1020 and AISI 1018 were compared (Table 2.) and we selected AISI-1018 because of its low base cost as well as low machining cost [6]. It is also easily available. Its strength is also high according to the use of the component.

Table-2 Comparison of AISI 1018 and AISI 1020

| Material	AISI 1018	AISI 1020
Yield strength (MPa)	317	294.4
Tensile strength (MPa)	440	294.74
Density	7.9	7.94
Cost/meter in USD (2018)	4.96	33.6

3.3 Meshing

Meshing is a process of dividing the whole component into a number of elements so that whenever the load is applied on the component it distributes the load uniformly. In this work we performed fine meshing for better load distribution as shown in the Figure-5.
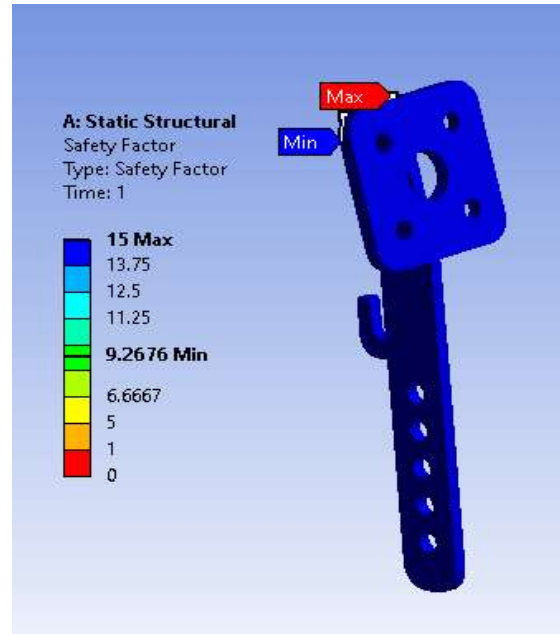

Figure-5 Meshing of Brake pedal
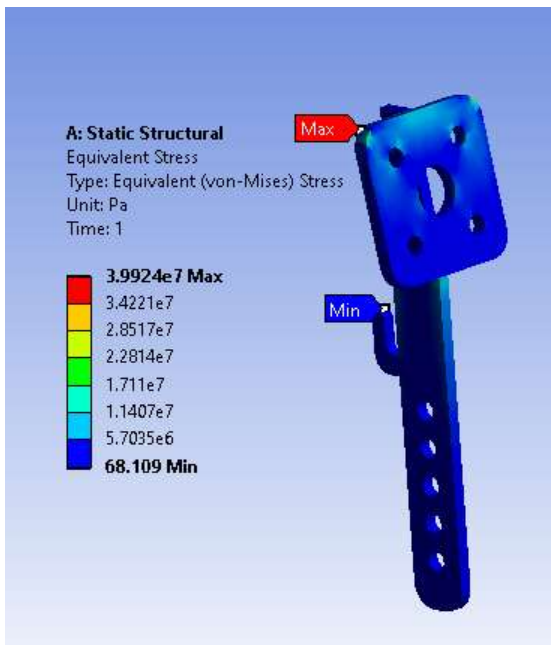
3.4 Loading and Boundary Condition

Point B has been provided as support, while point A is the application of the force of 200N. Figure-6 shows the loading and boundary condition in Ansys software
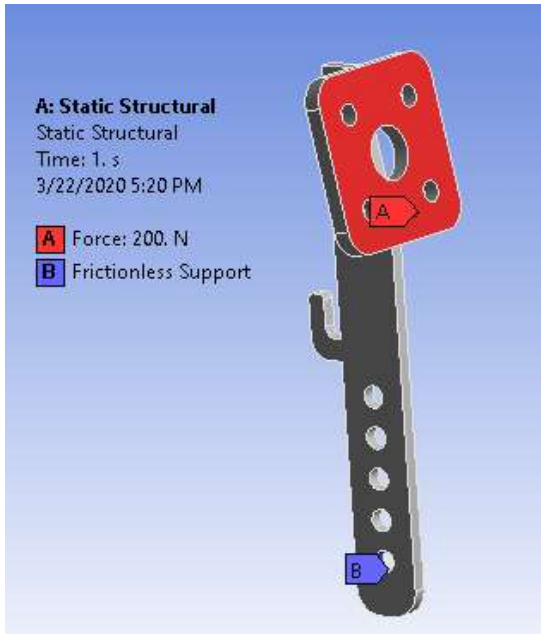
Figure-6 The pedal is fixed at point B and force is applied at point A

Figure-7 Equivalent (Von-Mises) stress

Figure-7 shows the equivalent stresses. The minimum stress is 68 Pa and maximum Stress generated due to application of 200N force by the driver is 3.992e7 Pa (39.924 MPa) which is very less as compared Tensile Stress limit.

The factor of safety after the analysis was found to be around 9 (figure-8). This indicated the brake pedal is very safe.

Figure-8 Factor of safety of brake pedal

4. RESULTS

The input parameters and output parameters obtained using Ansys of break pedal are given in Table-3

Table-3 Results of analysis of brake pedal

Input Parameters	
No. of nodes for meshing	8775
Applied Force	200
Output Parameter	
Minimum Stress	68 Pa
Maximum Stress	39.9 MPa
Factor of Safety	9.2

5. CONCLUSIONS

A detailed design procedure for drum brake is provided with calculations for OEM Parts. In addition to this brake pedal has a variable pedal ratio which can increase the applied force as per requirement. The Model was designed in Creo 3.0, and then was analyzed using Ansys. It has a capability of increasing or decreasing the leverage ratio in order to increase or decrease the actuation force. The static structural analysis of brake pedal infers that the stress generated is approximately 40 MPa which is under permissible tensile strength limit. The factor of safety obtained after analysis is 9, which is very high. In addition to this brake pedal has a variable pedal ratio which can increase the applied force as per requirement.

REFERENCES

[1] Peilong Li and Hongmei Xu, Braking Efficiency and Stability of Chassis Braking System of Combine Harvester: The Theoretical Derivation and Virtual Prototype Simulation, Hindawi Mathematical Problems in Engineering, Volume 2019

[2] Deepa.A, Yashwant Singh D, S. V. Mukesh Varma, Pranshu Khakhar, Analysis on Multi Linkage Brake System with Variable Pedal Ratio, International Conference on Materials Manufacturing and Modelling-2017

[3] Mohd Nizam Sudin, Musthafah Mohd Tahir, Faiz Redza Ramli, Shamsul Anuar Shamsuddin, "Topology Optimization in Automotive Brake Pedal Redesign", International Journal of Engineering and Technology, Volume 6, No 1 Feb-Mar 2014.

[4] Pawan Maske, Shreyash Shahane. Dr. Arvind Chel, Design of braking system for an electric vehicle, International Journal of Research and Analytical Reviews, Volume 7, issue 1, Page no. 868-873, March 2020.

[5] Anirudh L Subramanyam, Sandeep Banik, Maximum brake force calculations for drum Brakes, Intent Design.

[6] Arunkumar Gopal, Design and Analysisi of whishbones in Double Wishbone Suspension System: Technical Note, International Journal of Vehicle Structure and Systems, volume 10, issue 4, Page no. 260-262 Nov. 2018

[7] Ashwini n. Gawande, prof. G. E. Kondhalkar, prof. Ashish r.pawar International Research Journal of Engineering and Technology, Volume: 04 Issue: 05, page no. 3222-3227, May -2017

[8] K K Dhande, N I Jamadar and Sandeep Ghatge, design and analysis of composite brake pedal: an ergonomic approach, Int. J. Mech. Eng. & Rob. Res. 2014, Vol. 3, No. 3, page no. 472-482, July 2014.

[9] Kirpal Singh – "Automobile Engineering", Standard publication distributors, 1982.

[10] Robert Bosch GmbH, "Automotive Handbook", 2nd Edition, Stuttgart, 1996.

BIOGRAPHIES

Pawan Maske
UG student, MGM's Jawaharlal Nehru Engineering College, Aurangabad

Dr. Arvind Chel
Associate Professor, MGM's Jawaharlal Nehru Engg. College, Aurangabad

Kunal Taksande
UG Student, Deogiri Institute of Engineering and Managemental Studies, Aurangabad