Design and Fabrication of an Adaptive Left Throttling Pedal for V-Boot Wagon 230 for Right LEG Paraplegic Patient

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Abstract: This work is problem- solving oriented. It is all about Design and Fabrication of an Adaptive Throttling Pedal for V-Boot Wagon 230 for Paraplegic Patient who has a problem with his right leg and still desire to drive his car with ease. Although there were various car adaptations in existence mainly customized for paraplegia that have been developed by different International Automobile industries. Nigeria is yet to have one.. The clauses behind the design of this work are the difficulties to access left adaptive throttling accessories for V-Boot Wagon 230 for Right paraplegic patient and possibility of driving the car upon reverting the car to its existing state. In order to achieve this research work, the following factors were considered; Anthropometric data of the client, Physical dimensions of available spaces for left throttle, design analysis which includes adaptive link mechanism, material selection, strength, and forces were determined, fabrication, machining of parts and assembling, Installation of the product, equipment maintenance and Performance evaluation. Ordinarily the engines speed runs 2000rpm at an idle position of the existing pedal compared to what has been adapted which runs at 1500rpm. This low speed indicates improved efficiency and minimizes fuel consumption. Also when the two pedals were activated and pressed through an arc length of 45mm, both engine speeds read 6000rpm. Although there were little deviations in the curves at displacement position 20mm and 30mm. These deviations have no significant effect on the performance of the engine.

Keywords: Design; left leg throttling pedal; paraplegic; performance evaluation.

1. INTRODUCTION

Anthropometry has been defined as the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue (National Health and Nutrition Examination Survey III, 1988). In making life comfortable for human being through engineering innovations and inventions, the physically challenged human beings must not be left out. The left foot accelerator pedal (LFAP) is an inexpensive low-tech device commonly prescribed by driver rehabilitation specialists to allow persons who cannot use their right foot to operate a motor vehicle. Persons with amputations or right hemiplegia from any number of causes (such as traumatic nerve or muscular damage, post polio effects, stroke, multiple sclerosis, arthritic damage and others) benefit from this automotive adaptive aid.

The ability to drive a motor car can radically alter the quality of life led by disabled people as inability to drive causes brooding and frustration when they cannot do a useful day's work or occupy themselves. Well-advised disabled drivers can drive to offices, shops, pubs, and cinemas without the need of a helper (Tachakra, 1981). The objective of this work is to report the design and fabrication of an adaptive left throttling pedal for v-boot wagon 230 for right paraplegic patient. This is based on collected information to determine the need for standards or guidelines to govern the design, manufacture, installation, prescription and use of Left Foot Adapted Pedals (LFAPs) in a safe manner.

2. METHODOLOGY

2.1. *Design Considerations*

In order to achieve the set objectives of this research work, the following factors were considered.

Anthropometric data of the client (paraplegic patient) was taken.

(1) Physical dimensions of available spaces for left throttle adaptor were measured.

(2) Design analysis which includes adaptive link mechanism, material selection, strength, forces, moments and angle of depression were determined.

(3) Fabrication, machining of parts and assembling were based on the required standards and specifications

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(4) Installation of the fabricated throttle adaptor.
(5) Performance evaluation at the point of use.

2.2. *Anthropometric data of the client*

The following instruments were used
(1) Body measurement sheet
(2) Metre Rule
(3) Tri-square
(4) Vanier Calliper
(5) Set squares
(6) Pencil
(7) Eraser

2.3. *Adapted Measurement procedures for Anthropometric data of the Client*

The measurements were limited to the use of metre rule, measuring tape, body measurement log sheets and sitting height pictures.

(1) The client or patient was asked to sit conveniently on his car as if he is about to drive.
(2) The patient's head is maintained in the Frankfort Horizontal Plane position.
(3) The left leg of the patient is positioned so that the skin can be marked for thigh and calf measurements.
(4) The figure 1 shows the exact positions and dimensions of the dynamic parts required for effective driving.
(5) All dimensions in millimetres.

3. DESIGN ANALYSIS

3.1 Design Analysis of the Component parts of Adapted Left Foot Pedal

Shear force Distribution on the link rod
SF= W
Bending Moment, M_b= -WL (1)

Where: W is the human effort on the foot pedal and L, is the length of the rod;
Deflection on the link ∂ is given by

$$\partial = \frac{-WL^3}{3EI} \quad (2)$$

Where;
E = Modulus of elasticity
I is the Moment of Inertia, I for solid shaft is given by

$$I = \left(\frac{\pi d^4}{64}\right) \quad (3)$$

3.2 Design analysis for axial tensile stress on the link

This is given by the relationship;

$$\sigma_E = \frac{W}{A_r} \quad (4)$$

Where
A_r = crossectional area of the rod
σ_E = axial tensile stress

3.3 Design analysis for bending stress on the link rod.

This is obtained by the relationship,

$$\frac{M}{I} = \frac{\sigma_b}{y} \quad (5)$$

Where;
M_b = Bending moment acting at the given section
σ_b = Bending stress
y = Distance from the neutral axis to the extreme fibre
Therefore bending stress,

$$\sigma_b = \frac{My}{I} \quad (6)$$

3.4 Design analysis for safe tensile load on the bolt during tightening

P_i = 2840 d (7)
Where;
P_i= Initial tension on the bolt
d= Nominal diameter of the bolt
Stress Area on the bolt, A_s of size M8 is given by

$$A_s = \frac{\pi}{4}\left[\frac{d_p + d_c}{2}\right]^2 \quad (8)$$

Where;
d_p = effective pitch diameter
d_c = core diameter
d_n = Nominal diameter
$L_s = A_s \times Ps$ (9)
Stress build-up, $\sigma_u due$ to initial tightening is calculated thus,

$$\sigma_u = \frac{P1}{\frac{\pi}{4}dc^2} \quad (10)$$

Torsional shear stress caused by the frictional resistance of the threads during tightening is given by;

$$\tau_s = \frac{16T}{\pi[d_c]^3} \quad (12)$$

Where;
τ_s = Torsional shear stress
T = Torque transmitted during shaft coupling

$$T = n_b \frac{\pi}{4} d_b^2 . \tau_s \times R_b \quad (13)$$

n_b = Number of bolts
R_b = radius of bolt circle

3.5 Design analysis for fillet weld consideration.
When a connection with end fillet is loaded in tension, the weld develops high strength and the stress developed in the weld is equal to the value of the weld metal.
The weld is subjected to shear and the weld shear strength is limited to just about half the weld metal tensile strength. For intermediate weld positions, the value of strength and ductility show intermediate values.

Circular fillet weld subjected to bending moment
Maximum bending stress on the welded parts

$$\sigma_b(\max) = \frac{5.66\,M}{\pi s d^2} \quad (14)$$

(Khurmi and J.K Gupta, 2005)
Where M = Bending moment on the rod (Nm)
s = size (or leg) of weld
d = diameter of the rod.
In this case,
Maximum shear stress occurring at the throat is given by;

$$\tau_{tmax} = \frac{4.242\,T}{sL^2} \quad (15)$$

(Khurmi and J.K Gupta, 2005)
Where T is the torque transmitted in Nm,
s = size (or leg) of weld, and
L= length of the weld

4.0 PERFORMANCE EVALUATION

4.1 Existing Pedal
The car was fueled and started to read a number of various engine speeds with the corresponding pedal displacements from idle position. Table 6 shows the tabulated reading of engine Speed in RPM with its corresponding displacement in millimeters.

4.2 Adapted Pedal
The car was also fueled and ignited in order to read a number of various engine speeds with the corresponding pedal displacements from idle position. Table 7 shows the reading of engine Speed in revolution per minute with its corresponding displacement in millimeters.

5.0 REULTS AND DISCUSSION
The engines speed runs 2000rpm at an idle position of the existing pedal as shown by the red line in Figure 8 compared to the adapted pedal which runs at 1500rpm. This low speed indicates improved efficiency and minimizes fuel consumption. Also when the two pedals were activated and pressed through an arc length of 45mm, both engine speeds read 6000rpm. Although there were little deviations in the curves at displacement position 20mm and 30mm respectively. These deviations have no significant effect on the performance of the engine.

6.0 CONCLUSION

The Left Foot Adapted Pedal, LFAP design and fabrication were based on the anthropometric data of the client,
evaluating the performance of the existing pedal as basis for functionality comparison .The above facts have been justified by using the design parameters to fabricate the project. Revolution of engine speed of 6000rpm through 45mm displacement arc of left foot pedal was achieved as compared with the existing pedal. Since Engineering is all about problem solving and making life comfortable for people, this design goes along way putting smile in the face of disables who intend to drive himself around with ease.The left foot accelerator pedal (LFAP) is an inexpensive low-tech device commonly prescribed by driver rehabilitation specialists to allow persons who cannot use their right foot to operate a motor vehicle. The LFAP is a mechanical adaptive device that allows left foot operation of the accelerator. This device transfers the throttling mechanism on the right side of the vehicle throttle pedal to the right. This work was initiated in response to a Right Leg Paraplegic Patient (RLPP) coupled with the Supervisions to conduct technical and ergonomics evaluations of the LFAP to determine the degree to which this adaptation could be better compared with the existing right foot pedal. Although great progress has been made by manufacturers and mobility equipment dealers in the field of automotive adaptive devices, the performance and safety of LFAPs is not currently regulated by Nigeria standards or guidelines.

References

[1] Andras V. (2002): Speed Regulation in Car Active Accelerator Pedal, IATSS Research Journal Vol. 26(2), Pp 5, Department of Technology and Society, Lund University, Sweden.

[2] Jae Younglee (2010): A Novel Design of Active Accelerator Pedal using Linear Electromagnetic Actuator, A Journal of

Mechanical Science and Technology (2010) Pp 3, Department of Mechanical Engineering, Yeungnam University, Korea.

[3] James, C. Patry and Suanne, L. (2000): Left Foot Accelerator Pedal Evaluation, A Journal of Mechanical Science and Technology (2000), Pp71-80, and Transportation Development Centre, Canada.

[4] John Fulland and Bjorn Peters (1999): Regulation and Routines for Approval of Passenger Cars Adaptor to Drivers with Disabilities, VTI Rapport (447), Pp 35, National Road and Transport research institute, Sweden.

[5] Khupantavee, N and et' al (2008): A meaning of Well-being, Experience of Paraplegic Thai people, A Medical Journal of Human Science Vol. 12, Pp 3, Department of Medical Nursing, Faculty of Nursing, Prince Songkla University, Hat Yai, Songkhla.

[6] Khurmi, R.S. and Gupta, J.K. (2005): A Textbook on Machine Design, First Multicolour Edition.

[7] Tachakra S. (1981): "The Needs for the Disables" A British Medical Journal Vol. 283, Pp 25, British.

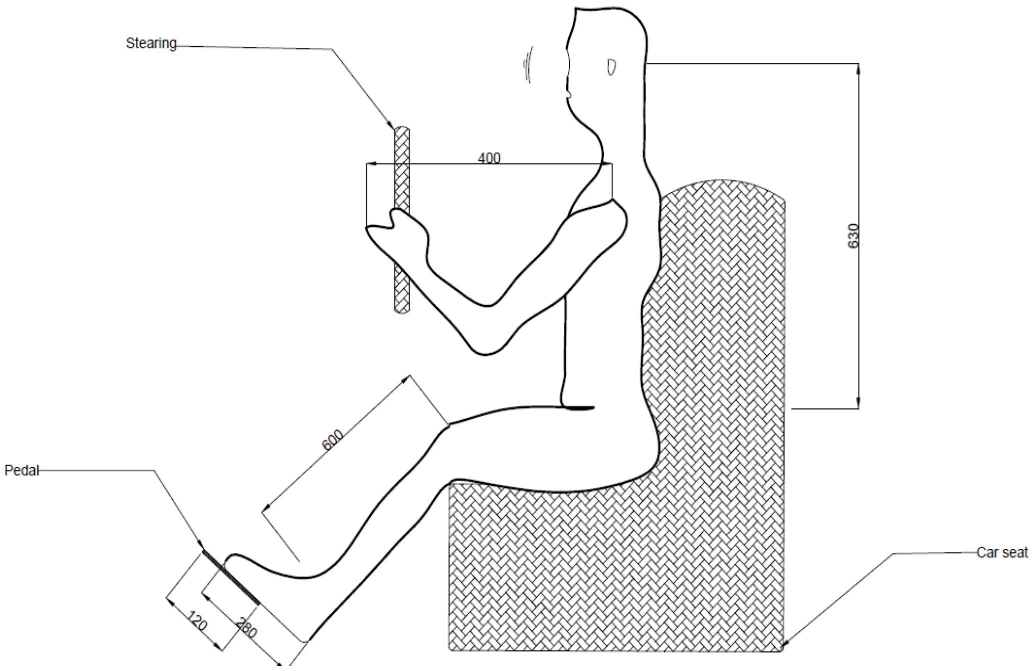

Fig 1: Anthropometric data of the patient taken and used for the design

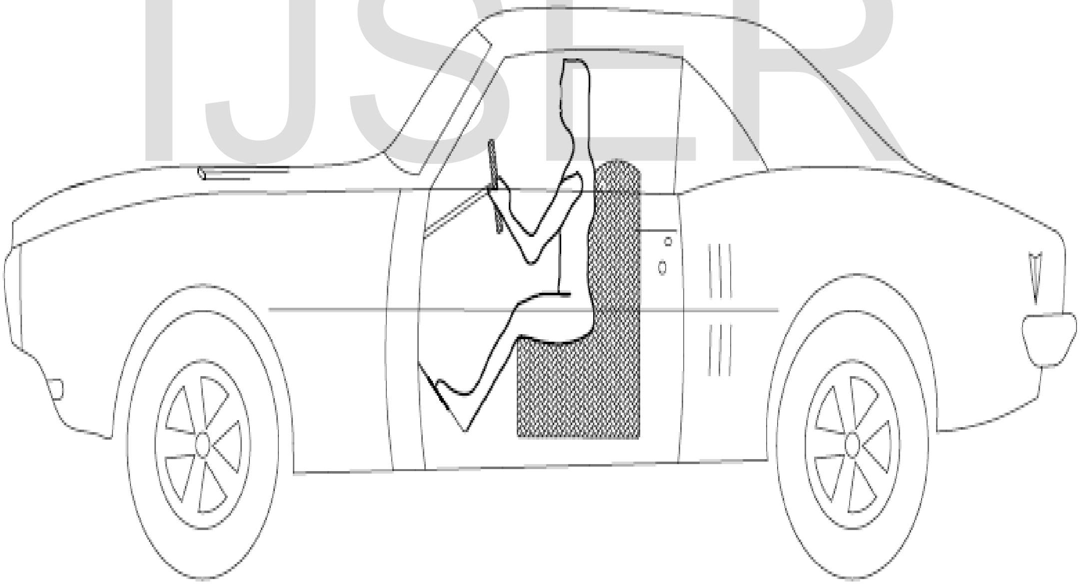

Fig 2: Position of the Driver on Vee-Boot Wagon Mercedes 230

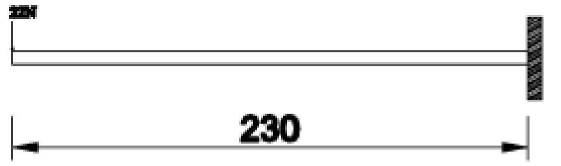

Fig 3: Static Loading Diagram

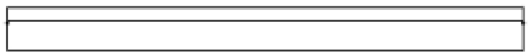

Fig 4: Shear Force Diagram

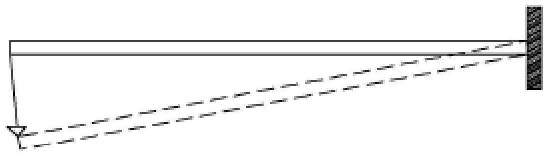

Fig 5: Bending Moment Diagram

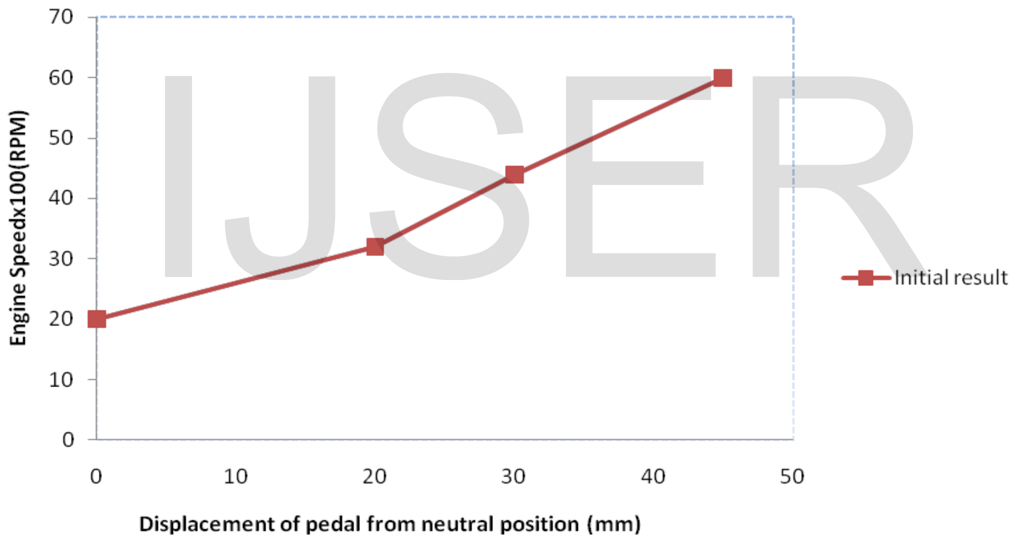

Fig 6: Performance Evaluation of the existing Pedal

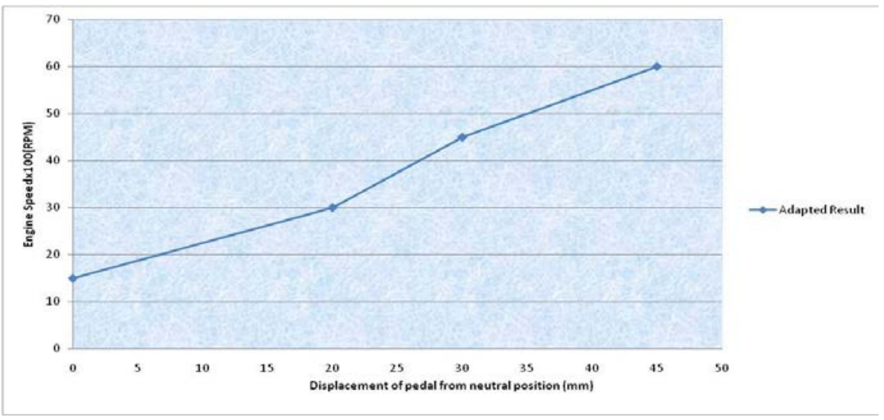

Fig 7: Performance Evaluation of Adapted Pedal

Table 1: Results of design analysis of the component parts of adapted left foot pedal

S/No	Parameter	Abbreviation	Value	Unit
01	Shear force Distribution on the link rod	W	22.00	N
02	Modulus of elasticity	E	200.00	N/mm^2
03	Rod length	L	230.00	mm
04	Deflection	∂	0.90	mm
05	Moment of Inertia for solid shaft	I	4.909E-10	m^4

Table 2: Results of design analysis for axial tensile stress on the link

S/No	Parameter	Abbreviation	Value	Unit
01	Diameter of the link shaft	d	10.00	mm
02	Crossectional area of the link shaft	A_r	7.855E-9	m^2
03	Axial tensile stress	σ_E	2.80	N/mm^2

Table 3: Results of design analysis for bending stress on the link rod

S/No	Parameter	Abbreviation	Value	Unit
01	Bending moment acting at the given section	M	5.06	Nm
02	Bending stress	σ_b	51.54	MN/m^2
03	Distance from the neutral axis to the extreme fibre	y	0.01	m

These values of axial stress and bending stress on the link rod form the basis for fastening selection and welding design analysis.

Table 4: Results of design analysis for safe tensile load on the bolt during tightening

S/No	Parameter	Abbreviation	Value	Unit
01	Nominal diameter of	d	8.00	mm
02	Effective pitch diameter	d_p	7.19	mm
03	Core diameter	d_c	6.47	mm
04	Nominal diameter	d_n	8.00	mm
05	Initial tension on the bolt	P_i	22.72	N
06	Stressed area on the bolt	A_s	36.6	mm^2.
07	Permissible stress on the selected bolt	P_s	60.00	MN/m^2
08	Safe load on the bolt	L_s	2.20	KN
09	Stress build-up, *due* to initial tightening	σ_u	0.69	MN/m^2
10	Torsional shear stress	τ_s	12.20	MN/m^2
11	Torque transmitted during shaft coupling	T	0.65	Nm

Table 5: Results of design analysis for safe tensile load on the bolt during tightening

S/No	Parameter	Abbreviation	Value	Unit
01	Maximum bending stress on the welded parts	σ_b(max)	9.12	MN/m^2
02	Bending moment on the rod	M	5.06	(Nm)
03	size (or leg) of weld	s	0.01	m
04	diameter of the rod	d	0.01	m
05	Maximum shear stress occurring at the throat	τ_{tmax}	0.31	MN/ m^2
06	length of the weld	L	0.03	m

Table 6: Readings obtained from testing the Existing Pedal

S/No	Engine Speed×100(RPM)	Displacement of pedal from neutral position (mm)
01	20	0
02	32	20
03	44	30
04	60	45

Table 7: Readings obtained from testing the Adapted pedal

S/No	Engine Speed×100(RPM)	Displacement of pedal from neutral position (mm)
01	15	0
02	30	20
03	45	30
04	60	45

Table 8: comparison of existing pedal and adapted petal

S/No	Engine Speedx100(RPM) Before	Engine Speedx100(RPM) After
1	20	15
2	32	30
3	44	45
4	60	60