Rao et al. 2018. *Int. J. Vehicle Structures & Systems*, 10(6), 411-414
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.10.6.07

International Journal of
Vehicle Structures & Systems
Available online at www.maftree.org/eja

Ride Comfort of Urban Minibus Driver through Optimization of Seating Parameters and Vehicle Speed

M. Jaganmohan Rao[a,b], S.P. Sivaprakasam[a] and G. Yan Arora[c]

[a]*Dept. of Mech. Engg., National Institute of Tech., Tiruchirappalli, India*
[b]*Corresponding Author, Email: mjrtvs@gmail.com*
[c]*Ashok Leyland, Chennai, Tamil Nadu, India*

ABSTRACT:

The current research details the urban minibus drivers comfort levels. These buses are used for shuttle services within the city as well as school services. Long seating is a vibrant risk factor for back pain for minibus driver's exposed to whole body vibration (WBV). In this paper, effects of seat inclination, speed and seat distance from the ABC pedal on seat acceleration are investigated by the statistical methods of analysis of variance (ANOVA), Taguchi's orthogonal array, regression analysis. Process parameters are prioritized by Taguchi's L27 orthogonal array. ANOVA determines the significance and percentage contribution of each parameter. Seat inclination has a greater contribution on ride comfort followed by the speed and seat horizontal distance. To optimize the human comfort vibration in minibus, genetic algorithms and multiple regression models were used. The values predicted from experimental, regression model and genetic algorithms values are found to be in good correlation.

KEYWORDS:

Minibus; Whole body vibration; Taguchi method; Genetic algorithm; Multiple regression models

CITATION:

M.J. Rao, .S.P. Sivaprakasam and G.Y. Arora. 2018. Ride Comfort of Urban Minibus Driver through Optimization of Seating Parameters and Vehicle Speed, *Int. J. Vehicle Structures & Systems*, 10(6), 411-414. doi:10.4273/ijvss.10.6.07.

1. Introduction

The automotive industry inspires research in the field of subjective and objective comfort assessment to the seat and the related postures. In the vehicle design process, the driver seating position is one of the important issues to be considered. In passenger and commercial vehicles such as buses, tractors and other heavy construction automotive, drivers are always in contact with the seat, the steering wheel, pedals and backrest. The transfer path of the vibration to the human body parts are the seat, steering wheel, pedal and backrest. The driver posture in the vehicle is the main reason for vibration transmitted to him. To decrease the vibrations transmitted to the driver, there is a systematic postural analysis required. Quite a few researches on postural changes effects have been described. Bovenzi and Zadini [1] have investigated the occurrence of low back symptoms in urban drivers.

Wlider et al [2] verified the effect of driver posture and seat suspension design on discomfort during simulated truck driving. Studies have been done in the field or lab in which subjective response and objective values human response of the vibration were explored. The main purposes of those investigations were to vary the different parameters were affecting the bio dynamics response to vibrations related discomfort [3]. In some research, the driver posture and the seat conditions were investigated and compared how those variables affect the ride comfort [4].

In the current research minibus driver ride comfort is studied by the input parameters - seat inclination (SI), seat horizontal distance (SHD) from the ABC pedal and vehicle speed (S) with the output parameter being driver seat acceleration. Most important parameter has been identified by using the statistical method Taguchi L27 orthogonal array and the ANOVA to find out the statistical significance of the process parameters. It was used to study the responses by changing the factors. To show the relationship between the dependent and independent variables regression analysis is applied. To derive the optimized process parameters of the human comfort to vibration for urban minibus driver genetic algorithm and multiple regression analysis have been used.

2. Instrumentation and procedure

Table 1 shows the characteristics of the vehicle considered for the measurement. The minibus was driven and the acceleration between the driver seat and driver is recorded in various combinations of test conditions. ICP type piezoelectric accelerometer was used for measuring the acceleration in x, y and z direction on the seat pad. Fig. 1 shows the accelerometer location. LMS data acquisition system and software were used for data acquisition and analysis as shown in Fig. 2. According to ISO 2631-1:1997 [5], the measurements were analyzed and compared. The measured x, y and z vibration acceleration values are used to compute the vibration total values using,

$$Av = (k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2)^{1/2} \quad (1)$$

As per ISO 2631 a_w is weighted acceleration and k is the multiplying factor. Table 2 shows the weighted acceleration levels in a minibus. In the current research, the highway type road condition with different speeds (30, 40 and 50kmph), different body postures (90, 110 and 130°) and seat distance from the ABC Pedal (400, 480 and 560mm) were considered for the vibration assessment in the minibus. For the human comfort, the frequency range considered for whole body vibrations (WBV) is 0.5 Hz to 80 Hz.

Table 1: Urban mini bus specifications

Parameter	Value
Wheel base (mm)	4835
Type of engine	Diesel
Weight - Unladen (kg)	3800
Weight- Laden (kg)	7500
Seating	27
Suspension	Air

Fig. 1: Accelerometer location on driver seat

Table 2: Minibus driver weighted acceleration level (Hz)

S (kmph)	SI (°)	SHD (mm)	x	y	z	Av
30	90	400	0.36	0.42	0.39	0.267
30	90	480	0.27	0.36	0.48	0.274
30	90	560	0.29	0.33	0.35	0.184
30	110	400	0.27	0.92	0.74	1.011
30	110	480	0.27	0.92	0.74	1.011
30	110	560	0.19	0.67	0.61	0.584
30	130	400	0.32	0.41	0.48	0.303
30	130	480	0.27	0.39	0.48	0.286
30	130	560	0.31	0.33	0.36	0.195
40	90	400	0.44	0.53	0.52	0.435
40	90	480	0.37	0.48	0.53	0.388
40	90	560	0.35	0.43	0.5	0.334
40	110	400	0.34	1.13	0.78	1.419
40	110	480	0.39	1.09	0.84	1.390
40	110	560	0.39	1.05	0.8	1.284
40	130	400	0.36	0.5	0.65	0.508
40	130	480	0.36	0.43	0.58	0.405
40	130	560	0.39	0.43	0.5	0.346
50	90	400	0.31	0.94	0.72	1.029
50	90	480	0.54	0.79	0.83	0.974
50	90	560	0.17	0.64	0.65	0.589
50	110	400	0.51	1.6	1.06	2.808
50	110	480	0.34	1.3	0.89	1.870
50	110	560	0.35	1.08	0.95	1.480
50	130	400	0.36	0.98	0.75	1.121
50	130	480	0.55	0.88	0.75	1.004
50	130	560	0.45	0.69	0.62	0.645

Fig. 2: LMS Scadas data acquisition system

3. Results and Discussion

3.1. Taguchi Methods

Taguchi is a statistical method; it involves reducing the process variation. To obtain the optimum results of the process, Taguchi method involves identification of proper control factors. To conduct a set of experiments, an orthogonal array is used. The process parameters considered in this study are - S (kmph), SI (°), and SHD (mm). Different factors are shown in Table 3. Table 4 shows the input and output parameters of the minibus. Table 5 shows that SI, S and SHD are ranked as 1st, 2nd and 3rd respectively.

Table 3: Main factors and their values

Factors	Level 1	Level 2	Level 3
S (kmph)	30	40	50
SI (°)	90	110	130
SHD from ABC pedal(mm)	400	480	560

Table 4: Input factors and output results

Exp. No	S (kmph)	SI (°)	SHD (mm)	Awt (Hz)
1	30	90	400	0.267
2	30	110	480	0.274
3	30	130	560	0.184
4	30	90	400	1.011
5	30	110	480	1.011
6	30	130	560	0.584
7	30	90	400	0.303
8	30	110	480	0.286
9	30	130	560	0.195
10	40	90	400	0.435
11	40	110	480	0.388
12	40	130	560	0.334
13	40	90	400	1.419
14	40	110	480	1.390
15	40	130	560	1.284
16	40	90	400	0.508
17	40	110	480	0.405
18	40	130	560	0.346
19	50	90	400	1.029
20	50	110	480	0.974
21	50	130	560	0.589
22	50	90	400	2.808
23	50	110	480	1.870
24	50	130	560	1.480
25	50	90	400	1.121
26	50	110	480	1.004
27	50	130	560	0.645

Table 5: Parameters ranking

Level	S (kmph)	SI (°)	SHD (mm)
1	30	90	400
2	40	110	480
3	50	130	560
Delta	0.8228	0.9313	0.3621
Rank	2	1	3

3.2. Analysis of variance (ANOVA)

ANOVA is a statistical based objective decision making tool in which two or more parameters vary or differ in an experiment. It measures the amount of variation between group and variation within group. Table 6 shows the ANOVA results. SI (51.01%) is identified as a first inducing parameter followed by S (32.34 %) and SHD (6.1 %). Fig. 3 shows the same. Fig. 4 shows the main effects plot.

Table 6: Percentage contribution of input parameters

Parameter	DoF	SS (Adj)	MS (Adj)	F	P	% contrib.
S (kmph)	2	3.1728	1.58638	30.65	0	32.34
SI (°)	2	5.0033	2.50163	48.33	0	51.01
SHD (mm)	2	0.5982	0.2991	5.78	0.01	6.10
Error	20	1.0351	0.05176			10.6
Total	26	9.8093				100

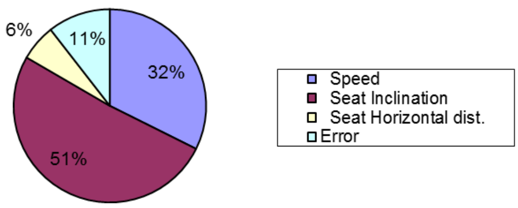

Fig. 3: Process parameters contribution in percentage

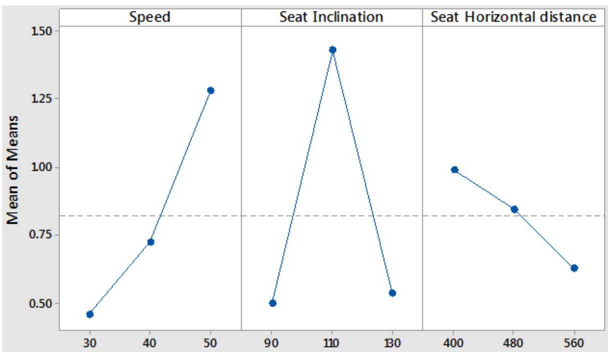

Fig. 4: Main affects plots

3.3. Optimization of input parameters for better ride comfort

3.3.1. Multiple regression analysis

Multiple regression analysis is a statistical tool that allows examining how multiple independent variables are related to a dependent variable. Once you have identified how these multiple variables relate to your dependent variable, you can take information about all the independent variables and use it to make much more powerful and accurate predictions about why things are the way they are. This latter process is called "Multiple Regression" [6]. The equations of weighted RMS acceleration were produced based on the control factors and their interactions. The regression equations (model building) created for Awt is given by [8],

$$Awt = -27.87 + 0.0063X1 + 0.5029X2 + 0.00451X3 + 0.001452X1^2 - 0.002281X^2 - 0.000169X1 * X3 \quad (2)$$

Where X1 = S, X2 = SI andX3 = SHD from ABC pedal. R^2 = 0.916 which means regression model with 91.61% fit of the variation in Awt. Fig. 5 shows the multiple regressions for Awt. When S and SI were low and SHD is large, we will achieve less WBV. At high S and low SHD, the vibration levels are high. Fig. 6 shows the effect, prediction and optimization report of multiple regression analysis. For the lower WBV, the optimum values of S, SI and SHD are 30 kmph, 90 ° and 560 mm respectively.

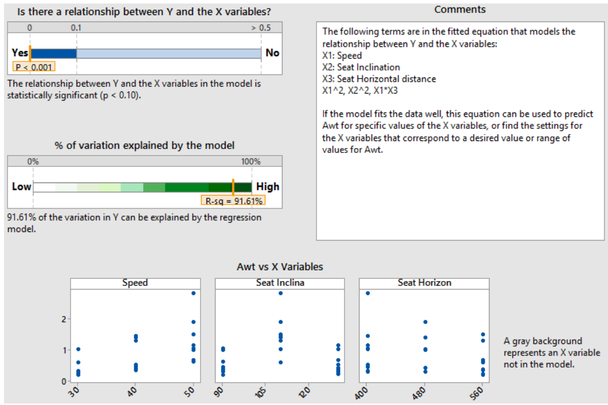

Fig. 5: Summary report of regression analysis

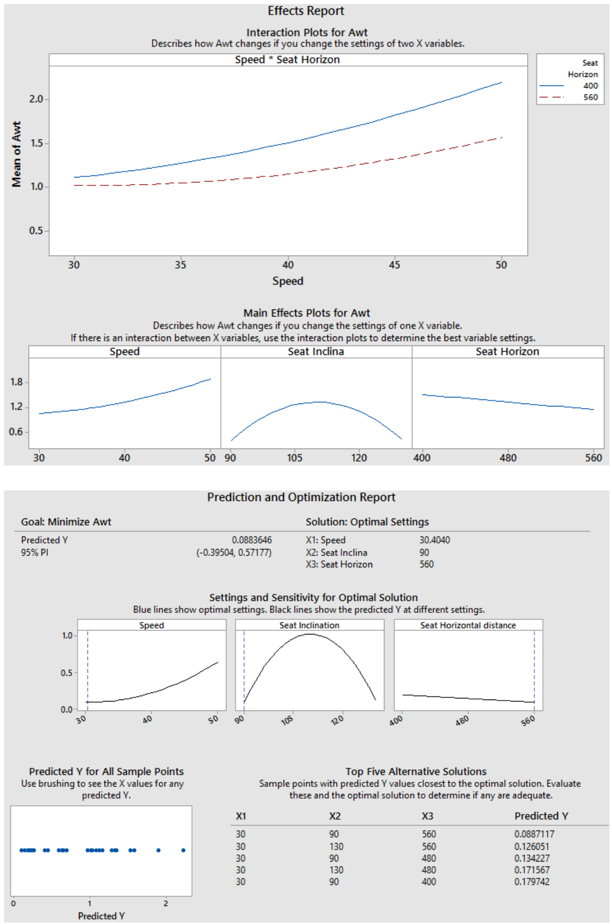

Fig. 6: Effect, prediction and optimization report

3.3.2. Genetic algorithm

Genetic algorithm (GA) is a search technique used in computing to find the approximate solutions to optimization and search problems [7]. They are a class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection and crossover. Fig. 7 shows the structure of GA. In our research, the GA basic elements are the value of S, SI, SHD and WBV = f (S, SI, SHD). Table 7 shows the parameters used in GA. The limitations during WBV analysis, ride comfort parameters are - 30 <= S < = 50kmph, 90 < =SI < = 130° and 400 < = SHD < = 560mm. For the minimum acceleration, the optimized parameters are presented in Table 8. The GA, multiple regression analysis and experimentally obtained values for driver seat acceleration are almost same values. By optimization study, the minimum acceleration levels have been achieved.

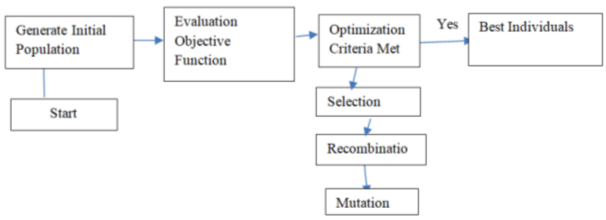

Fig. 7: Structure of GA

Table 7: GA parameters

Parameter	Value
Population size	100
Length of chromosome	20
Section operator	Stochastic uniform
Crossover probability	0.8
Mutation probability	0.2

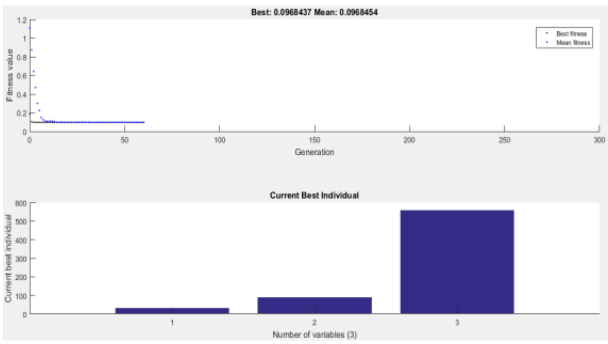

Fig. 8: GA convergence results

Table 8: Optimized results

Method	S (kmph)	SI (°)	SHD (mm)	Awt (Hz)
GA	30.42	90	560	0.097
Regression model	30.40	90	560	0.09
Experimental	30	90	560	0.1

4. Conclusions

In this study, a process has been developed to reduce the human comfort vibration for minibus drivers. The process is capable of improving the driver comfort with less fatigue. Taguchi's L27 orthogonal array was used to prioritize the process parameters. Process parameters SI, S and SHD are ranked as first, second and third respectively. In ANOVA study, SI makes the highest contribution (51%), followed by S (32%) and SHD (6%). Multiple regression analysis and GA were used to optimize the ride comfort parameters. The optimized values of SI, S and SHD are 90°, 30kmph and 560mm respectively. The experimental data, GA and multiple regression model optimized values are almost the same. Because of the coherence between the theoretical and experimental optimized values, there is a high potential for applying GA to the human comfort vibration for minibus drivers.

ACKNOWLEDGEMENTS:

The authors are thankful to the management of Ashok Leyland, Chennai for the support rendered to carry out the experiments.

REFERENCES:

[1] M. Bovenzi and A. Zadini. 1992. Self-reported low back symptoms in urban bus drivers exposed to whole body vibration, *Spine*, 17(9), 1048-1059. https://doi.org /10.1097/00007632-199209000-00007.

[2] D. Wilder, M.L. Magnusson, J. Fenwick and M. Pope. 1994. The elect of posture and seat suspension design on discomfort and back muscle fatigue during simulated truck driving. *Applied Ergon.*, 25(2), 66-76. https://doi.org/10.1016/0003-6870(94)90067-1.

[3] N. Nawayseh and M.J. Griffin. 2012. Power absorb during whole-body fore-and-aft vibration: effects of sitting posture, backrest, and footrest, *J. Sound and Vibration*, 331, 252-262. https://doi.org/10.1016/ j.jsv.2011.08.015.h.

[4] W. Wang, S. Rakheja and P.E. Boileau. 2004. Effects of sitting postures on biodynamic response of seated occupants under vertical vibration, *Int. J. Ind. Ergon*, 34, 289-306. https://doi.org/10.1016/j.ergon.2004.04. 009.

[5] *Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-body Vibration - Part 1: General Requirements*. 1997. ISO, 2631-1.

[6] A.K. Sahoo, A.N. Baral, A.K. Rout and B.C. Routra. 2012. Multi-objective optimization and predictive modeling of surface roughness and material removal rate in turning using grey relational and regression analysis, *Int. Conf. on Modelling, Optimization and Computing, Proc. Engg.*, 38, 1606-1627. https://doi.org/10.1016/j.proeng.2012.06.197.

[7] D. Kim and S. Rhee. 2001. Optimization of arc welding process parameters using a genetic algorithm, *J. Welding*, 80(7), 184-189.

[8] *MINITAB TM*, Statistical software, Release 15.