

Investigation of Shock Signals from SAE J577 Mechanical Shock Machine

Barış Ediz^{1*}, Erhan Ay¹, Emre Öztürk¹

0000-0002-2704-7090, 0000-0001-9621-6030, 0000-0001-5492-9358

¹ Marelli Mako Turkey Electric Industry and Trade Inc., Bursa, 16140, Turkey

Abstract

In this study, acceleration signals measured from the SAE J577 mechanical shock machine are investigated in detail. The aim of this investigation is to derive representative standard acceleration signals to be used as acceleration loads for finite element fatigue analysis of Automotive Lighting parts. These signals can also be used as load inputs for vibration shakers which have the capability of driving time domain signals. First of all, acceleration signals have been measured from the free machine table and by the help of the signal analysis software, automatic averaging operation has been performed from the long data of shock signals to have a single average acceleration shock signal. Furthermore; because the machine is force controlled, it is understood that the total weight and the overall dimensions of the device under test (DUT) and the fixture have significant effect on Grms levels transmitted to DUT. Thus, measurements are repeated on the different sized fixtures and the results are compared in order to understand the effects of the fixture size and the weight on test severity.

Keywords: Automotive Lighting; SAE J577; Signal Averaging; Test fixture

* Corresponding author

Barış Ediz

baris.ediz@marelli.com

Adress: Organized Industrial Zone,
Yesil Street, No:28, 16140,
Nilufer/Bursa

Tel:+902242195684

Fax:+902242195799

Research Article

Manuscript

Received 31.05.2019

Revised 15.11.2019

Accepted 17.02.2020

Doi: 10.30939/ijastech..572497

1. Introduction

Automotive Lighting products such as headlamps, rear lamps, day time running lights (DRL), fog lights, etc., are subject to shock and vibration loads during their service life. Society of Automotive Engineers (SAE) recommends a test machine for simulating these harsh conditions in SAE J577 recommended practice [1].

During design and development stage of lighting products; it is possible to determine the strength and life of the structures against dynamic loading by the help of finite element analysis (FEA) if a standard dynamic load is present. In SAE J577 test method, minimum Grms limit transmitted to DUT and maximum total weight limits are given for the fixture and DUT. Hence, depending on the weight of fixture + DUT; energy levels transmitted DUT may vary. As a result; evaluation of the designed product strength is not reliable until the date of physical tests. Over design can be done or failures after development leads to further rein-

forcements on failed parts and modifications are required on production equipment, like molds. In other words; product development cost increases. Thus, determination of a standard acceleration shock signal which is applicable to wide range of products to be used as a load input for transient FEA is inevitable.

Schrader et al (2006) have inspected one automotive headlamp using the SAE J577 shock test procedure and measured acceleration signals. They used acceleration signals as load inputs for FEA and compared the measured strain and transient FEA strain results. They took the average of signals by time synchronous averaging technique. However, in the study, the effect of fixture size/weight and the effects of positions of accelerometers on the severity of the test were not inspected [2]. Xie, K. 2007 performed a study in this field to detect failures by different methods during SAE J577 shock test performed on an automotive headlamp. Also, time synchronous averaging technique has

been used to derive a single average shock signal. The effect of the size/weight variation of the DUT and the fixture on the severity of the test was not inspected [3]. Ediz, B. & Telli Çetin, S. (2019), have derived average acceleration signals during SAE J577 tests on a DRL and used them as loads on an updated finite element model (FEM). They have validated measured and calculated strains. However, they did not expand their studies and did not investigate the effects of different sized/weight fixtures and products on the severity of the test [4, 5]. Braun, S. 2010, have explained to extract periodic components from shock signals and they presented different signal averaging and signal filtering techniques [6].

The main aim of this study is to derive a standard acceleration signal to be used as an acceleration shock load on automotive lighting housing attachment points during transient FEA analysis without including the fixture model. Another aim is to derive a standard acceleration shock signal to be used by vibration shakers to simulate SAE J577 test. In order to achieve these aims, first of all, acceleration signals from the machine table measured when operating without pay load by the use of 3 axis accelerometer. Later on, measurements are repeated on 3 different sized fixtures from the positions of 3 attachment points of automotive lighting products. At the end, average signals are calculated and results are compared. A standard average acceleration shock signal applicable to wide range of automotive lighting products is derived.

2. SAE J577 Test Machine

In order to perform mechanical shock tests; a special machine manufactured according to SAE J577 specification is used.(Fig.1). Machine model is BAT-Mechanik 016-019-001-2015-BG. Technical data is given in Table 1. The vibration test machine is built with its components drive motor, drop arm and anvil on a common base plate made of steel. The vibration isolation to the site via four maintenance-free vibration mounts which are secured to the underside. The drop arm is mounted on one side on the base plate and is raised by a cam. After reaching the highest point of the arm falls on an anvil. The drop arm is biased by springs with $290\text{N} \pm 20\text{N}$, whereby an increase in the rate of fall is achieved. The cam is driven by a V-belt by a three-phase motor [7].

Lighting product is mounted on a fixture and the fixture is bolted to the clamping plate. Drop arm impacts to the anvil at a frequency of $12,5\text{Hz} \pm 0,17\text{Hz}$ and with displacement amplitude of $3,2\text{mm} \pm 0,25\text{mm}$. The weight of the DUT and the fixture shall be a maximum of 27.0 kg. Resultant energy imparted to the DUT shall be a minimum of 4.0 Grms as measured with a 200G accelerometer with a signal processing bandwidth of 600Hz [1].

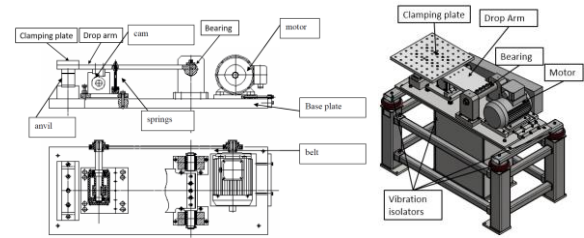


Fig. 1. SAE J577 Shock Machine

Table 1. SAE J577 Shock Machine Technical Data

Dimension (mm)	1140x900x640
Mass (kg)	400
Clamping Plate (mm)	200x100
Tightening Torque (Nm)	34
Max. Test Object Mass (kg)	55
Drop Height (mm)	3.175
Frequency (Hz)	12,5 (Cam speed 750 1/m in)
Drive	Three-phase motor 230/400 V;50Hz;0,75kW750 1/m in
Sound Level	<120dBA (measured at 1 m distance)

3. Shock Acceleration Measurements

At first; measurements are performed from the clamping plate without load to understand machine behavior during idle operation. Afterwards, measurements are performed on the product mounting locations of the fixtures while 3 different sized fixtures mounted on the clamping plate of the machine.

3.1 Measurements on machine clamping plate without load

3 axis accelerometer is attached on the middle point of the clamping plate shown on Fig.2.a. Measurement is performed for 10 minutes and acceleration signals are recorded for all 3 directions. Coordinate system of the accelerometer is marked on it and shown on Fig.2.b. X-axis is for measuring the accelerations in longitudinal direction, Y-axis is for measuring the accelerations in lateral direction of the clamping plate, Z-axis is for measuring the accelerations in vertical direction to the mounting base. 16 channel signal acquisition hardware and its signal processing software is used

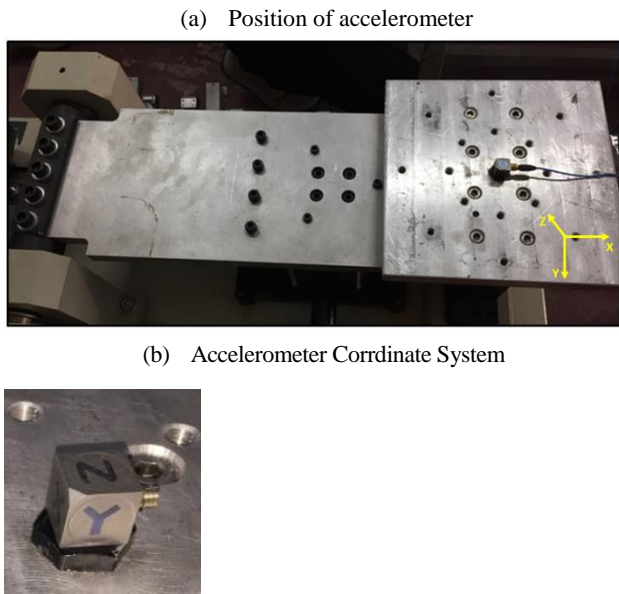


Fig. 2. (a) Position of axis accelerometer position, (b) Coordinate system of accelerometer

3.2 Measurements on Different Sized / Weight Fixtures

Measurements are repeated on three different sized fixtures. (Fig.3 & Fig.4). Even one of them is heavier than the defined weight limit in SAE J577 specification; it is tested to understand the effect of weight on test severity and the level of Grms transmitted to DUT. Other two are in the weight range. Fixtures are numbered from 1 to 3. Fixture 1 and 2 are used for vibration durability testing of different brand automotive DRL's (Fig.3.1 & Fig.3.2). Fixture 3 is used for vibration durability testing of one automotive headlamp (HL) (Fig 3.3)

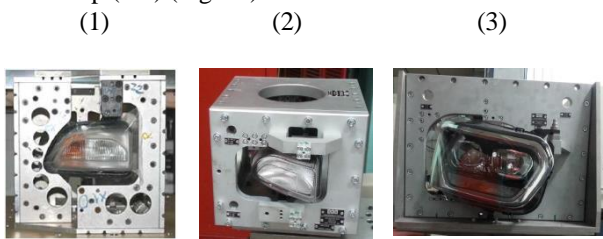


Fig 3. Automotive Lighting Products Mounted on Test Fixtures

There are 3 attachment points for automotive lighting device on these fixtures. Accelerometers are placed close to 3 attachment points and measurements are done for 10 minutes duration. 3 axis accelerometers are used. Accelerometers are from 1 to 3. Accelerometer located at the base of the fixture designated with the letter B. General dimensions and weight of the fixtures are given on Table.2

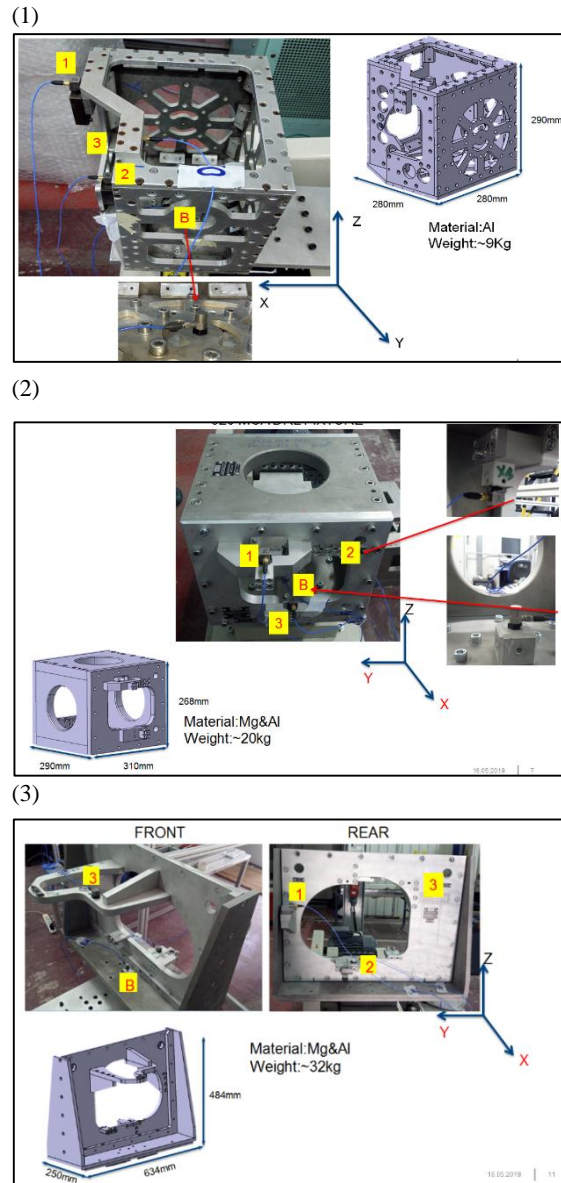


Fig 4. Fixture 1 (1) & Fixture 2 (2) & Fixture 3 (3)

Table 2. Fixture sizes and weights

	Fixture 1	Fixture 2	Fixture 3
Height (mm)	290	268	484
Width (mm)	280	310	634
Depth (mm)	280	290	250
Weight (kg)	9	20	32>27

4. Measurement Results

At first, acceleration signals from clamping plate without load are inspected and then results from 3 different fixtures mounted are inspected. All results summarized and tabulated.

Time Synchronous Signal averaging technique is used (Fig.5) and average signals are calculated from the repetitive acceleration shock signals by the help of signal acquisition software. A trigger signal is used in order to determine the instant of each impacts. All signals are cut from the start and end points then aligned. Afterwards, all of them are added. As a result; arithmetical average is taken; such as dividing by the number of shocks.

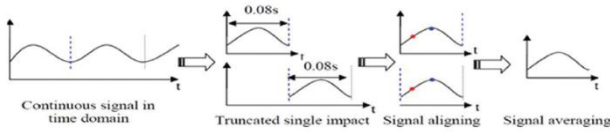


Fig 5. Time Synchronous Signal Averaging (Kongying, X. 2007)

4.1 Results of Clamping plate without load

10 minutes long acceleration shock signal data is given for all 3 directions on Fig.6.

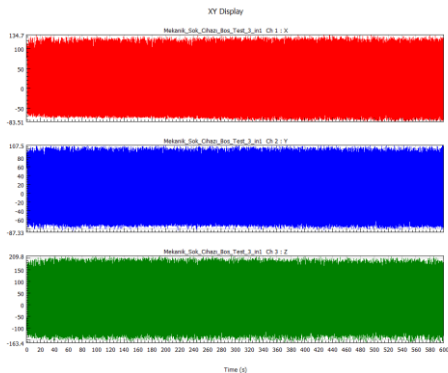


Fig 6. Acceleration Shock Signal data for 3 Directions

The calculated average acceleration signals are given on Fig. 7.

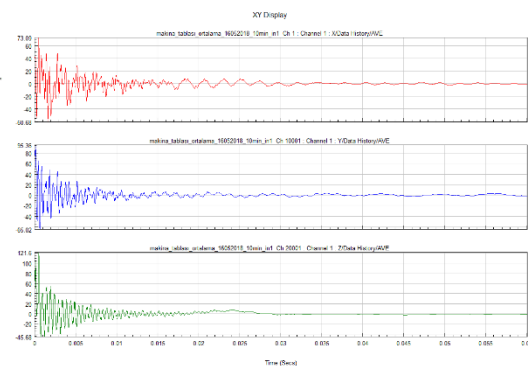


Fig 7. calculated average acceleration signals

Statistical information about the averaged processed shock signals is given on Table 3.

Table 3. Statistical Information of Averaged Processed Shock Signals

	X (g)	Y (g)	Z (g)
Peak	74,82	81,69	130,5
RMS	8,987	7,341	12,98

4.2 Results of Different Size Fixtures

As explained on section 4.1; 10 minutes long synchronous measurements have been done from each fixture locations. There are 3 different fixtures and 4 measurement locations for each fixture, 3 positions for DUT attachments and 1 for the fixture base. All accelerometers except for the base used are 3 axis accelerometers. Base accelerometer has only z-direction. As a result, there are 30 shock data and 30 single averages. Calculated average signals of fixtures for each location in 3 directions are given in table 4, table 5 and table 6.

Table 4. Average Acceleration Shock Signals for Fixture 1

Location&Direction	Result Graph
Location 1_Dir. X	
Location 2_Dir. X	
Location 3_Dir. X	
Base_Dir. X	n/a
Location 1_Dir. Y	
Location 2_Dir. Y	
Location 3_Dir. Y	
Base_Dir. Y	n/a
Location 1_Dir. Z	
Location 2_Dir. Z	
Location 3_Dir. Z	
Base_Dir. Z	

Table 5. Average Acceleration Shock Signals for Fixture 2

Location&Direction	Result Graph
Location 1_Dir. X	
Location 2_Dir. X	
Location 3_Dir. X	
Base_Dir. X	n/a
Location 1_Dir. Y	
Location 2_Dir. Y	
Location 3_Dir. Y	
Base_Dir. Y	n/a
Location 1_Dir. Z	
Location 2_Dir. Z	
Location 3_Dir. Z	
Base_Dir. Z	

Table 6. Average Acceleration Shock Signals for Fixture 3

Location&Direction	Result Graph
Location 1_Dir. X	
Location 2_Dir. X	
Location 3_Dir. X	
Base_Dir. X	n/a
Location 1_Dir. Y	
Location 2_Dir. Y	
Location 3_Dir. Y	
Base_Dir. Y	n/a
Location 1_Dir. Z	
Location 2_Dir. Z	
Location 3_Dir. Z	
Base_Dir. Z	

5. Comparison of Results

Results are tabulated for individual fixtures in order to understand the difference in transmitted acceleration levels on different measurement locations. Tables can also be compared with each other in order to understand the fixture size effect to the transmitted G levels to DUT.

Peak and RMS values of average signals are calculated for comparison. Tabulated results for fixture 1, fixture 2 and fixture 3 are given in Table 7, Table 8 and Table 9, respectively in order to understand the difference between the acceleration amplitudes on different locations of the fixtures.

Table 7. Comparison table for fixture1 measurement positions

	Direction X			
	Location 1	Location 2	Location 3	Base
Peak(g)	102,1	102,4	109,6	---
RMS(g)	11,98	15,06	28,04	---
	Direction Y			
	Location 1	Location 2	Location 3	Base
Peak(g)	103,2	68,2	88,07	---
RMS(g)	9,217	13,37	12,43	---
	Direction Z			
	Location 1	Location 2	Location 3	Base
Peak(g)	82,05	124,4	94,13	55,74
RMS(g)	11,26	12,74	14,72	4,155

Table 8. Comparison table for fixture 2 measurement positions

	Direction X			
	Location 1	Location 2	Location 3	Base
Peak(g)	35,58	60,25	69,99	---
RMS(g)	3,934	5,211	6,886	---
	Direction Y			
	Location 1	Location 2	Location 3	Base
Peak(g)	36,63	52,02	44,51	---
RMS(g)	5,551	7,159	5,633	---
	Direction Z			
	Location 1	Location 2	Location 3	Base
Peak(g)	67,75	109,3	58,09	40,48
RMS(g)	10,21	10,75	5,897	3,369

Table 9. Comparison table for fixture 3 measurement positions

	Direction X			
	Location 1	Location 2	Location 3	Base
Peak(g)	14,22	26,14	11,65	---
RMS(g)	2,084	4,621	3,254	---
	Direction Y			
	Location 1	Location 2	Location 3	Base
Peak(g)	23,26	10,08	16,26	---
RMS(g)	5,871	1,492	3,729	---
	Direction Z			
	Location 1	Location 2	Location 3	Base
Peak(g)	27,48	32,18	26,31	45,66
RMS(g)	2,776	3,421	9,547	2,266

By inspection of above comparison tables; it is clear that the amplitudes of acceleration signals are different than each other on each location. Depending on the modal characteristics of the fixture, due to resonance and mode shapes; measured accelerations are different on each locations and Grms values are higher than the base signal Grms value.

Table 10 compares the base acceleration of fixtures with respect to free machine clamping plate acceleration in z direction.

Table 10. Effect of fixture size on base acceleration

		Peak(g)	RMS(g)
Clamping Plate w/o load		130,5	12,98
Fixture 1		55,74	4,155
Base	% Decrease	-57,2%	-68%
Fixture 2		40,48	3,369
Base	% Decrease	-69%	-74%
Fixture 3		45,66	2,266
Base	% Decrease	-65%	-85,5%

By inspection of table 10; it can be concluded that as the fixture weight increases, base acceleration amplitude levels decrease. It can be said that the size and the weight of the fixture has significant effect on transmitted G levels to DUT.

In order to understand if there is a possibility to use a standard and safe shock signal for transient FEA's as load inputs; below table 11 is prepared for comparing the base acceleration signals of machine clamping plate without load and measurements results for all fixtures.

Table 11. Comparison of all measured signals from all fixtures and from DUT attachment locations with the signals measured from machine clamping plate without load.

		Direction X			
		Loc. 1	Loc. 2	Loc. 3	Base
Fix.1	Peak(g)	102,1	102,4	109,6	---
Fix.2	Peak(g)	35,58	60,25	69,99	---
Fix.3	Peak(g)	14,22	26,14	11,65	---
Clamping plate w/o load	Peak(g)	74,82			
Fix.1	RMS(g)	11,98	15,06	28,04	---
Fix.2	RMS(g)	3,934	5,211	6,886	---
Fix.3	RMS(g)	2,084	4,621	3,254	---
Clamping plate w/o load	RMS(g)	8,987			
		Direction Y			
		Loc. 1	Loc.2	Loc. 3	Base
Fix.1	Peak(g)	103,2	68,2	88,07	---
Fix.2	Peak(g)	36,63	52,02	44,51	---
Fix.3	Peak(g)	23,26	10,08	16,26	---
Clamping plate w/o load	Peak(g)	81,69			
Fix.1	RMS(g)	9,217	13,37	12,43	---
Fix.2	RMS(g)	5,551	7,159	5,633	---
Fix.3	RMS(g)	5,871	1,492	3,729	---
Clamping plate w/o load	RMS(g)	7,341			
		Direction Z			
		Loc. 1	Loc. 2	Loc. 3	Base
Fix.1	Peak(g)	82,05	124,4	94,13	55,74
Fix.2	Peak(g)	67,75	109,3	58,09	40,48
Fix.3	Peak(g)	27,48	32,18	26,31	45,66
Clamping plate w/o load	Peak(g)	130,5			
Fix.1	RMS(g)	11,26	12,74	14,72	4,155
Fix.2	RMS(g)	10,21	10,75	5,897	3,369
Fix.3	RMS(g)	2,776	3,421	9,547	2,266
Clamping plate w/o load	RMS(g)	12,98			

From the table 11, if free machine clamping plate signals are compared with all measurements; it can be concluded that free machine clamping plate acceleration signals are safe enough to be applied as acceleration loads on the automotive lighting housing attachment points for transient FEA in case of total weigh of DUT & the fixture are between 20kg and 27Kg; similar to fixture 2. Moreover, it satisfies minimum 4 Grms level defined in SAE J577 specification.

6. Conclusions

In this study, it is shown that fixture size/weight and attachment location of DUT to the fixture have significant effect on the acceleration shock signals transmitted to DUT during SAE J577 test. As fixture weight increases, base acceleration signal's peak and rms values decrease. However, due to mode shape of corresponding resonance of the fixture and due to the position and distance of DUT attachment points with respect to base, acceleration Grms levels increase.

It can be concluded that the acceleration signals measured from free machine clamping plate can be safe enough to be used as acceleration loads on automotive lighting housing attachment points during transient FEA analysis without including the fixture model. This will reduce calculation time and analysis result file size.

Another output of this study is that the derived standard acceleration shock signal can be used on vibration shakers which have capability to apply loads in time domain, and which can drive high force and displacements in case of total weight of the fixture and the DUT is between 20kg to 27kg.

References

- [1] J577-201509. (2015). Vibration test machine and operation procedure. *SAE International*.
- [2] Schrader, CD. (2006). Dynamic structural simulation of the SAE J577 vibration test. *SAE Technical Paper Series*.
- [3] Kongying, X. (2007). Automotive light assembly failure detection. *MSc Thesis, Department of Mechanical and Materials Engineering, Queen's University Kingston, Ontario, Canada*
- [4] Telli Çetin, S., Ediz, B., Ay, E., Çal, T. (2019). Shock tests on car daytime running light and FEA validation study. *Uludag University Journal of the Faculty of Engineering*, 24 (1), 1-12.
- [5] EDİZ, B. (2018). Updating and verifying the finite element model of a passenger vehicle daytime running light for computer shock tests, *MSc Thesis, Department of Mechanical Engineering, Uludag University, Bursa/Türkiye*
- [6] Braun, S. (2010). The synchronous (time domain) average revisited. *Proceedings of ISMA2010 Including USD2010, Technion City, Haifa, Israel*.
- [7] Manual SAE J577.(2011) *BAT Mechanik GmbH*