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Development of Driver Analysis System to Improve Driving Comfort and to Reduce Mechanical Abrasion in Vehicles

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Accelerometer,
microprocessor,
road analysis,
shock absorber,
abrasion

Abstract: The purpose of this study is; to develop a system that can detect road disturbances and can warn the driver. For this purpose, a measurement method which tracking as a 3-axis of the road situation with a semiconductor MEMS-based accelerometer has been developed to be used to detect vehicle vibration and drive conditions which has a serious effect on the driving quality of the road. With the developed measuring system, road wear and tear can be successfully reported. Thanks to the improved system, the driver can also be warned by detecting vehicle suspension damage. In addition, a driver performance report may be drawn up under the project that is very important for fleet and service owners (universities, municipalities and other similar public and corporate entities). Thus, the damage caused by the bad use of the vehicles can be reduced to the minimum; the operating costs can be reduced.

The sensor on the measurement card developed for this purpose is placed at the lower control arm portion point of the vehicle to be used in the test drives (Renault Thalia II/Symbol brand 2012 model). A testing road with a length of 135 meters was constructed and test runs were carried out at different speeds (10km/h, 20 km/h, 30 km/h, 40 km/h and 50 km/h). 7 bumps with varying dimensions were placed on the created road route at intervals of 5 meters. The obtained data were recorded on the SD card and then analyzed in the Matlab program by filtering it from the noise. A total of 2099 data were analyzed. As a result, driver performances can be categorized successfully (Normal, Medium, Bad, Very Bad, Very Very Bad) for each test drive according to the speed and condition of the road bumps. Sound and light stimulation of the driver when the bulges and the pits are entered in the test runs repeated in the result of the determined threshold acceleration value after the reference driving has also been successfully achieved.

Sürüş Konforunu Artırmak ve Araçlarda Mekanik Aşınmayı Azaltmak için Sürücü Analiz Sisteminin Geliştirilmesi

Anahtar Kelimeler
İvmeölçer,
mikroişlemci,
yol analizi,
amortisör,
aşınma.

Özet: Bu çalışma; yol bozukluklarını tespit edebilen ve sürücüyü uyaran bir sistem geliştirmeyi amaçlamaktadır. Bu amaçla, yarıiletken MEMS tabanlı bir ivmeölçer ile yol durumunun 3 ekseni olarak izleyen, araç titreşimi ve yolun sürüş kalitesi üzerinde ciddi etkisi olan sürüş koşullarının tespitinde kullanılmak üzere bir ölçüm yöntemi geliştirilmiştir. Geliştirilen ölçüm sistemi ile yol kaplaması ve yırtıkları başarılı bir şekilde tespit edilebilir. Geliştirilen sistem sayesinde, araç süspansiyonunun hasar görmesi durumunda sürücü uyarılabilir. Buna ek olarak, filo ve servis sahipleri (üniversiteler, belediyeler ve benzeri kamu ve tüzel kişiler) için çok önemli olan proje kapsamında araç sürücüsü performans raporu hazırlanabilir.

Böylece araçların kötü kullanımından kaynaklanan hasar minimuma indirgenebilir; işletme maliyetleri azaltılabilir.

Bu amaçla geliştirilen ölçüm kartındaki sensör, test sürüşlerinde kullanılacak aracın (Renault Thalia II / Symbol marka 2012 model) alt salıncak kolu üzerine yerleştirildi. 135 metre uzunluğunda bir test yolu düzenlendi ve farklı araç hızlarında (10 km / s, 20 km / s, 30 km / s, 40 km / s ve 50 km / s) test çalışmaları yapıldı. Oluşturulan yol güzergahına 5 m aralıklarla değişen boyutlarda 7 adet tümsek yerleştirildi. Elde edilen veriler SD karta kaydedilmiş ve daha sonra Matlab programında gürültüden filtre edilerek analiz edilmiştir. Toplam 2099 veri analiz edildi. Sonuç olarak, sürücü performansları yol testlerinin hızına ve durumuna göre her test sürüşü için başarıyla kategorize (Normal, Orta, Kötü, Çok Kötü, Çok Çok Kötü) edildi. Test sürüşünde tümsek ve çukurlara girildiğinde sürücünün ses ve ışık ile uyarım işlemi, referans sürüşü yapıldıktan sonra belirlenen eşik hızlanma değeri sonucunda tekrarlanır. Referans sürüşü başarı ile yapıldıktan sonra, test sürüşü sırasında tümsek ve çukurlara girildiğinde sürücü ses ve ışık ile uyarım işlemi, belirlenen eşik hızlanma değerlerinde de sonuç tekrarlanır.

1.Introduction

The automobile companies have been developing diverse methods to improve driving comfort and to reduce mechanical abrasion in vehicles. One of the important methods is using handheld devices [1]. Another method is nanotechnology used in automotive in order to customers' demands to improve safety and comfort [2]. In this study; a system that can detect road disturbances and warn the driver is developed. So, a measurement method has been developed which can be used to detect vehicle vibration and drive conditions, which are generated by a 3-axis tracking of the road situation with a semiconductor MEMS-based accelerometer and which has a serious effect on the driving quality of the road.
During the acceleration and deceleration of the vehicle, inertia forces are generated in the vehicle in the reverse direction. The force encountered during the movement of the vehicle is called the "Acceleration Resistance", since it is opposite in direction to the acceleration and consists of the inertia forces of the masses in linear motion and the rotational inertia forces of the wheels [3]. Braking, accelerating, and changing the direction of a vehicle creates momentum on the vehicle [4]. For this reason, acceleration and deceleration of the drivers cause acceleration resistance on the vehicle. There are systems that provide audible stimulation to drivers according to acceleration resistance, allowing them to drive more controlled [5]. But these systems are not cheap and do not have widespread use.
With the developed measurement system, road wear and tear status can be report. It is by detecting the vehicle suspension damage and the driver will be alerted.

2.Materials and Method

2.1.Acceleration and Accelerometer

Accelerometers were first used for walking analysis in 1950. After 1970, studies on the identification of human movements using accelerometers have started. With the development of MEMS technology, the costs of accelerometers have decreased considerably and this has made the accelerometers more popular. In the same way, the power consumption of the accelerometers has decreased considerably with the MEMS technology and the sensor sensitivity has increased considerably. Using the first sensor developed by MEMS was 1979. Since then, the use of accelerometers in wearable systems, in-vehicle applications and in physical activity monitoring has become widespread in various commercial and academic researches [6].

The differences between the accelerometers are due to production techniques such as low power consumption, low cost and small size. These features are preferred in most accelerometer applications. In this study; due to the features of small size, low power consumption, low cost, high data transfer rate, high sensitivity, high resolution and low noise ratio in the Cartesian coordinate system, which can give 3-dimensional numerical output, produced by Analogue Device, MEMS-based semiconductor The accelerometer ADXL345 is preferred. The ADXL345 accelerometer has become very popular in recent years and is widely used in many different applications [7-13]. Figure 1 shows the block structure of ADXL345 [14].

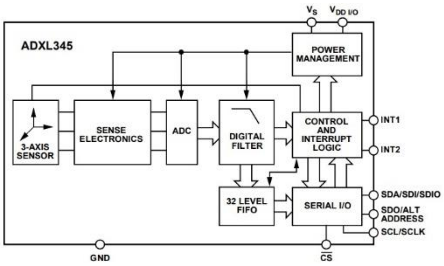
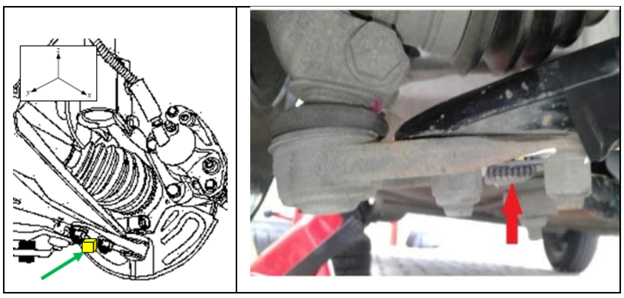


Figure 1. Block diagram of the ADXL345 accelerometer.

2.2.Position of the Accelerometer on the Vehicle

Gardulski's study on the diagnostic tests of shock absorbers in 2006 aimed to determine the proportional effect of the contact force of the wheel on the soil in a method developed by the European Shock Absorber Manufacturers Association (EUSAMA) to evaluate the suspension efficiency. In the shock absorber tests, two transducers (transducers) are adapted by means of a magnet to the lower wishbone and damper mounting tower in the housing. The transducers are mounted axially next to the vehicle damper mountings. The measured values have been shown to accelerate according to the movement of the damper [15]. In another study examining the effect of road noise on in-car noise; the contribution of road noise from each vehicle axle to acoustic amplification within the cabin was investigated by transfer path analysis (TPA) s application. In the operation, reference sensors are used in the wheel suspension hubs, around the chassis - body connection points and in the receiver inside the cab. These three reference sequences are presented for the basic component decomposition and their applications are examined considering their physical meaning and understanding of vehicle structural dynamics. The results showed that it could be applied to the development of full-vehicle computer-aided engineering (CAE) applications [16].

Based on the literature review, the lower control arm section were preferred in order to measure the effect of the hills and pits on the ground in the road analysis system. The sensor was attached to this point by means of plastic band and measurements are carried out. Figure 2 shows the position of the sensor at the lower control arm point.



(a) (b)

Figure 2. Lower control arm measuring point, a) Lower control arm accelerometer connection point, b) Lower control arm accelerometer position.

The sensor is attached to the lower control arm by closing the sensor with a plastic band in order to avoid any change in the sensor position, to be not affected by dust and similar materials and to make the measurement faultless.

2.3.Hardware Components of the measuring system

The system consists of many electronic components; Microcontroller, Accelerometer, Real Time Clock, Micro SD Card & Adapter, LCD Display, Buzzer, Button, Led. The motherboard circuit installed on the board is drawn with the help of the Fritzing program as shown in Figure 3.

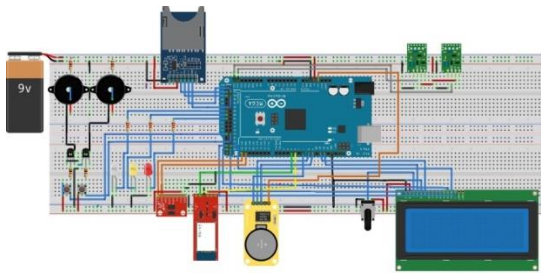


Figure 3. The fritzing drawing on the main circuit on board.

When the device is energized, the device first controls its peripheral equipment (SD card, RTC module, sensor connection). When there is a problem in the equipment, the device gives an audible and light warning and informs the user about the error and wants to restart the device by removing the fault. If the connections are checked and the error is cleared, the device will be ready for use. When the START option is selected from the menu, the program starts processing according to the algorithm. The measuring system is designed and executed as a closed loop. The developed measurement kit is shown in figure 4.

Figure 4. The developed measurement kit.

2.4.Testing Road

The total length of the road is 135 meters and the bumps are placed in the road with 5 meters each. The characteristics of the road are given below and the points where actual pictures and bumps are placed are shown in Figure 5.

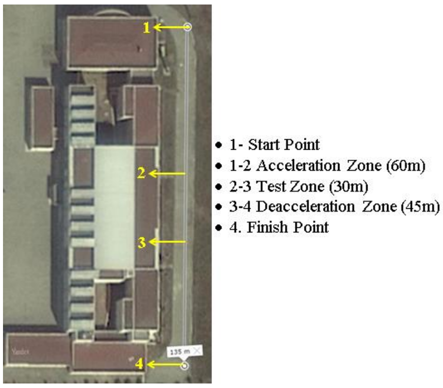
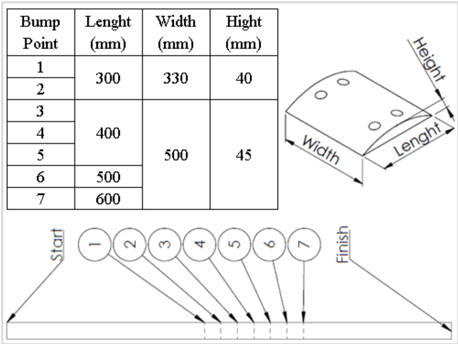


Figure 5. Testing Road

The bumps placed in the road during measurement have various lengths, widths and heights. The bumps used in the testing road are shown in Figure 6.



Bump Point	Lenght (mm)	Width (mm)	Hight (mm)
1	300	330	40
2			
3	400	500	45
4			
5			
6	500		
7	600		

Figure 6. Bumps used in testing road.

2.5.Results

The accelerometer was mounted on the lower control arm and measurements are made at different speeds. The graphs obtained are as shown in figure 7.

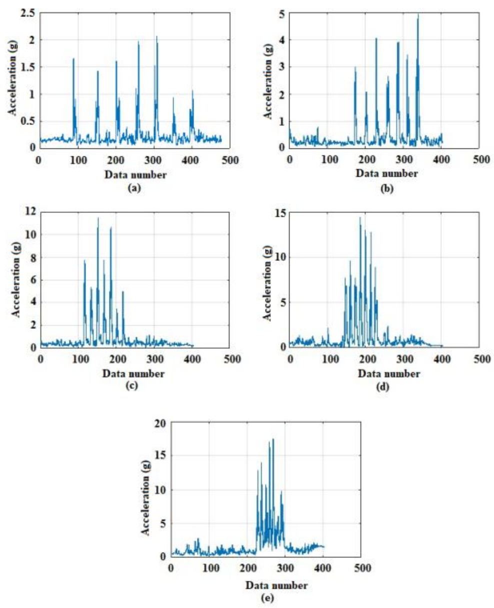


Figure 7. Vibrations measured at different speeds through the lower control arm, (a) 10km/h, (b) 20km/h, (c) 30km/h, (d) 40km/h, (e) 50km/h.

When the Figure 7 is carefully examined, the vibrations of the bumps on the vehicle are measured in proportion to the vehicle speed and the acceleration amplitudes increase considerably according to the speed of the previous measurement point. When the speed of the vehicle increases, the frequency of vibration increases and this makes the vibrations felt in the vehicle more permanent and continuous. When the graphs are examined, it can be easily understood that this measurement point is subjected to more vibration than the vehicle body. From the graphs, the number of bumps in the road and the speed of the vehicle can also be understood. As the speed of the vehicle increases, the frequency of vibration increases and causes more sensible vibrations in the vehicle. This shows that the in-car comfort deteriorates and indicates that the vehicle is more worn out. Similar to the first measurement, an acceleration threshold value was determined according to the measurement results, and in the same way from the same point.
Figures 8 and 9 are screenshots of the driving record with data sent to the computer via the serial port.

```
Total Bumps: 3
Total Pits:3
Total Bumps and Pits:6
Recording Stop Time: 09:20:02

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Driving Performance: Normal
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```

Figure 8. Reporting of the driving record-1.

According to this, the vehicle entered a certain number of pits and bumps on Monday 18.06.2018 at 09:05:16. In this way, a data base can be created by reporting and recording the data specific to the tools.

```
 YOL ANALİZ SİSTEMİ
Sensorleri Baglayiniz..
Kayit Baslatilacak..
Onay Icin Tuslayiniz
SD Karta Kaydediyor.
Kayit Bas. Zamani:
2018-06-18 09:20:15
  X     Y     Z     R     Gun   Tarih       Saat    Esik Durumu
  _     _     _     _      _    ______      _____   ___________
0.15  0.16  0.94  0.22  Pazartesi 2018-06-18 09:20:15    ------
0.14  0.14  0.94  0.21  Pazartesi 2018-06-18 09:20:16    ------
0.15  0.14  0.95  0.21  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.14  0.96  0.20  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.14  0.95  0.20  Pazartesi 2018-06-18 09:20:16    ------
0.13  0.14  0.94  0.20  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.14  0.95  0.21  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.15  0.95  0.21  Pazartesi 2018-06-18 09:20:16    ------
0.13  0.15  0.96  0.20  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.14  0.94  0.21  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.14  0.94  0.21  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.09  1.01  0.16  Pazartesi 2018-06-18 09:20:16    ------
0.13  0.06  1.04  0.15  Pazartesi 2018-06-18 09:20:16    ------
0.14  0.42  0.75  0.51  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.20  0.57  0.76  0.65  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.27  0.61  0.72  0.72  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.28  0.58  0.80  0.67  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.20  0.73  0.64  0.83  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.26  0.71  0.73  0.80  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.25  0.64  0.70  0.75  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.23  0.70  0.73  0.78  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.18  0.70  0.71  0.78  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.19  0.71  0.69  0.80  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.26  0.66  0.86  0.72  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.24  0.65  0.70  0.76  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.03  0.62  0.63  0.72  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.18  0.39  0.92  0.43  Pazartesi 2018-06-18 09:20:16    TÜMSEK
0.16  0.25  1.07  0.30  Pazartesi 2018-06-18 09:20:17    ------
0.06  0.26  0.96  0.27  Pazartesi 2018-06-18 09:20:17    ------
0.10  0.23  0.92  0.26  Pazartesi 2018-06-18 09:20:17    ------
0.08  0.24  0.88  0.28  Pazartesi 2018-06-18 09:20:17    ------
0.12  0.18  0.96  0.22  Pazartesi 2018-06-18 09:20:17    ------
0.15  0.08  0.89  0.20  Pazartesi 2018-06-18 09:20:17    ------
0.13  -0.04  0.88  0.18  Pazartesi 2018-06-18 09:20:17    ------
0.07  -0.10  1.00  0.13  Pazartesi 2018-06-18 09:20:17    ------
0.07  -0.28  0.90  0.31  Pazartesi 2018-06-18 09:20:17    ------
0.24  -0.45  0.80  0.54  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.21  -0.44  0.88  0.50  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.19  -0.46  0.89  0.51  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.16  -0.44  0.84  0.49  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.19  -0.47  0.87  0.53  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.16  -0.46  0.78  0.54  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.19  -0.48  0.86  0.53  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.17  -0.46  0.86  0.50  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.20  -0.46  0.84  0.53  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.17  -0.45  0.90  0.49  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.17  -0.45  0.88  0.50  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.20  -0.45  1.14  0.51  Pazartesi 2018-06-18 09:20:17    ÇUKUR
0.13  -0.29  0.74  0.41  Pazartesi 2018-06-18 09:20:17    ------
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Figure 9. Reporting of the driving record-2.

3. Discussion

Within the scope of the project, a measurement system has been designed and implemented for user driving performance and road analysis. For this purpose, the accelerometer (ADXL345) was placed in different points on the vehicle (suspension cover, damper, front panel) and the vibrations occurring at these points were recorded to the SD card in real time and 3 axes in a defined way to the Cartesian coordinate system. For this purpose, a national and national software and algorithm has been created. In addition, the driver excitation system with LCD display, buzzer and light (led) warning system is installed in a vehicle (above the torpedo) that will not disturb the user. When the driver started to drive and started to use the vehicle, the vibrations due to the disturbances in the road and the driver errors were measured by the accelerometer and sampled by the microcontroller (arduino) to the SD card in real time. In this process, the driver's accelerator pedal or brake pedal interferences were determined by means of a clamp meter and added to the system as a driver vehicle usage characteristic. If the previously defined lower and upper limit acceleration values are exceeded, the driver is warned by sound and light exciter. These warnings can be recorded by using the vehicle driver's bad road conditions.

4. Conclusion

With the help of the accelerometer placed on the vehicle, the vibrations on the vehicle are measured in 3 axis and recorded on the SD card. The data can also be viewed in real time via the LCD screen on the computer or on the card. The recorded data can be transferred to the computer with a USB or SD card and filtered and free of noise. The silent data obtained were analysed by Matlab with the help of Matlab and some important parameters related to vibration were obtained by means of feature extraction method.
According to the data obtained;

The braking and throttle response of the driver may be observed during the passage of the wheels through the pits and bumps.

In vehicles with defective shock absorbers, wheel responses at low speeds increase.

Driver performances can be categorized successfully (Normal, Medium, Bad, Very Bad, Very Very Bad) for each test drive according to the speed and condition of the road bumps.

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