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Design and manufacturing of Shock pot mounts for Road Quality Analysis

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Retraction

Retraction: Design and manufacturing of Shock pot mounts for Road Quality Analysis (*IOP Conf. Ser.: Mater. Sci. Eng.* **1145** 012044)

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This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

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Design and manufacturing of Shock pot mounts for Road Quality Analysis

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Abstract. The main purpose of this project was to design and fabricate a system that can be used for road quality analysis. It incorporates a linear potentiometer sensor to sense the displacement of the wheel, a data logger module to collect and store the sensor data, and a mechanical mount to hold the sensor rigidly in the desired position. The sensor data stored in the datalogger is then filtered and smoothened using Butterworth filter to get clean data. This data is further plotted on a displacement v/s distance graph. Standard color codes are decided and are assigned to each condition based on their ratios. Color codes, therefore, helps in the quick graphical interpretation of the data. The solid model of the mounts is done on solid modelling software and the data interpretation part is done using MATLAB. The proposed system can be mounted on various vehicles and can be further improved by analysing the live data and representing them on the navigation systems.

Keywords: Road Quality analysis, linear potentiometer, Shock-pot mounts, Rapid Prototyping, Electrical harness, Data-logger, data interpretation, MATLAB

1. Introduction

One of the most important means of transport in India are roads. Since 1990s, major efforts have been taken to modernize the road infrastructure in India and accordingly National highways Development project (NHDP) was started by then prime minister Atal Bihari Vajpayee. There are many factors by which road performance can be indicated like the Pavement Condition Index (PCI) and the Present serviceability index (PSI) the most widely used is the International roughness index (IRI) [1]. The PCI lacks because it is a statistical measure based on visual survey of the number and types of the distresses present on roads. The second shortcoming is that it requires trained personals to complete a complicated survey procedure. The PSI also requires a panel of observers to actually, rate the pavement in question based on their riding experience thus this method proved impractical for large scale network. The IRI is roughness scale brought by the 'World Bank'. The World Bank at that time was aiding many projects which were involved in many different developing countries in the world thus there came an urgent need of a method which could categorise road quality in a way which is reproducible by different agencies using different measuring equipment and method [2]. Lesser the IRI better is the condition of road. The way in which longitudinal profile can be measured can be classified into direct and response type. A common example of response type measurement is that by an accelerometer. An example of direct measurement is that of the amount by which a shock potentiometer will displace which would be fixed using a mount. Thus, a critical issue is the placement and design of the mount. It is easier to obtain a reading in a motorcycle than in the car because reading for a car may vary for the right and left side. By calculating the IRI a comparison can be made by colour coding the quality of road for easier representation.

2. Need for the project

Though India is home to the world's second biggest road network, which sprawls 5.4 million km throughout the vast country, its roads are among the worst on the planet. In the last decade alone around 1.2 million people have died of road-related accidents which costs India about 3% of its GDP. The condition of urban roads especially has a great impact on daily economic activities. Considering a city like Mumbai which has a dense network of roads, among them there are many roads which are not considered main roads but are used more often. Quality of such roads is also not regularly monitored by the municipal authorities and thus repairing is also done less often which becomes a reason for loss of property and time for lots of daily commuters. A real time road quality monitoring system can be of great help in such situations, it would provide real time data which can be compared with international standards. Also, such data can be used by municipal authorities to grant bonus's to contractors who commit properly to the deadlines given [3]. Additionally, the colour coding system makes it much easier to interpret the data for a common man. The shock pot can be attached to majority of motorcycles and thus making it easier for obtaining data. Linking this data with google maps would make it much better as it could now provide real time traffic as well as road quality data.

3. Methodology

The objective of the research is to create a successful road surface monitoring system accepted by wide user community and it is important to make it affordable and easy to assemble. There are various existing methods to find the quality of road which includes use of infrared imaging or accelerometers. In this project, we have decided to use a linear potentiometer sensor accompanied by a data logger module. The linear potentiometer sensor also known as the 'shock pot' is mounted on the rear side of the bike suspension system. A mount is made which aids in aligning the linear sensor with the suspension spring, which helps us in getting an accurate reading and minimal compliances in the system. The sensor readings are recorded in a memory storage card which is inserted in the port on the data logger. The readings are then exported to the laptop and filtration followed by graph plotting is done.

4. Components Used and their description

4.1. Shock pots

It is a linear potentiometer which varies its output voltage signal by varying the length of the resistive element and is attached rigidly to the damper of the vehicle to measure its displacement as shown in Figure 1.

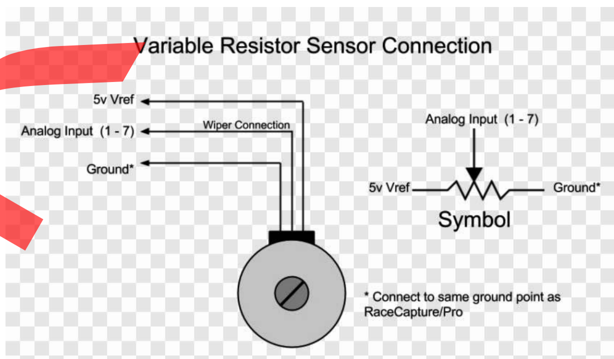

Figure 1. Electrical connection of shock pots

It is an electromechanical sensor and works when a 5 VDC input is provided and according to the extension or compression of the damper, the output analog signal voltage is varied as shown in the figure 1 above. There are many types of shock pots available in the market and the appropriate one was chosen by the method explained below.

4.1.1. Sensor Selection

Requirements:

1. Measuring range from 260 to 360 mm
2. Rose ends
3. Solid body casing
4. Sealed as standard
5. Resistance 10k Ohms
6. Super low noise output signal
7. Long operational life
8. Rigid mounting points

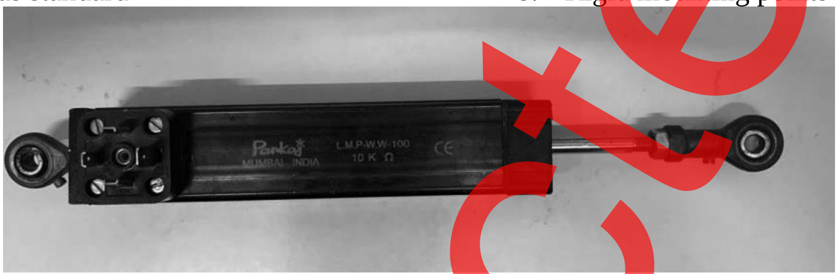

Figure 2. Assembly of the shock pot unit

Figure 2 depicts shock pot selected for the project for the above-mentioned reasons. It had to be calibrated according to our system as the mechanical and electrical travel is not the same, hence a metal fixture plate with different positions marked was taken and the calibration was done accordingly.

4.1.2. Calibration of the sensor:

The sensor calibration was done with the help of the metal plate wherein the plates had the maximum and minimum position marked [4]. The minimum position wherein the total shock pot length was 260 mm corresponds to damper length of 210 mm.

The maximum position of shock pots was 360 mm which corresponded to damper travel of 350 mm. Thus, in static position when the damper length was 280 mm the length of shock pot was 310 mm as tabulated below in Table 1.

Table 1. Calibration of shock pots

Damper Length (mm)	Shock pot Length (mm)	Voltage (V)
210	260	0
280	310	2.5
350	360	5

4.2 Shock pot mount

The Shock pot mount is used to hold the shock pot parallelly to the damper of the vehicle in order to travel the same distance as the damper and to obtain accurate readings from the same. A key consideration for its design is to avoid any bucking to occur in the system, although the shock pot is designed in manner to avoid bucking but the mount aids its design. The Shock pot mount was designed with the following considerations:

i. The mount needed to clamp the shock pot and the damper
ii. The design needed to have a clip which would sit in the slot of the shock pot
iii. It should sit between the two circlips of the damper
iv. Its purpose is to only align and avoid bucking

v. Avoid relative motion between the two entities
vi. Constant distance to be maintained between them

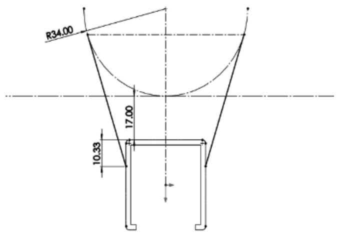

Figure 3. 2D drawing of Shock-pot mount

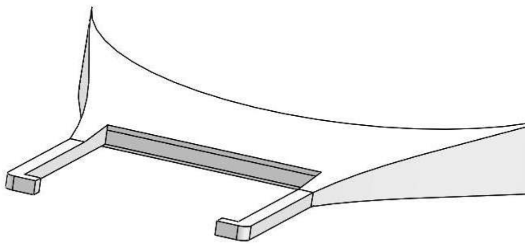

Figure 4. 3D model of the shock-pot

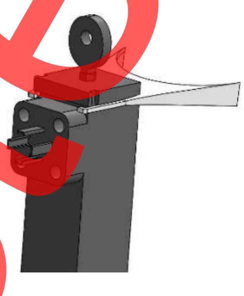

Figure 5. Assembly of our prototype

The design was made on SolidWorks by first aligning the shock pot with the damper in the assembly and keeping a distance of 17 mm between the two as shown in Figure 3. The design started with making the clip on the shock pot slot, the width of the slot was 2mm so the width of the mount on the clip side was kept 1.9 mm ensuring there would be no interference between the two and the clip would slide in easily as seen in Figure 4. Next the damper was roughly sketched and the mount had to hold it just beyond its point of tangency when a line is drawn from the edge of the shock pot and the distance between the two entities is kept 17mm. The height of the shock pot on the damper side is only taken from the distance between the two circlips on the damper being 10 mm as seen in Figure 5. Rest of the profile is lofted from one side to the next and necessary fillets are given to avoid any stress concentration.

4.3 Data logger

As the name suggests, the data logger is a device used to store all the momentary values received from the sensors and save that on a memory card so that the data can be read later. We chose the RaceCapture Pro Mk3 as our choice of data logger for the project for the following reasons:

4.3.1 Selection of the data logger:

The data logger chosen for this project would have to fulfil the following criteria's

i. Compatible to the chosen shock pot sensor
ii. Works on DC supply from vehicle's battery
iii. Onboard SD card logging
iv. Sampling rate up to 100 Hz
v. Has multiple analog ports for the sensors
vi. Has inbuilt GPS module
vii. Has inbuilt 6 axis Accelerometer and gyroscope

Amongst all, the best suited data logger for our application was the RaceCapture Pro Mk as shown below, since it met and sometimes exceeded our requirements.

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Figure 6. Race Capture module

4.3.2 Storage and telemetry:

The data logger has a provision for slotting in a SD card for data logging which starts logging as soon as the action button is presses on the module which can be seen in Figure 6. Once the data is retrieved, the SD Card can be removed and burnt on the laptop to read the data. The RaceCapture Module has another advantage of having its own application which provides the following features:

i. Live data monitoring
ii. Links the GPS co-ordinates with the sensor data
iii. Data can be viewing on any device with Bluetooth and cellular service
iv. Compare plots against each other

4.4 Harness

An electrical harness needed to be manufactured for the project to make the appropriate connections and to establish a safe and reliable system. The harness was for the following connections is shown in Table 2.

Table 2. Harness connection diagram

From	To	Nomenclature
Power Distribution Module (PDM)	Data Logger	RCP 12V In
Data Logger	Shock pot	VCC (+5 VDC)
Grounding Point	Data Logger	GND
Ground Point	Shock pot	GND
Shock pot	Data Logger	Signal

The wire to have the highest potential difference across it was the one from the Power Distribution Module (PDM) to the Data logger which worked at 12 VDC. There was a buck converter already in the PDM which would give this supply. Next came the supply VCC (+5 VDC) for the shock pot which would be from a pin off as shown in Figure 7.

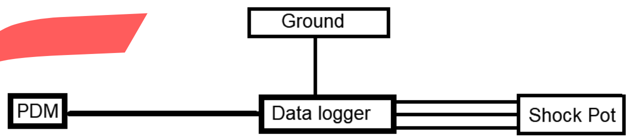

Figure 7. Harness Diagram

After inserting the crimps to the wires, the harness is twisted for the following reasons:

i. Removal of external noise from external and internal sources like
   a. Natural origins (electrostatic interference and electrical storms)
   b. Electromagnetic interference (EMI) - from currents in cables

c. Radio frequency interference (RFI) - from radio systems radiating signal
d. Cross talk (from other cables separated by a small distance).

ii. In some parts of the signal lines the direction of the noise current is the opposite from the current in other parts of the cable. Because of this, the resulting noise current is much lower than with an ordinary untwisted cable as observed in figure 8.

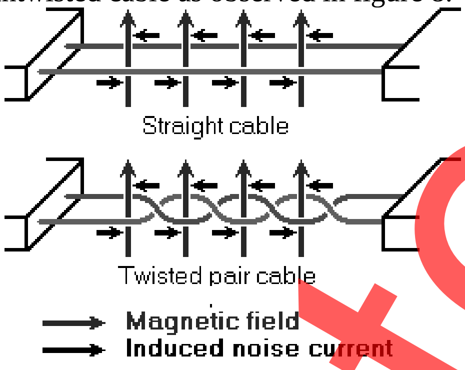

Figure 8. Effects of twisting on wiring harness

After twisting it is checked for end-to-end continuity so that there is no current leak and no defects were induced during the manufacturing of the harness.

5. Working Vehicle

Automobile suspension system utilizes the simple laws of mechanical physics to dissipate the uneven and dynamic forces acting on the wheels, in order to give a smooth and jerk-free ride. Each system's unique geometry and mechanism allows them to function according to vehicle and user specific needs. While the function of suspension is quite clear, the best design to achieve this goal is hardly so apparent. Suspension systems consist of various components and sub-systems, including the springs, the damping agent and the swing arm linkage mechanism.

5.1 Damper & Spring system

The springs in the suspension plays an important role in the functioning of the system. The force stored in the compressed springs can be given by the equation

$$F_{Spring} = -k*x$$

Where, k = spring constant for the given spring and
X = the distance the spring is compressed.

The kinetic energy (KE) stored in a compressed spring is given by the equation below.

$$KE_{Spring} = 1/2k*x2$$

While considering motorcycle suspension springs, pre-load and sag of the spring plays an important role. When the suspension system is fully extended, the amount of spring that is compressed can be defined as pre-load. The difference in the displacement of the spring from no load condition to a certain applied static load is defined as spring sag. In this case, the weight of the rider is considered to be the static load [5]

The main part of the vehicle is the damping system which consist of the shock absorbers. These are designed mechanically to handle shock impulses and dissipate kinetic energy. The function of shock absorbers is to reduce the effect of traveling over rough ground, which leads to increase in ride quality and vehicle handling.

6. Working of the system

The core function of suspension system on a vehicle is to retrace the wheels back to its normal positions after it is being acted upon and displaced by the forces of potholes or irregularities on the road surface while in motion and to dissipate the energy associated with it to ensure a smooth ride.

These dynamic forces compress the springs, which results in upward movement of the wheels. The role of the damping agent in the suspension system is to cushion these movements of the wheels and control the rate of its movement with the help of the damping fluid. In the absence of damping system, the bike would continue to remain in oscillating motion until neutralised by the friction forces. Load Transfer plays an important role in a motorcycle suspension. While acceleration and braking, the motorcycle tends to squat and anti-squat. The compression of rear suspension springs during acceleration is known as Squat. The major reasons for load transfers are i) Drag forces ii) Inertial forces due to acceleration iii) Hill Descent iv) Torque from crankshaft and clutch.

7. Manufacturing & Assembly

7.1 Fabrication of Mounts

After designing and analysing the mount for various forces, we started with the fabrication of mounts. The shock pot mount should be able to sustain the various forces and shock loads acting on it, and at the same time be lightweight, rigid and aesthetic. The mounts are needed to be sturdy such that it could absorb shocks. It requires to be made dimensionally accurate such that the mounts lie in the line of force to avoid unnecessary stresses in the component and to get precise readings. The weight of the mounts could hamper the static ride height of the two-wheeler since it would act as a pre-load for the springs. Hence the mounts should be made as light weight as possible. At the same time, the other factors to be considered are the machining time, material availability, machining cost and the lifespan of the component. The various materials and processes shortlisted are given below: The various options we had in mind were using Aluminium 6061/7075, 3D Printing (ABS) or DMLS. We aligned their properties fulfilling the functions and arrived on the conclusion to use Additive Manufacturing process (3D Printing) to fabricate the mounts.

7.2 Fused Deposition Modelling:

DM printing is done with the help of filaments or thermoplastic spools which are around 1.5 – 3mm in diameter. The Filament spool is fed to the machine through the head. A desired temperature is set to melt the filament at the extrusion nozzle. The nozzle hovers over the tray layer by layer according to the design depositing the melted material at the required locations. These melted material cools down and solidifies on the printing bed. The printing bed then moves down by 1 unit and the process in repeated until the complete part is printed.

7.3 Support Structures

Support structures are needed at some locations in FDM to obtain a précised component. These areas of support can be identified when the layer is shallower than 50 degrees when compared to the horizontal bed. These support structures help in building another layer on top of it. This makes it possible to print an overhanging layer. The support material can be easily removed afterwards. The only disadvantage of using support structures is that it affects the surface finish of the layer in contact with it.

7.4 Post Processing

For FDM printed parts it is necessary to undergo post-processing of the component to get the required dimensional accuracy and surface finish to increase the aesthetic of the product. The most commonly used post processing techniques are support removal, sanding and polishing. After printing of the component, the supports have to be removed. They are either cut, broken off or can also be dipped in solutions where the support material will dissolve. The surface in contact with support materials needs to be sanded for smooth surface. The sanding of FDM components is usually done with high grit sand paper (600 or greater) for smooth surface finish. After sanding, a plastic polishing compound is applied on the surface for aesthetic purposes.

8. Working and data acquisition

As explained before the SD Card is copied on the laptop and the data is exported to a spreadsheet and the data is viewed with its GPS co-ordinates and time. The data acquired was in delimited and in .txt form which needs to be processed further to be viewed [6]. The time, GPS coordinates and the Shock pot data was selected and transferred into another spreadsheet for keeping only the necessary tables. The data acquired is viewed on the Race Capture application and the data is compared with the previous iterations to compare the various sets of data. The application is only a mode of viewing and comparing but for the project, we had to first transfer all the data to MATLAB for the data filtration.

8.1 Procedure for Data Acquisition

Once the data logger and the shock pot sensor are mounted rigidly on the vehicle, the following procedure is followed for acquiring the data:

1. The damper is first checked for mechanical integrity
2. The main connector from the Power Distribution module is checked
3. Kill switch is turned on and values on the data logger is checked for mean position
4. The rider rides the bike at a constant speed of 20 km/h
5. No hard braking and clutch jerking are ensured
6. The data from both sides are taken and the GPS Co-ordinates are compared for every run
7. The most occurring value of the displacement of the shock pot is taken.

9. Data Smoothening

After recording various kinds of errors in the data [7], it was clear that the data acquired needed filtration. The data filtration was digitally done using MATLAB software and the results are shown in Figure 9 and 10 respectively.

Filters in consideration were:

- Butterworth
- Chebyshev Type 1
- Chebyshev Type 2
- Elliptic

Based on the output of the above filters, Butterworth Filters were chosen as they had much more smooth and flat output. 3rd Order Butterworth was used for this [8]. It is a type of signal processing filter designed to have a frequency response as flat as possible in the pass band. It is also referred to as a maximally flat magnitude filter. The frequency response of the Butterworth filter is maximally flat (i.e., has no ripples) in the pass band and rolls off towards zero in the stop band.

Given below is the code that was input in MATLAB to get output filtered data.

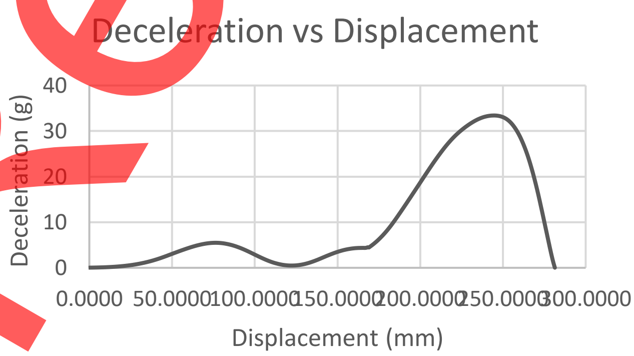

Figure 9. Unfiltered data representation

```
Data=table2array (MBARMI0000ACXP2M);
time-Data (:,1);
```

```
acc-Data(:, 2);
[b, a]-butter (3,0.01);
Filacc=filter (b, a, acc)
plot (time, filace)
title('GT curve')
Xlabel ('Time (ms)')
Ylabel ('Acceleration (gs)')
```

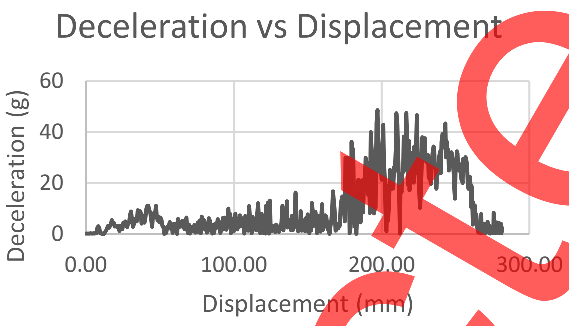

Figure 10. Filtered data representation

10. Data Representation

The data acquired will be segregated into three bands according to the International Roughness Index (IRI) where the data will be distributed into three bands of amplitude as shown in Figure 11.

Low roughness Index
Medium Roughness Index
High Roughness Index

Figure 11. Bands of road roughness

The data filtered is then plotted for the GPS co-ordinates vs the variation in the displacement from the mean position of the shock pot. The Green band indicating that the road doesn't have any potholes or undulating surface. It is in its best condition such that the car doesn't face any bumps whatsoever while travelling on the road. Since the road quality is at its best the suspension system won't undergo major compression or elongation, hence the data obtained will be closest to the mean position of the dampers. The Yellow band indicates that the road quality is mediocre. The road may have a few undulations. This may also be caused due to presence of speed-breakers on the road. This band suggests that they could be tolerable at slower speeds since there are a few undulations present. In this band since the suspension system does undergo a few bumps, the band if further away from the damper's mean position. The Red band indicates the worst road quality. The road has a lot of potholes, puddles, undulations etc. This isn't fit for use. The Suspension system undergoes most fluctuations in these road conditions thus the red band lies farthest from the mean damper position. These roads are not fit for high-speed cars, and barely fit for use, hence the authority must be alerted so that they can take necessary actions. The 3 bands will represent how the road is going to be on any route and can show how undulated the path is. Ordinary maps only show the route but with the help of this, the road's quality can also be seen as the GPS co-ordinates will be shown with the variation in the displacement from the mean position of the shock pot.

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11. Results

Figure 12. Depiction of the road quality analysis

As shown in the above figure 12, the depiction of road quality analysis on a patch of road. There are small regions of red and yellow zones which mean the shock pot was compressed beyond the green zone for the patch. A continuous zone of red depicts very bumpy road, where the magnitude of deviation from rest position is the greatest. The road might have potholes and harsh speed humps due to which the rider was uncomfortable.

12. Conclusion

The conceptual idea which was initially thought of has been successfully incorporated in the design. There are several areas where the design has lacked due to which several problems were encountered during the manufacturing phase. After ensuring the working of all the components individually and calibrating them according to the required conditions, the sub-assembly was also tested for functionality and compatibility with each other and all worked according to the plan.

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