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## WAKE UP CALL FOR ELECTRIC VEHICLES AND POSSIBLE MORNING FOR MULTIPLE, OUTER ROTOR IN-WHEEL MOTOR DRIVE SYSTEM

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**Abstract:** The incessant chase behind reducing air pollution have seen a lucrative result after the ongoing massive impact of COVID-19 corona virus. Starting with the source country China, removing a massive number of 192,000 cars, NO<sub>2</sub> levels in some areas in China have dropped 40% in the months of January and February. Similar changes were seen all around the world creating another inflaming question, what happens after this watershed???

With each economy along with its infrastructure requiring a resurgence, this also marks the time when government and adjoining agencies along with the car manufacturers need to provide a new-bound revitalization to electric vehicle industries

Apart from going into explaining how this is the right time to give more importance to electric vehicles, this study also goes into the details of implementing multiple motors in electric vehicles, namely in-wheel, outer rotor motors especially in developing countries like India. Its perks and non-perks. Ironically this pandemic situation proves to be beneficial in doing so as every industry is going to undergo a rejuvenation and hence adjoining the EV industries with newfound technologies is possible, necessary as well as advantageous

**Keywords:** electric vehicles, in-wheel motors, outer rotor motors, aftermath of corona

### I. INTRODUCTION<sup>1</sup>

THE present generation is witnessing a shooting star. But instead of granting us a wish, this once in a lifetime event is actually taking away the wishes and dreams along with the lives of millions of people. But the word 'IRONY' cannot be stressed more. Because along with destructive rapid changes, the world is also seeing a handful of wonderful changes. Most prominent among them would be on air pollution.

The scientists first noticed a significant change in China, the country from which the deadly novel coronavirus (nCOV) originated. After the precipitation of nation-wide lockdown, China witnessed a massive 25% decrease in carbon emission, 50% decrease in nitrogen dioxide emission which one Earth system scientist estimated may have saved at least 77,000 lives over two months. The European space agency, between 1st January to 1st

march of 2020 observed a significant decrease in nitrous oxide emissions from cars, power plants, and factories in the Po-valley region in northern Italy, coinciding with lockdowns in the region.

European space agency's Sentinel-5P satellite's measurement showed that during late January and early February 2020, levels of nitrogen dioxide(NO<sub>2</sub>) over cities and industrial areas in Asia and Europe were lower than in the same period in 2019 by as much as 40%.

Two weeks into Nationwide lockdown, NO<sub>2</sub> pollution in some cities in UK (United Kingdom) fell by 60% compared to previous year.

According to NASA, NO<sub>2</sub> pollution over New York and other major metropolitan areas in north-eastern USA was 30% lower in March 2020, compared to monthly average from 2015 to 2019.

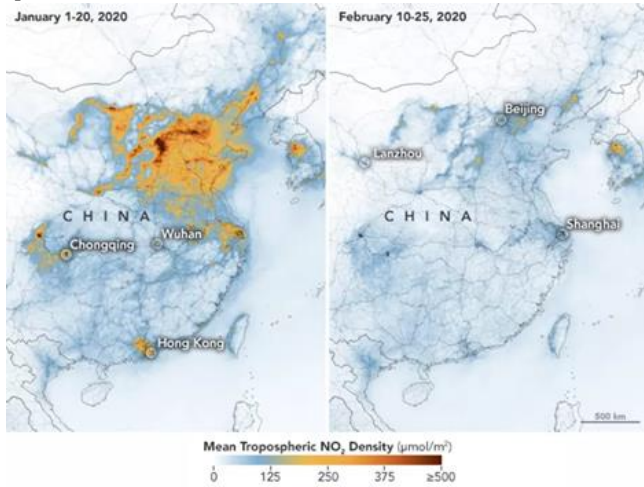
In New Delhi, the capital of India, the government data shows that, the average concentration of PM 2.5 plunged by 71% in the space of a week falling from 91 micrograms per cubic meter on march 20 to 26 on march 27, after the lockdown came into existence. Keeping in mind that the WHO (World Health

Organization) consider anything above 25 to be unsafe. Nitrogen dioxide went from 52 per cubic meter to 15 in the same period, also a 71% fall

States like Mumbai, Chennai, Kolkata and Bangalore have also recorded a fall in these air pollutants.

Gufran Beig, a scientist with System of Air quality and weather Forecasting and Research (SAFAR) under India’s ministry of earth science said that, during the first three weeks of march, the average nitrogen dioxide levels declined by 40-50% in the cities of Mumbai, Pune and Ahmedabad compared with the same period in 2018 and 2019

“The reduced fossil fuel emissions due to the transport sector and slowdown in other emission related activity is slowly reducing the air pollutants” BEIG said.



## II. PROBLEM CASE: INDIA

Today in India, there are about 33 million vehicles running on the streets. In addition to the 3.38 billion population, this adds quite significantly to the chart which makes India one of the most densely populated countries in the world. India is also the 2nd most populated country in the world after China which makes me question, **doesn't that make this country the most affected by this pollution? What exactly are my options? And what all improvements can I do about it given the time and scenario?**

TYPE OF VEHICLE	VEHICLES PER 1000 PERSON
PASSENGER VEHICLES	22
TWO-WHEELERS	108
BUSES	0.11

TYPE OF VEHICLE	MARKET SHARE
PASSENGER VEHICLES	14%
COMMERCIAL VEHICLES	3%
THREE-WHEELERS	3%
TWO-WHEELERS	80%

India is the

- Largest two-wheeler manufacturers
- Largest tractor manufacturer
- 6th Largest car manufacturer
- 6th Largest commercial vehicle manufacturer
- 2nd Largest bus manufacturer

As you can see from the tables, two-wheelers dominate the Indian market share with a whopping 80% followed by passenger vehicles. At present, there are about 5 lakh electric scooters and a few thousand electric cars on Indian road which clearly depicts how long an investment in electric car industry could go about in the future. Even though the amount of vehicles per person is less compared to other countries like China which in turn has 600 vehicles per 1000 person, considering the land area that we have, this number is more than enough to create level of pollution that could create an epidemic because unlike China, India has a pernicious population density which makes them virulently vulnerable to pollutions, extrapolation of which is clearly visible in the widespread of coronavirus.

In China, the most populous country, the government has issued various immaculate policies in order to overcome these problems. One among them is partnering up with Volkswagen in investing around 10 billion euros in industrialization of E-vehicles in China. And that is just the tip of the iceberg. Similarly, many of the European and American countries exhibits a similar exuberant environment for the electric vehicle industry. But that is not the case for India.

Being in the top 100 unemployed country and ranked 112 out of 117 extreme poor countries in the world, the development policies and industrialization plans of India is always under apprehension. With more than 50% of population still depended on farming and with an 8.5% unemployment rate, and don't forget the virulent conundrum created by the novel coronavirus pandemic, a large investments and industrialization on electric vehicle sector seems to impractical for the nation.

What we require is an undivided attention and contemplation to the amicability existing in this sector and the serendipity behind it.

## III. ELECTRIC VEHICLE IN INDIA-ADVANTAGES

- It is a myth that, since electric vehicles run on electricity produced from fossil fuels and other similar sources, it has less efficiency compared to that of an IC engine. But in reality, electric vehicles are actually 3-5 times more efficient than IC engines.
- They have high efficiency in terms of power conversion through its propulsion system of electric motor.
- Maybe one of the top-most advantage or characteristic features of electric vehicle is its property of Regenerative Breaking. Almost 30-70 % of the energy used for propulsion can be recovered during breaking. This comes in handy during the city drives which involves a lot of stop-and-go driving.
- The obvious harmful effect of IC engine on air pollution indices does not require a formal introduction. Usage of electric vehicles drastically reduces air pollution.
- In addition to air pollution, IC engine vehicles also has a wider impact on noise pollution. Some of the Indian cities are very much affected by the above problem in such a way that they are named some of the worst cities in the world in terms of noise pollution.

Hence electric vehicles, which are relatively less quitter vehicles can create an impact on this matter in hands as well.

- The amount of crude oil required for the running of electric vehicles cannot be met by India alone which force the country to import them. In 2018, India became the third largest crude oil importer in the world by spending an estimated amount of Rs.8.81 lakh crore (120 billion dollar) to import 228.6 million tons of crude oil in 2018-2019.
- Moving and rotational parts are much lesser in electric vehicles when compared to that of an IC engine vehicle making it simple in construction, cheaper and less friction which in turn results in less maintenance.
- Another significant advantage which cannot be missed is its torque capability. Electric vehicles can deliver high torque at low speeds. Thus, they can achieve very higher speed in very short time, deliver better performance and acceleration, even on slopes.

#### IV. WHY NOW???

Even though it is under a lot of pressure, India is one of the fastest growing economy. Foreign investments have also seen a lot of growth in the past few years. Most importantly the corona pandemic has completely shattered the entire economy, and that's not just the case of India. This catastrophe creates a condition in which the government as well as people are forced to see how the IC engine vehicles has been polluting the air for the 7 billion people as well as disrupt the cycle of flora and fauna/eco-system. Post pandemic economy also requires a complete makeover for each and every industry which provides us with an opportunity to start a fresh venture in the electric vehicle industry. And like I said before, it might not be a viable choice depending upon the other crises that hangs above the head of our nation but what you have to analyze is the fact that Indian market, just like Chinese market, is humungous, and have the potential to be turned into a very profitable one given the push and opportunity. Also, on the other hand, giving it back to the hands of already existing IC-engines unequivocally results in going back to the air conditions that existed before the pandemic.

There are still a lot of people who believe electric vehicles produces CO<sub>2</sub> emissions too and I don't blame them because it is true.

German automaker Volkswagen done a cradle to grave study on electrical(E-Golf) and IC-engine (Golf TDI) version of its model Golf to assess the emission of CO<sub>2</sub> over its life cycle.

- The whole life cycle was divided into three: Production, Use-phase and recycling
- On the whole life cycle, Golf –TDI produces 140gram CO<sub>2</sub> per kilometer.
- E-Golf produces 119gram CO<sub>2</sub> per kilometer.

It was seen that, for an electric vehicle, the major carbon dioxide emission was seen during its production phase while for an IC engine vehicle, it was during the running phase.

Also for the electric vehicle, carbon dioxide emission was very less during the use phase and the good news lie in the fact that, if renewable energy like solar can be used instead of fossil fuels, emission can be completely eliminated. And thus, the technology can be then concentrated towards the isolation of CO<sub>2</sub> emissions during production and ultimately can achieve a dream of 0

emission state. Electric vehicles provide us with opportunity to tap and make use of wide variety of renewable sources.

#### V. CASE STUDY- CONCLUSION.

As you can understand, electric car is the future by all means. Countries like United States of America, China, Germany etc. have already invested and showed significant results in the fields of electric vehicle industry. The need for India to step up among their world of electric vehicle industry is not only necessary for the country's development but also to strengthen its health and environment sector. Like my study details, the post corona time-period provides an opportunity that have the potential to fast forward our development to 10 years. Not just that, this will significantly create a boom in the unemployment rate of the

PHASE	GOLF-TDI	E-GOLF
Production	29 gramCO <sub>2</sub> /km	57 gramCO <sub>2</sub> /km
Use	111 gramCO <sub>2</sub> /km	62 gramCO <sub>2</sub> /km

country where the number of graduates with the technical skills also improves with our development in education system and being one of the topmost countries with the most number of youth, I see why not.

Government should make policy amendments to attract more foreign investments in this industry and also help the existing manufacturers.

#### VI. IS IT ENOUGH???

Like I mentioned before, these investments and promotions in the EV-industry have the potential to fast-track our development to 10 years. **But is that enough??**

With numerous countries already invested and made significant research and development in this fields over the past decade, maybe just an investment might be erroneous. From people who neglected people like Elon Musk because of his ridiculous ideas to people fighting over investing in his companies like TESLA and Space-X, it is pretty much clear that the world look forward to innovative technologies and ridiculous ideas that could change the way how we perceive technology. With that kept in mind, miniaturization of technology had played an important role over the past few decades when it comes to marketing the products. People are always behind technology that could reduce the size, weight, cost but can output maximum performance. And since reduction of size and various body parts could go hand-in-hand with reduction of cost, development in this discipline is always welcomed by any field.

In early times and maybe even today, most people never usually give many thoughts to the tires of a vehicle. Why? Because their purpose is to roll and displace vehicle flawlessly and as long as they faithfully serve that purpose, there isn't a need for further concern. Even now, when we are about to buy a vehicle, our topmost research about tires is about their cost and their durability. But lately there has been a notable shift from these ideas among the producers. The idea was to place multiple motors adjacent to wheels, either rear-wheels, front-wheels or all-wheels and the term was coined as In-wheel Motors.

Towards the end of 19th century, the creator of the world-

renowned car manufacturing company PORSCHE, Ferdinand Porsche along with Joseph Ledwinka and Fred Newman in Chicago conducted an experiment to attach the electric motor directly to each wheel of their horseless carriages. Little did they know back then that the underpinning of the modern world in-wheel drive technology lied in their little experiment

In this type of placement where motor is placed adjacent to wheels, provides a driving more aligned with driver's wishes and increases the joy and comfort of driving experience. This type of configuration/layout offers great deal of freedom for the driver when it comes to turns and narrow roads as each of the tires can be controlled individually.

## VII. IN-WHEEL MOTOR DRIVE TECHNOLOGY

Amidst the inextricable conundrums that made the field stay shied for a very long time, in-wheel systems have seen a lot of researches and development over the past couple of decades but the earliest U.S patent dates back to 1884. Further development was conducted when Ferdinand Porsche in 1990 introduced a wheel hub motor for the first hybrid vehicle Lohner Porsche

In a traditional IC engine vehicle, there is a centralized single engine kept either in the front or back side of the vehicle. It produces the power required for the vehicle to run. And when we say the power required by the vehicle to run, we are actually talking about the power needed by/at the wheels. This power from the centralized engine is delivered to each of the tires using a transmission system which comprises of different shafts, differential and other similar mechanical components. Electric transformation of this involves replacing that IC engine with an equally capable electric motor which now provides power to the wheels just like as in the IC engine vehicles. But now, there is a provision to replace some mechanical components in the car and replace it with the wires, which in fact reduces losses to an extent. But in both these cases, there involves a certain transmission loss because in both of them, the power is generated at one place and is required at another, which opens up the portal to an entire new era of in-wheel motors. In this model, instead of using a single centralized motor, we use multiple motors. Two different motors are placed at either front or rear wheels and the output generated is directly used by the motor instead of transmitting it through different other components. In the hub motor configuration, which are most commonly seen in electric scooters in India, the rotor itself is attached to the wheels.

comes to automobile construction. Parts like engine, clutch, transmission, suspension and certain others can be completely eliminated as in-wheel components handles all these part's function. These configurations in which mechanical functions are replaced with electrical function is often referred to as By-Wire technology such as drive-by-wire or brake-by-wire. Elimination of these major space consuming parts now offers us with opportunity to add structural, aesthetic, and design enhancement to a vehicle and also provides more space.

- This also reduces the overall weight of the vehicle by a significant amount which results in the vehicle providing greater range and reduced running cost.

- One of the most important problems faced by electric vehicle is the charging rate and frequency. The need to recharge battery again and again. In-wheel motors with its structural advantages significantly reduces the charge frequency as well.

The greatest advantage of in-wheel technology is the fact that the power goes directly to the wheel. This configuration reduces the distance that the power needs to travel and hence increases the efficiency of the motor. They could potentially use 96% of the generated energy while hybrids use 85% and IC engines use 50%. In city drives, an IC engine have 20% efficiency while an in-wheel electric motor possesses 90% efficiency.

## VIII. SO WHAT ABOUT TORQUE???

So far, we've talked about power and other structural components. Does this configuration provide better torque? Or does this system affect torque in any way?

Torque is equally or more important in an automobile. A vehicle requires an instantaneous power at wheels at times. Torque play a vital role in a vehicle's quick response and performance. So, does in-wheel system provide that?

Quick answer is YES. And that too quicker and more efficiently when compared with conventionally powered vehicles

We have learned before that electric motor produces high torque and since it is directly attached to tires, this high torque can be directly provided to tires without any delay and there is only little lost in the transfer. Each wheel can also be equipped with separate sensors to determine how much torque can be delivered to individual tires making it easier for drivers to make turns and immediate displacements. Even though similar settings exist in already existing normal automobiles, their response time is slower due to the reason that they have a lot of components involved which makes the system complex. This is where in-wheel system comes into the plot with their minimized components and quick delivery configuration.

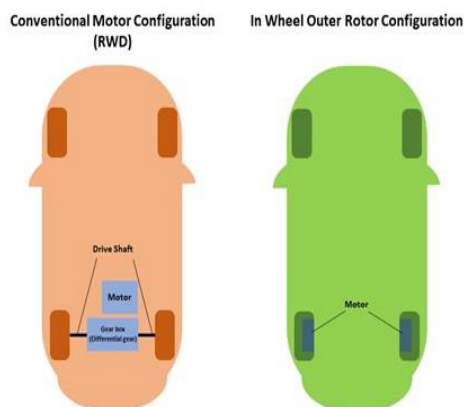
## IX. THEN WHY??

Seems like it is obvious that in-wheel motor system vehicles not only provide us with abundant advantages but also has a very promising future. And with the fast rate at which the technology grows, this system is becoming more efficient by the day. Then the question arises, why is it not being adopted by more people? Why is it less in number when it comes to the number of manufacturers who adopt this technology let alone seen on the roads?

Again, the single answer is unsprung mass.

Unsprung mass or unsprung weight is the mass of suspension, wheels and other components directly connected to them and

- In-wheel motors exhibit a wide variety of advantages when it



these does not involve those parts and components supported by the suspension for that is referred to as the sprung mass. Or simply, it is the mass of everything between a car's suspension system and the road. As components inside the tires (say motor mainly) increases, the unsprung mass also increases.

An increase in unsprung mass is an undesirable feature for an automobile. Lower unsprung mass increases the comfort and quality of the driver and that of the vehicle by keeping the vehicle on the ground(road) as much as possible when it has to roll over humps and similar obstacles or objects that are in a different level in terms of height of the ground(road) level in which the vehicle moves. It also provides faster response to the road. Lower unsprung mass also benefits in better fuel economy.

Owing to the conundrum exhibited by the unsprung mass, it seemed necessary to address this concern properly. As a result, US based in-wheel technology company Protean Electric came forward and reached out to an UK based engineering firm called Lotus Engineering (Lotus cars) which was an expert automotive consultancy. Engineers at the firm made a thorough research on the effects of unsprung mass on vehicle. They added about 30 kilograms of mass to each wheel and measured the vibrations and movements of a Ford Focus using computer simulation and other similar technologies. Professional drivers were also made to drive the vehicle under the same circumstances to give the study a metaphoric spine.

Lotus came to an understanding that the effects put forward by the unsprung mass was really not that significant though understandable by a trained driver. There sure was a difference in the performance though it was undistinguishable by commonage. And to Protean's fortune, these changes could be eliminated to a lion's share by adding more suspension damping and several other common engineering processes during development. Top of all this, study showed that these changes mainly came because of the addition of individual motors to the wheels which in fact made the car's handling way better.

Protean Electric carried several other studies as well. In all the cases, the net effect on the vehicle's handling and performance was better and ergo realized that unsprung mass is not actually a deal-breaker

And the next problem is with the difficulty that arises with the complexity of the circuits and software that had to be accommodated with the in-wheel configurations. These have to faithfully do their respective job and there is always a concern about the successful completion of this job getting done and this involves distribution of torque, brake acceleration and also several other ones and that too for different motors. And further, there is the case of cost for these configurations.

For starters, let us take the concern of cost. We have seen how cost efficient in-wheel configuration can be in the manufacturing and will be in the long run in the earlier parts of this article. And to further justify, 'Better things comes with a cost'. Now as for the safety concern. It was implemented that every such vehicle has to meet ISO-26262, a very difficult standard to satisfy that applies for the risk-based safety standard associated with electric and/or electronic systems in automobile production. It calls for proving that a hazardous technical failure is extraordinarily unlikely.

Thereby we can actually say that the concerns faced with the in-wheel technology is actually negated by their advantages, new-found technologies and proper measures.

## X. CONCLUSION

As we can see, in-wheel motor configuration comes with a lot of advantages. And that doesn't mean it has no disadvantages, it does. We have come across them but has also seen how it has been tackled. Long story short, future calls for in-wheel system vociferously. A developing country like India requires a technology like this to stand out among the so-called tech-giants like USA and China. And that is in addition to the need of India as well as other countries to maintain the stable pollution free environment achieved during the global corona pandemic by gathering a significant shift from IC engine vehicles to electric motor vehicles. It is with no doubt a long shot for many countries, but the need to reconstruct each and everything in the economy demands an attention for automobile sector as well and that means an opportunity to make/take that long shot. Also, it'd be shame to forget the ever-glowing R&D (research and development) going on in the field of reinvigorating the renewable energy sources. Any leap in this field could actually make the electric vehicle industry unequivocally great as well. And within 10 to 20 years, the chances are, this leap will happen and hence this opportunity to make a significant shift from IC engine to electrical motor is a pre-requisite and is definitely needed for a smart and bright future.

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