Active Steering Wheel, a new solution to implement active steering functionality into a vehicle

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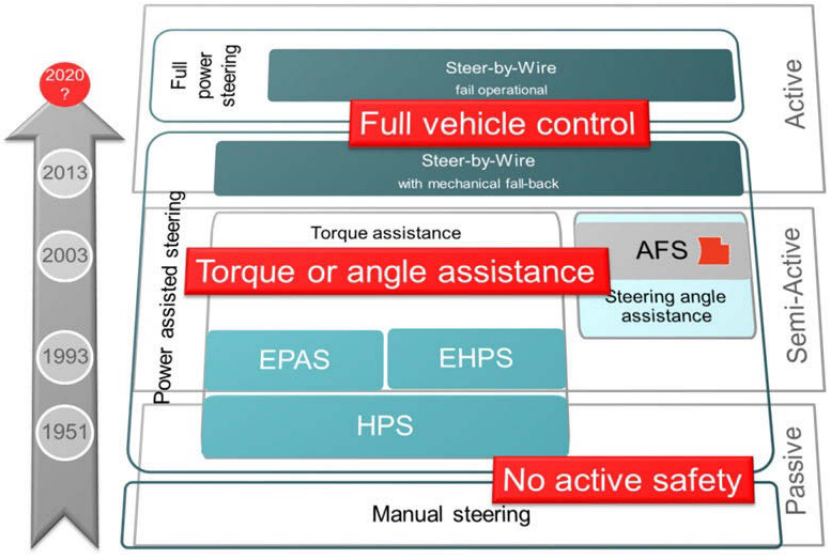
Development of Steering Systems

Since motorized vehicles are on the road, they all have an element to steer the vehicle. At the beginning it was a pure mechanical connection steering wheel – steering column – steering gear – front axle – front wheel. In the 50's of last century the first systems of steering assistance were developed and introduced into the market. A hydraulic system supported the driver to turn the steering wheel with lower torque, so especially steering at low speed became more convenient. To reduce the fuel consumption of the vehicles the hydraulic system was replaced by electrical systems in the 90's. Beside torque assistance, almost 10 years ago angle assistance was introduced to steering systems.

In 2013, Nissan launched the first steer-by-wire vehicle with a mechanical fall-back system. That means, there is a clutch available which would shortcut in an event of system failure the steer-by-wire system and realizes a mechanical connection between steering wheel and front wheels.

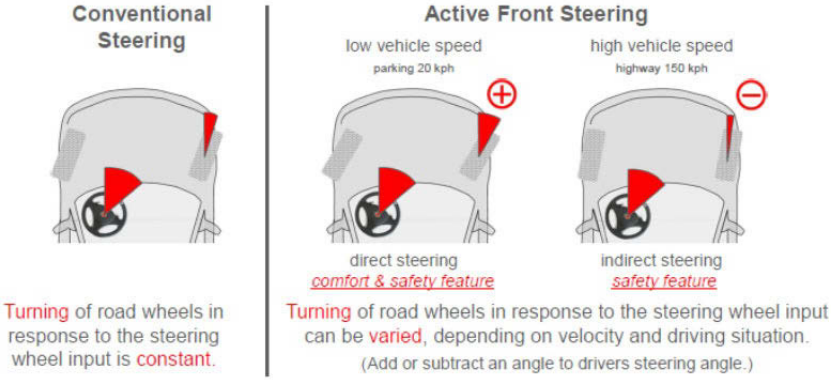


Picture 1: Development of Steering Systems over the past 60 years

Where does the journey go? When will we have a pure steer-by-wire system without mechanical feedback and what will be the advantage of such a system?

Active Steering functionality

Active steering describes a steering system in a vehicle where the ratio between the driver's steer inputs and the angle of the steered road wheels may be continuously and intelligently altered. Active steering technology was introduced in 2002 in Germany and Japan almost at the same time by two different OEM's. At lower speeds, this technology reduces the amount that the steering wheel must be turned – improving performance in situations such as parking and other urban area traffic manoeuvres. At higher speeds, the performance is such that the normal increased responsiveness from speed is avoided and it provides improved directional stability.



Picture 2: Functionality of an active steering system

But an Active Steering System is not only useful for parking manoeuvres; it can also be used to improve the chassis behaviour of the complete vehicle. Fast lane changes, extreme steering manoeuvers can be supported in a way that the vehicle remains in a more controlled situation.

In addition, all interactions which are actually done by ESC systems can be supported by an Active Steering System more agile. Side wind correction, lane keeping, braking on roads with different friction.

TAKATA solution “Integration into steering wheel”

The central component of active front steering is a superposition gear, driven by an electric motor and embedded in the steering system. At all active steering systems on the market this central component mounted in the steering column or in the front axle. The TAKATA active steering system is mounted directly in the steering wheel.

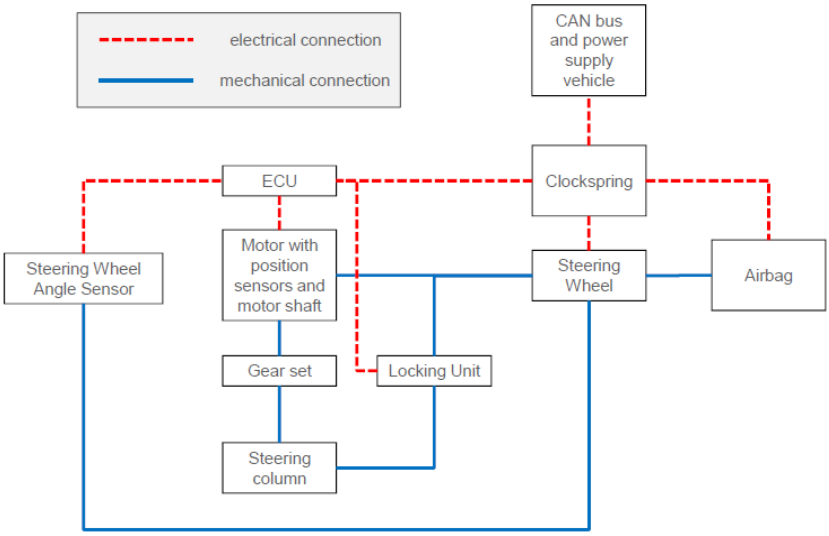
Picture 3: Market solutions and TAKATA’s solution

The take rate of the available Active Steering Systems is low as it is a luxury option. So an integration of this system in the area of the steering column or front axle requires a big change in the vehicle front part. That means a high variance at the OEM in an early phase of the assembly process. Bringing the functionality into the steering wheel offers the possibility to the OEM to put the variance at the end of an assembly process. It is attractive for the OEM to assemble either a leather wrapped steering wheel or a steering wheel with heating or an Active Steering Wheel into the car.

The integration of the Active Steering System into the steering wheel reduces total weight and costs because parts of the steering wheel itself are used for this system. Of course the integration into the steering wheel also has challenges like acoustics, EMC issues, weight increase of the steering wheel and thermal management only to mention some of them.

System Design

In the block diagram below the main components of the Active Steering Wheel are shown.



Picture 4: System Design Active Steering Wheel

The Electrical Control Unit (ECU) receives the signal of the Steering Wheel Angle Sensor, mechanically connected to the steering wheel. That is the so-called requested angle from the driver. Beside of this signal the ECU is connected to the vehicle CAN-bus via the Clockspring and gets relevant signals from the vehicle e.g. vehicle speed, yaw rate, etc. The ECU calculates the requested angle position of the electrical motor and turns the motor accordingly. By turning the motor, an angle is superposed to the steering column, in addition to the steering wheel angle. In other words, in addition to the steering column angle rotation by the steering wheel angle, the motor angle additionally turns the column.

This ECU must fulfil all requirements according ISO 26262 because the Active Steering Wheel is rated as an ASIL D product. The position of the motor is monitored continuously by the ECU.

All calculations are done with a dual core microprocessor. If one of the numerous diagnosis signals indicates a failure or an implausible value of the sensors the ECU

forces the Locking Unit to lock the system. In case of a deviation between calculated and actual motor position the system will be mechanically locked via the Locking Unit. In this case, the Active Steering Wheel behaves like a normal Steering Wheel, i.e. has a fixed mechanical steering ratio.

System Components

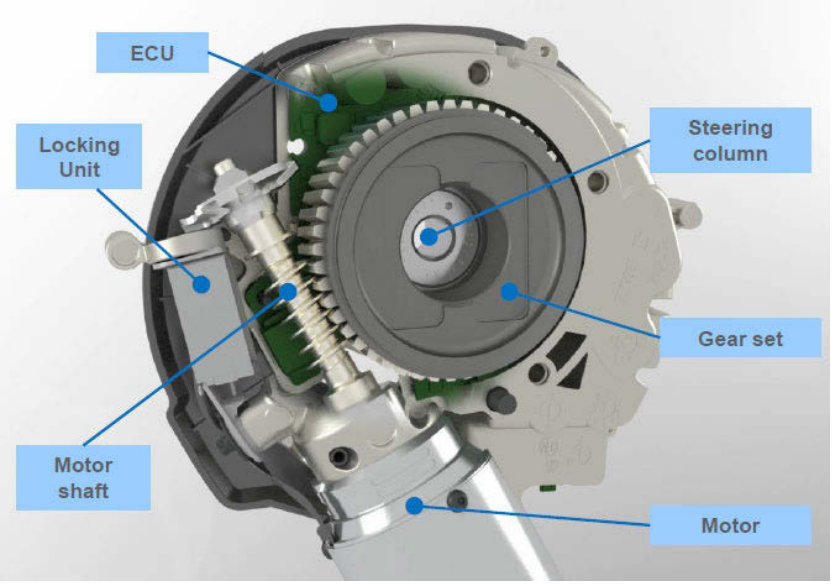
Active Steering Unit

The Active Steering Unit is placed in the middle on in the 6 o'clock spoke of the steering wheel. It is important that the centre of gravity of the Active Steering Wheel is always in the vertical line with the steering column, preventing it to turn by itself under the influence of gravity.

Picture 5: The Active Steering Unit in the Steering Wheel

The Active Steering Unit itself consists of a housing which is mechanically connected to the armature of the steering wheel. The motor is fixed into the housing and has a helical motor shaft. The motor shaft itself drives the helical gear set which is directly mounted on the steering column.

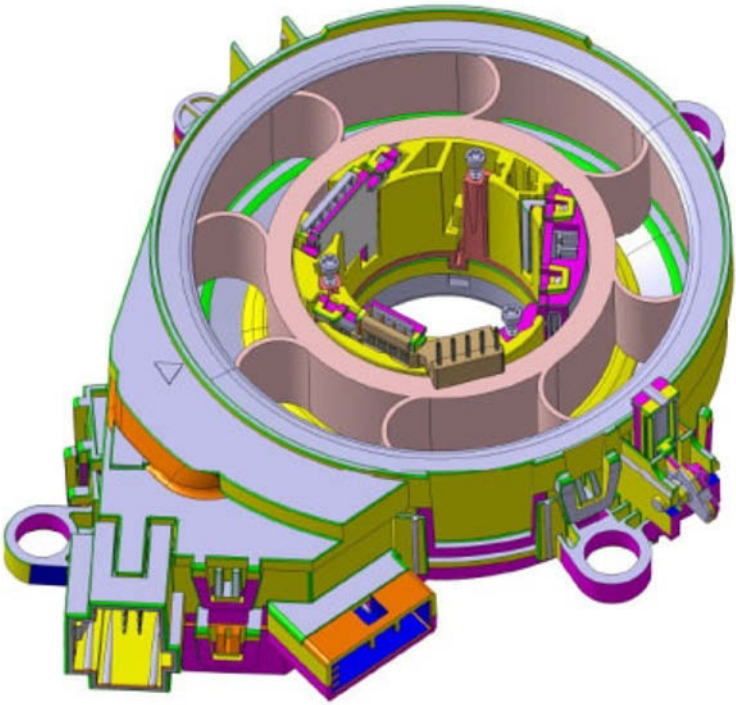
The gear set is not self-locking so a locking unit is necessary to lock the system in case of power supply loss. The Electrical Control Unit is mounted in the housing of the Active Steering Unit. At every start of the system the ECU controls the proper function of the system.



Picture 6: Main components of the Active Steering Unit

Clockspring Module

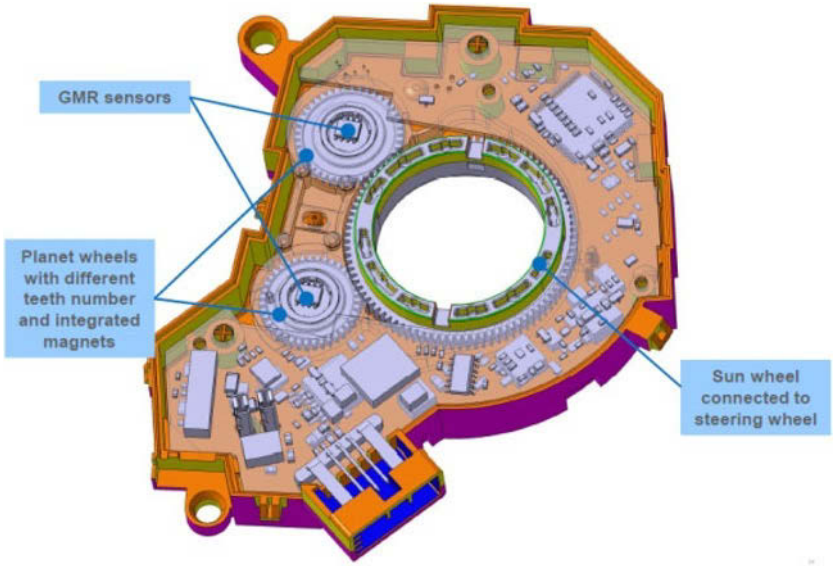
The power to the system is supplied via the Clockspring Module. Although normal driving behaviours normally draw currents around 5A, misuse cases can draw up to 40A. Therefore, the design of the Clockspring has to be adapted.



Picture 7: Clockspring Module

Inside of the Clockspring Module eight flexible flat cables connect the rotor with the stator. Six are used for the power supply of the Active Steering Unit and two of them are used for the normal signals of switches, airbag deployment, horn signal, etc.

On the back side of the Clockspring Module a Steering Angle Sensor is attached. The Steering Angle Sensor basically consists of a planetary gear set where the sun wheel is mechanical attached to the steering wheel. The two planet wheels have different number of teeth and an integrated Magnet inside. Two GMR sensors determine the direction of the magnetic field and a microcontroller calculates the absolute steering angle out of these signals.



Picture 8: Steering Angle Sensor

System Performance Tests

To validate the System Performance of the Active Steering Wheel almost twenty test benches were built up at TAKATA Berlin. Torque and High Speed turning has to be applied to the Active Steering Wheel and to the steering column at the same time

Picture 9: System Test Benches for Active Steering Wheel

Table 1: Active Steering Wheel Test Equipment

STB01	System test bench with Temperature / Humidity	All round Test stand with ability to test in Dual load
STB02	System test bench with Temperature / Humidity	
STB03	System test bench with Temperature	
STB04	System test bench with Temperature	
STB05	System test bench	
STB06	System test bench	
STB07	System test bench with Temperature	
STB08	System test bench with Temperature	
STB09	System test bench with Temperature	
STB10	System test bench with Temperature	
STB11	System test bench	
STB12	System test bench	
CTB01	Component Test bench	Related to Component test Gear/Mechanics
CTB03	Component Test bench	Related to Component test Gear test
		- Efficency
		- Pretension
		- Idle Torque
HDTB	High Dynamic Test bench	Related to System tests
		- Step Response
		- Rotational Fatigue
		- System-Input Vibration
NVH	Noise / Vibration Test bench	
DTB01	3x Durability Test bench	Related to Component test Gear test on System level
DTB02	3x Durability Test bench	

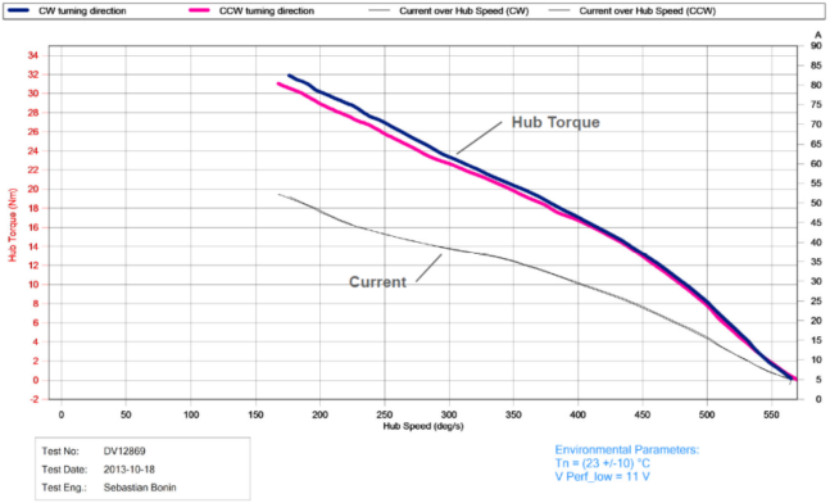
System performance

The quality of an Active Steering System can be defined by several parameters. In this presentation, the focus is on the system performance itself. That means how powerful, how fast is the system. In addition, these tests represent the so-called release-testing, being a short test program conducted for each sample, before it is officially released.

Obviously, the Active Steering Wheel has to meet requirements like noise behaviour, EMC behaviour, high/low temperature, vibration, etc. as well.

Dynamic Performance

Picture 10 shows the Dynamic Performance of the Active Steering Wheel, indicating the torque and angular speed that the system can superpose to the steering column. The motor efficiency, the complete gear set as well as the motor control electronic and software are the main influence parameter on the Dynamic Performance.

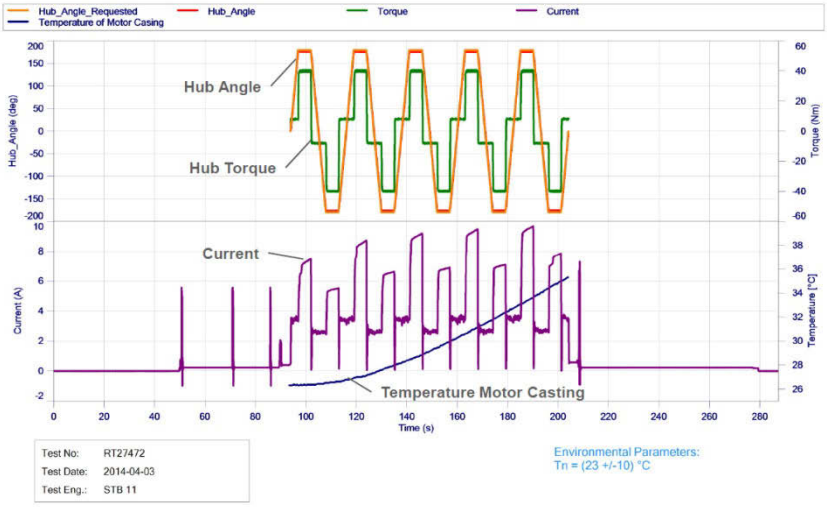


Picture 10: Dynamic Performance Active Steering Wheel

The system must support hub torques up to 70 Nm. Normal driving manoeuvres are far below this value. But we have to consider also some misuse cases which can happen e.g. turning the front wheels against a curb. On torque values higher than 70 Nm the Active Steering Wheel will be locked automatically and has then to withstand hub torque up to 260 Nm.

Parking cycle

Picture 11 shows the Parking Cycle Test with the Active Steering Wheel. In this test, 5 cycles of steering wheel hub turns with a maximum hub torque of 40 Nm are conducted by the system.

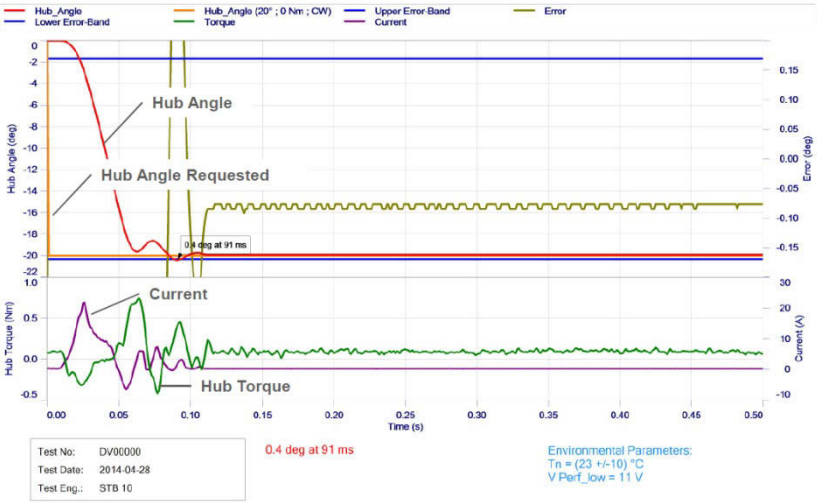


Picture 11: Parking Cycle Active Steering Wheel

The total current during the Parking Cycle Test rises up to 10A and the temperature of the motor housing increases by 10°C.

Step Response

Picture 12 shows the Step Response Test with the Active Steering Wheel. In this test you measure the response time of the complete system on a 20° stepwise change of the requested hub angle. The requested angle is applied electrically to the system and the real hub angle is measured. The system has to react fast but smoothly damped.

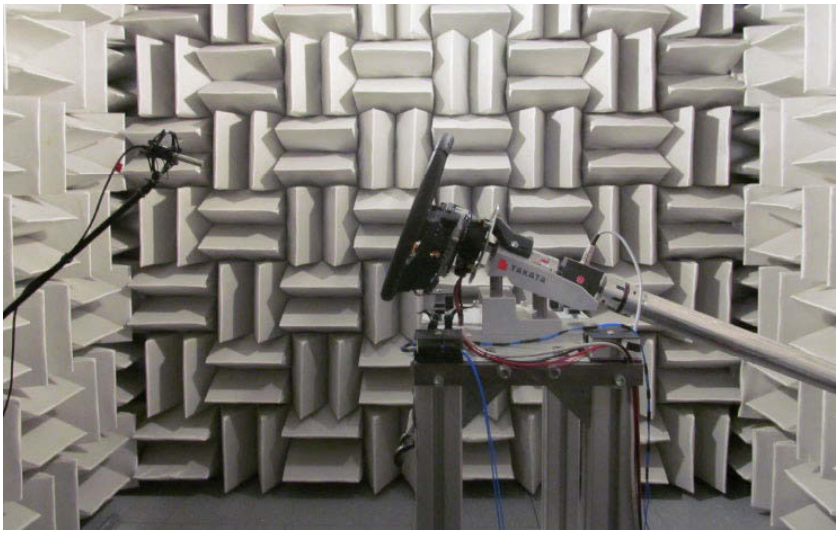


Picture 12: Step Response of the Active Steering Wheel

Picture 12 diagram shows the Active Steering Wheel response to the requested step within less than 100 msec. The maximum of the total current is in the range of 20 A.

NVH Behaviour

Beside of all mechanical requirements the Active Steering Wheel has also to meet requirements concerning noise. The TAKATA solution brings the active elements closer to the driver because they are integrated in the steering wheel and not somewhere in the steering column or front axle area. Therefore the NHV behaviour of the complete system has to be considered intensively. Like the mechanical efficiency of the Active Steering Wheel the NVH behaviour is not only influenced by mechanics itself but also by the complete control of the motor



Picture 13: Active Steering Wheel in the TAKATA NVH chamber at Berlin

Vehicle Evaluation

Even if more than hundred tests (mechanical tests, electrical tests and NVH tests) are done on component level, the final quality assessment of the Active Steering Wheel has to be done in the vehicle itself.

The so-called “good steering feeling” is difficult to specify within test specifications and the fingers, the hands and the ears of an experienced driver are much more sensitive than any test bench ever. Therefore TAKATA trained vehicle test engineers together with the customer to assess the quality and the performance of the Active Steering Wheel by driving the vehicles on test tracks.

Assembly Line

Picture 14: Assembly line Active Steering Wheel

The assembly line of the Active Steering Wheel was built up in Aschaffenburg, Germany and has already passed the run@rate. Beside of the high accuracy of adjustment processes a main focus was given to several test station. The performance of each sample will be measured in terms of torque and hub speed and also the noise behavior of each produced part will be monitored.

A close teamwork between engineering and operations was the key factor for the success.

Summary

With the Active Steering Wheel, TAKATA offers an innovative solution to implement active steering functionality. This is an opportunity for the OEM to adapt active steering functionality very flexible to different platforms, vehicle lines and continents.

Nevertheless, some challenges had to be met during the development. Extremely high awareness on all NVH related issues was necessary. Material studies to find the optimal material for every single component were executed. Buildup of specialized test equipment was mandatory to validate the performance of the system. Development according functional safety norms (ISO 26262) was a must to get an approval for an ASIL D product.

The Active Steering Wheel is not only a product for convenient driving but it is also a component to adapt the chassis behaviour, as seen by the driver. Moreover, it is a component of an active safety system.

Last, but not least, the Active Steering Wheel consists of all components that are required for Steer by Wire. Whether the market will push towards a Steer-by-Wire System instead of an active Steering Wheel? Time will tell.