Case Study

Redesign Torque Sensor for EPS system

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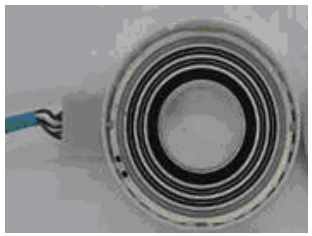
1. Introduction

Most of the vehicles are fitted with HPS (hydraulic power steering) system.
Although this system is used about 50 years, it has some shortcomings.
In comparison with EPS system, it is constituted with more components.
This implies usually HPS system is heavier than EPS system and inferior in the point of fuel efficiency. In addition, hydraulic system is operated by oil which might be leaked and is difficult to reuse or recycle.
Moreover, it is necessary to develop power steering system which uses electricity because automobiles are evolving oil-powered vehicle to electric-powered vehicle.

Torque sensor is one of the components of the EPS system.
It detects the motion and torque of the steering column, and a computer module applies assistive torque via an electric motor coupled directly to either the steering gear or steering column.
This allows varying amounts of assistance to be applied depending on driving conditions.

Torque sensor can be divided into two types; contact type and non-contact type. The representative type of the contact type torque sensor is potentiometer. However, as time goes by, reliability of torque sensor gets lower because brush wears out. Therefore, nowadays, designers choose non-contact type torque sensor for durability.

Comparison of key features of the torque sensor

	Contact type	Non-contact type		
Type	Potentiometer	Optical	Magneto-Resistance	Hall-IC
Structure				
Feature	measure torque with changing resistance by brush rotation	measure torque with changing amount of received light	measuring torque with changing magnetic field by bar torsion	measuring torque with changing magnetic flux by bar torsion
Reliability	low	medium	high	high
Size	medial	rather big	rather big	small
Cost	cheap	expensive	expensive	medium

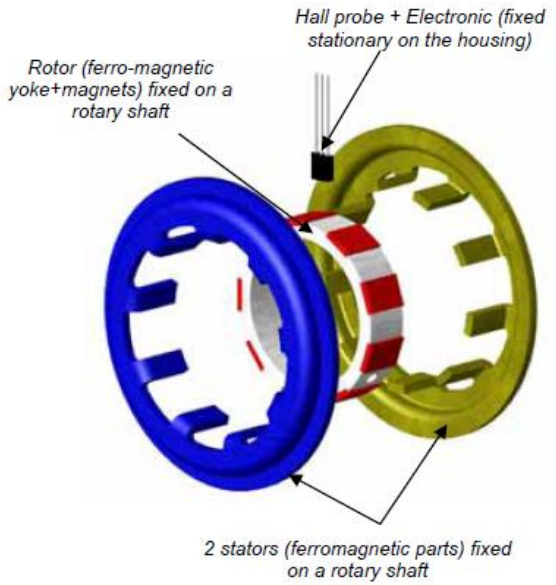
2. Problem

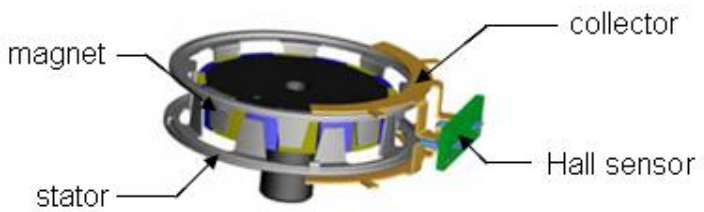
Hall type sensor

- constructed by the first and second magnetic ring to detect torsion.
- magnetic flux between first and second ring varies as steering column rotates. Hall IC gauges the difference of the magnetic flux and send signals to ECU.
- cost of the Hall type torque sensor is cheaper than optical or magnetoresistive type with high detection reliability.

Therefore, in LS Cable Co., Hall type torque sensor is selected for target product to redesign.

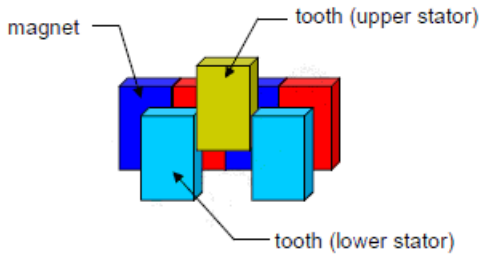
Hall type torque sensor which was developed by Moving Moving Magnet Technologies (MMT) was selected to target product; it has the simplest structure.

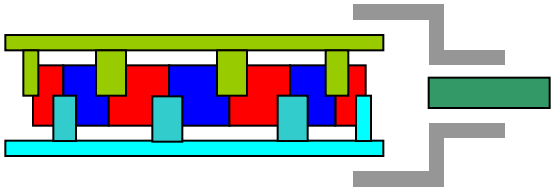




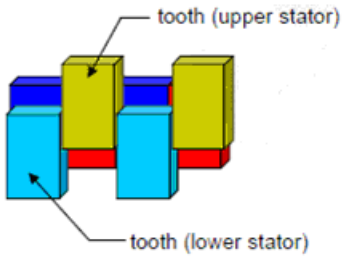
Didier Angleviel et al., "Development of a Contactless Hall effect torque sensor for Electric Power Steering", SAE 2006 World Congress, April 2006, http://www.movingmagnet.com/medias/download/2006-01-0939.pdf

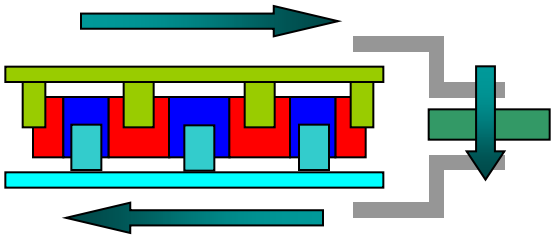
Flux Flow



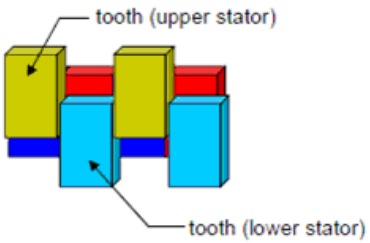


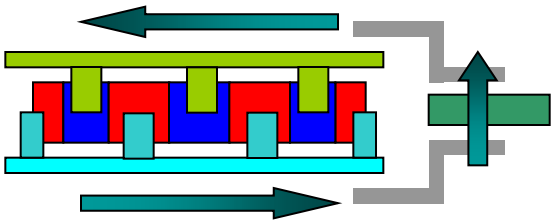
No flux flow at collectors
→ neutral position





Downward flux flow at collectors
→ turned right

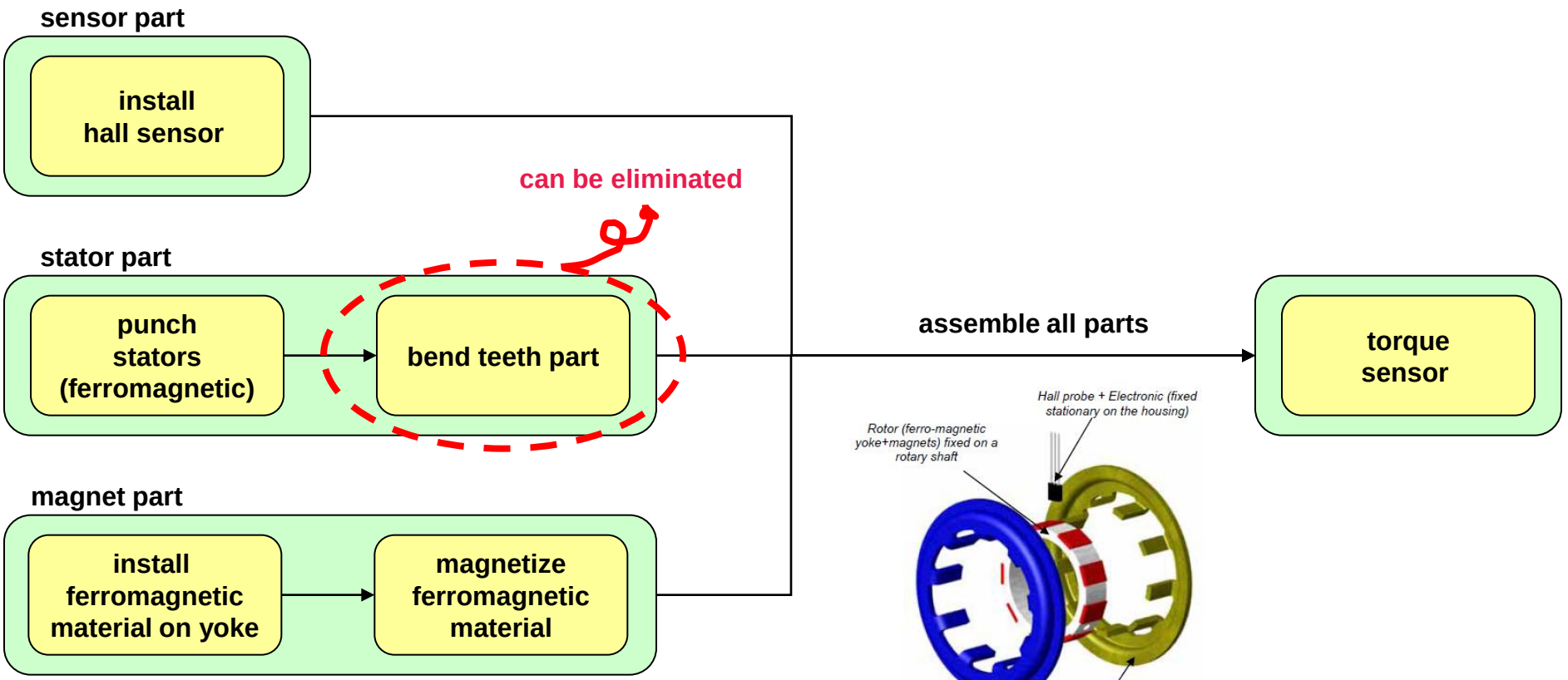




Upward flux flow at collectors
→ turned left

Torque sensor which was developed by Moving Moving Magnet Technologies has very simple structure; therefore, hard to find any contradictions or problems.

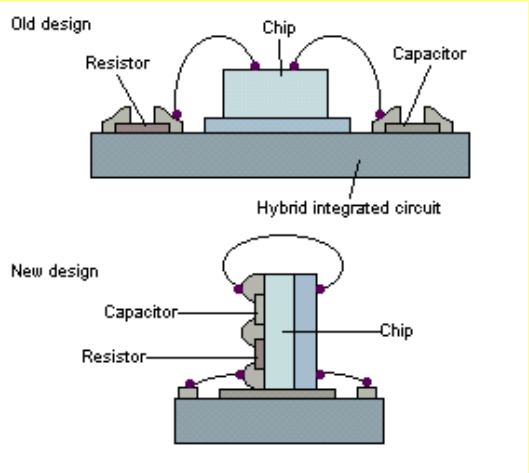
Thus, process analysis was done.



Thus, 40 principles were applied to redesign the torque sensor.
(eliminate bending process)

Inventive Principle 17 ‘Dimension Change’ (from GoldFire)

- move an object in two-dimensional or three-dimensional space
- use a multistory arrangement of objects instead of a single-story arrangement
- tilt or reorient the object; put the object on its side
- use a different side of the given area



example

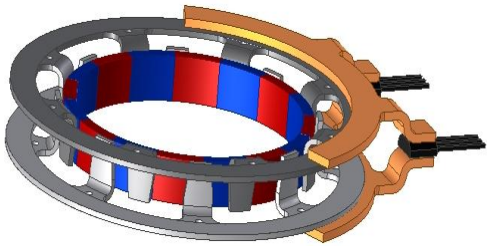
Placing some elements of a microcircuit on the reverse side of others.
For instance, resistors and condensers are formed on the reverse side of the crystal of an integrated circuit stood edgewise by means of a sequential deposition of insulating, conducting, and resisting layers.

Application of Japan (NEC) 1 283 896 H05R1/16 H01L 27/04 Review Magazine "Radiotechnika", 1991

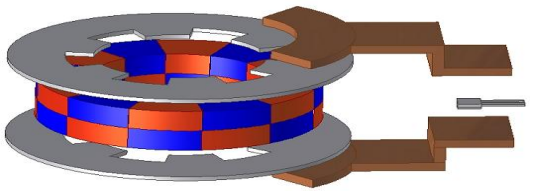
Inventive Principe # 17

Former design : teeth and magnets are faced each other along the circumference of the rotor/yoke.

New design : teeth and magnets are confronted each other with upper and lower sides of the rotor/yoke.
→ teeth of the stators need not to be bent
→ manufacturing cost slightly down



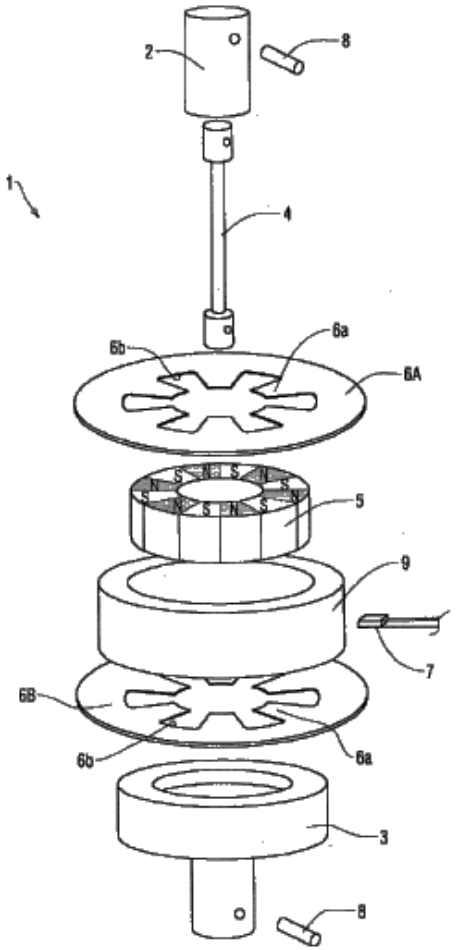
former design



new design

New problem

The new concept design was already published in US patent (#6810336) by Denso Co..



US006810336B2

(12) **United States Patent**
Nakane et al.

(10) **Patent No.: US 6,810,336 B2**
(45) **Date of Patent: Oct. 26, 2004**

(54) **TORQUE SENSOR HAVING A MAGNET AND A MAGNETIC SENSOR**

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(73) Assignee: **Denso Corporation**, Kariya (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 48 days.

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(52) **U.S. Cl.** **702/43**; 702/151
(58) **Field of Search** 702/41, 43, 151; 73/862.321, 862.325–862.331, 862.335–862.337, 379.03, 1.75, 1.79; 324/207.13–207.15, 207.22, 207.25; 341/15

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Primary Examiner—Marc S. Hoff
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(57) **ABSTRACT**

A torque sensor includes first and second shafts, an elastic shaft, a magnet, a pair of ring plates, and a magnetic sensor. The elastic shaft connects the first and second shafts coaxially. The magnet is fixed to the first shaft. The pair of ring plates is fixed to the second shaft, and faces each other in an axial direction of the elastic shaft so that the pair of ring plates sandwiches the magnet. The magnetic sensor is disposed in a gap between the pair of ring plates so that the magnetic sensor detects a magnetic flux density in the gap. Each ring plate includes a convexity and a concavity in an inner circumference of each ring plate, respectively. The pair of ring plates is rotatable against the magnet in accordance with a twist of the elastic shaft so that the rotation of the ring plates causes the magnetic flux density in the gap.

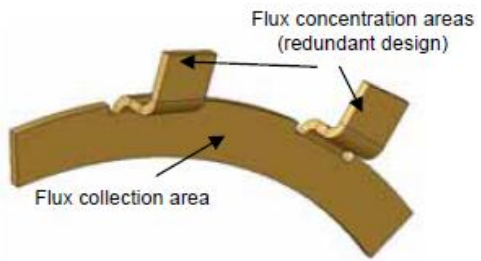
21 Claims, 16 Drawing Sheets

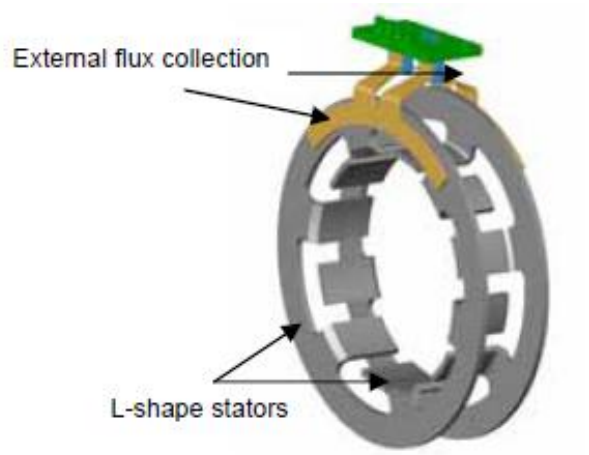
Torque sensor designed by Denso has simple design as that of the MMT. However, it has a problem.

The function of collector is collecting the flux which is generated on two stators.
Besides, the collected flux is gathered by 'L' shaped flux concentration areas in collector.
Thanks to them, magnetic force needs not to be too strong; magnet which has stronger flux is more expensive.

However, this function will not perform properly unless the distance between upper and lower flux concentration areas is rather smaller than the gap between upper and lower flux collection areas or two stators.

The reason is that flux flows much more between small gaps than big, thus if gap between the flux concentration areas is bigger than that of the stators flux cannot be concentrated, namely, it leaks.



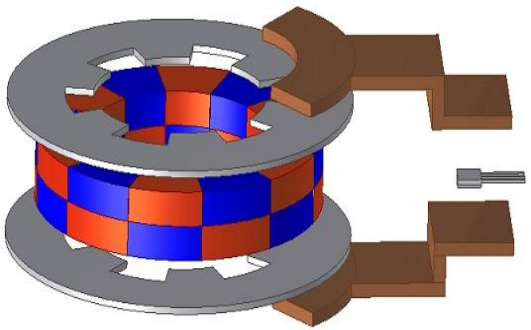


The technical system <for sensing rotation> includes <stators, magnet, collectors, hall sensor, yoke, etc.>.

TC-1: if the height of the magnet is high, the distance between upper and lower flux concentration areas becomes relatively closer; thus magnet flux does not leak.
However, bigger magnet is needed so manufacturing cost increases.

TC-2: if the height of the magnet is not high, the distance between upper and lower flux concentration areas becomes relatively farther ; thus magnet flux leaks.
However, smaller magnet is needed so manufacturing cost decreases.

It is necessary with minimum changes to the system, to <sense rotation without using big magnet>.



Define the operational zone

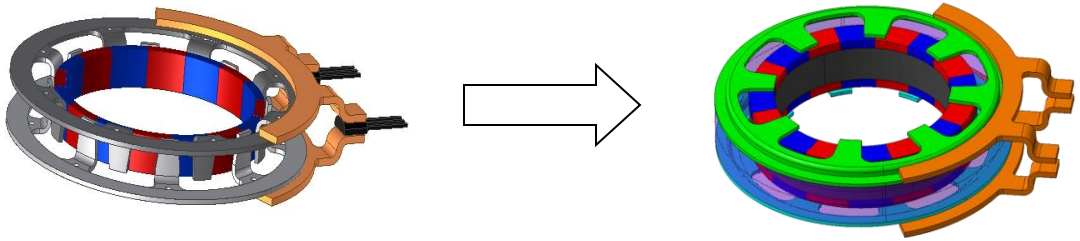
Seperation principles (in space)

3. Final Solution

-. Cheap plastic part is introduced between thin magnet, instead of using big magnet.

-. Manufacturing cost was reduced.

-. In addition, this concept design is international patent pending.



Abstract: (EN) A torque sensor for an EPS (Electronic Power Steering) according to the present invention includes: at least two stators; a magnet member that is installed between the stators to rotate relative to the stators according to the variation of a detected target object and comprises a non-magnetic body with magnetic bodies placed at both ends thereof; and a magnetic sensor that measures magnetic fields provided from the magnetic bodies to the stators through the relative rotation between the magnet member and the stators.

(KO) 본 발명에 따른 전자식 파워 스티어링 시스템용 토크센서는, 적어도 둘 이상의 스테이터(Stator); 검출 대상체의 변화에 의해 상기 스테이터에 대하여 상대적으로 회전하도록 상기 적어도 둘 이상의 스테이터 사이에 설치되고, 비자성체와 상기 비자성체의 양단에 구비된 자성체로 이루어진 마그네트 부재; 및 상기 마그네트 부재와 스테이터 간의 상대적 회전에 의해 상기 자성체로부터 스테이터에 제공되는 자기장을 측정하는 자기센서;를 포함한다.

Designated States: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI