A Study on Novel Slotless Design of Variable Reluctance Resolver

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***Abstract*— This paper deals with design and characteristic analysis for variable reluctance resolver with slotless type using finite elements method. Position sensor of variable reluctance resolver is required in permanent magnet motors for electric vehicle and hybrid electric vehicle in order to control position or rotating speed. Slotless variable reluctance resolver has high reliability in external disturbance as well as position angle error. Moreover, it has high degree of freedom in designing step because of elimination of stator teeth. In this paper, the design and analysis methodologies are proposed and the proposed variable reluctance resolver is compared with original teeth type resolver.**

***Index Terms*— Sensor systems, finite element methods, error analysis, slotless variable reluctance resolver.**

I. Introduction

Nowadays, permanent magnet motors are used for electric vehicle / hybrid electric vehicle and widely automobile application [1]. They need appropriate position sensors in order to be controlled in accordance with position reference or speed reference by an inverter. Currently, position sensors are generally used as encoder, resolver, hall sensors, etc [2], [3]. However, in case of EV/HEV, variable reluctance resolver is used because of vibration, durability and reliability of position signal. VR Resolver generates output signal as SIN, COS and it converted position of rotor through Resolver-to-Digital Converter [4], [5]. If output signal is ideal signal, it will detect exact position angle of rotor. However, winding arrangement is limited because of slot in stator to improve quality of position angle in rotor. Thus Position signal will be improved through distributed winding by slot-removal. Also, efficient area use can compact and it can facilitate robust design through distributed winding. To design slotless VR Resolver, design parameters such as winding ratio, coil pitch and winding area are selected. Fig.1 shows VR Resolver of slot type and slotless type.

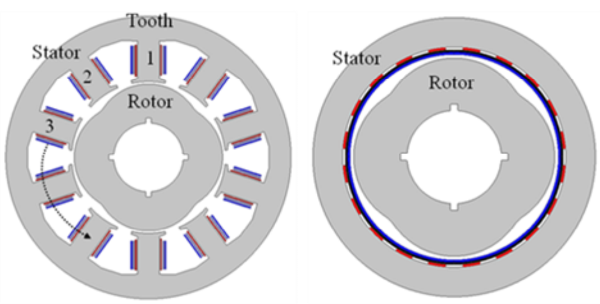


Fig.1. VR Resolver of slot type and slotless type

II. Design Parameters for Slotless VR Resolver

Design of Slotless VR Resolver's exciting winding is concentrated winding and, design of sine and cosine signals' winding is distributed winding. Fig. 2 shows part of winded coil by linearly spreading out.

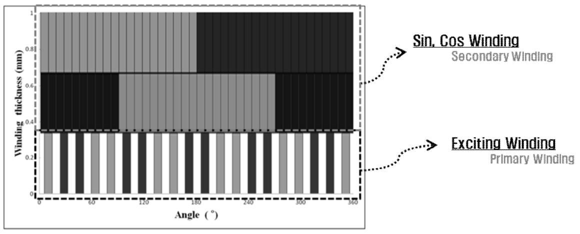


Fig.2. Scheme of Slotless VR Resolver Winding

In the Fig. 3, sine and cosine signals are superimposed so that sin and cosine waves are formed. As a result of this design, maximum position angle error factor is 38.08 ° through RDC because cosine wave is sinusoidal in Fig. 4 while sine wave is not sinusoidal.

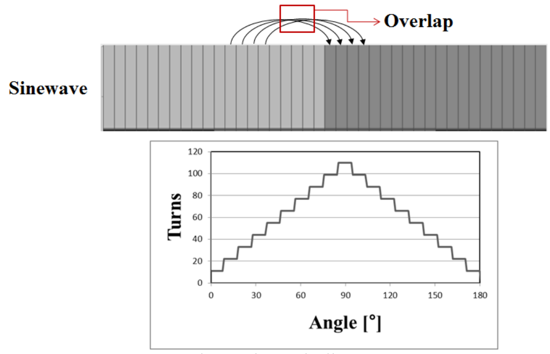


Fig.3. Sine Winding

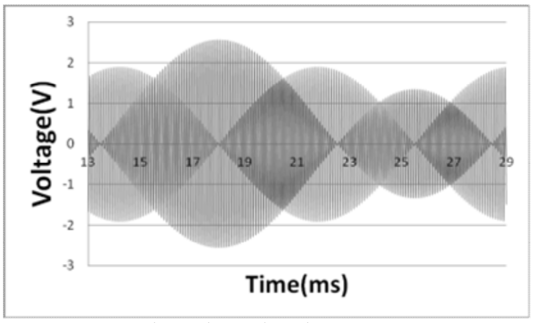


Fig.4. Sine and Cosine Waves

In this paper, there is coil pitch to reduce error factor. Fig. 5 shows the method to wind the coil at the regular interval and the coil pitch is analyzed by giving three parameters. At this time, the coil pitch interval is given three degrees from center in circle and by using FEM and RDC, error factors are presented like Table I.

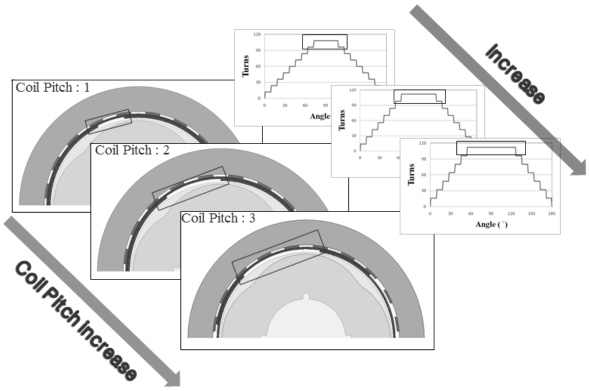
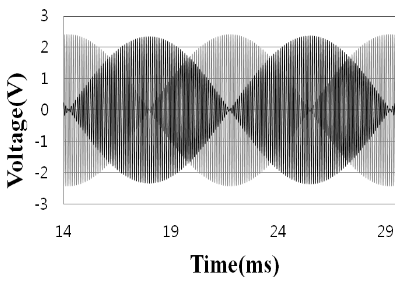


Fig.5. Increase of Coil Pitch

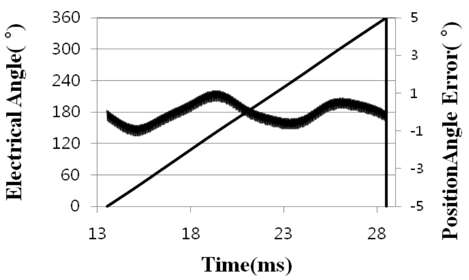
TABLE I
DEFINITION OF EACH PARAMETER

Level	Error Factor
Coil Pitch : 1	27.41°
Coil Pitch : 2	1.27°
Coil Pitch : 3	28.57°

As a result of analysis, Coil Pitch 2 is the lowest error factor. Fig. 6 shows results of each wave and error factor.

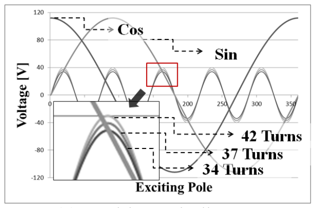


(a) Sine and Cosine Waves of Coil Pitch 2

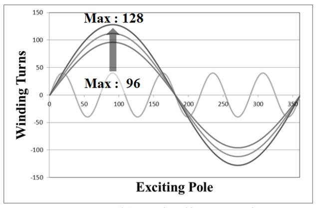


(b) Position Angle Error of Coil Pitch 2
Fig.6. Sine and Cosine Waves and Error factor of Coil Pitch 2

Now, with keeping Coil Pitch2, the error factor is compared and analysed following increase of winding's turns in Fig. 7. After error factor is analysed following change of exciting winding's turns, the error factor is analysed following change of sine and cosine winding's turns.



(a) Exciting Winding turns



(b) Winding Ratio
Fig.7. Exciting winding, Sine and Cosine winding

Table II shows that angle error factor increases with change of exciting winding and change of sine and cosine windings' turns.

TABLE II
RESULT OF ANALYSIS WITH EACH PARAMETER

Level	Error Factor
(a) Exciting Winding turns	
Exciting turns : 32	1.32°
Exciting turns : 37	1.27°
Exciting turns : 42	1.26°
(b) Winding Ratio	
Sin, Cos Max turns : 96	1.32°
Sin, Cos Max turns : 112	1.27°
Sin, Cos Max turns : 128	1.19°

III. CONCLUSION

As a result of Slotless VR Resolver, giving a distributed winding as sine and cosine windings' turns, we could know that angle error factor is emerged. Just, like this the error factor could be declined enough by using a winding law and it is demonstrated in the paper. Also, when the coil pitch is level 2, there is the lowest error factor, and there is a little error factor's change according to the change of the number of turn.

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