Analysis of the feasibility of using an AC motor with new winding type for building electric vehicle

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Abstract – Induction machines are widely used in all spheres of our life. They have different advantages and disadvantages. This paper consider one of the approaches to improve them – new type of winding Slovyanka. A comparative research of motors with different windings on electric vehicle example where conducted. Economic efficiency is shown.

Keywords – AC motor, windings, Slovyanka, electric vehicle.

Introduction

Induction machines are the keystone of world industry. AC motors are the most used motors in the all of industries, in varied aggregates and machines, even electric vehicle. Squirrel-cage induction motors (SCIMs) are probably the most frequently used compared to other AC motors. Such widespread use of this type of motors is due to their high reliability, cheapness, easy use and manufacturing. In spite of all advantages of AC motors there are also disadvantages: significant consumption of magnetization current, large starting currents (5-7 of nominal), small values of starting and minimum moments.

For quite a long time of its existence, asynchronous motors improved their characteristics (by improving insulating materials and steel grades, reducing the air gap between stator and rotor, even appeared AC motors with a copper rotor), but did not undergo any significant changes. The only part of the induction motor, which has not changed is three-phase stator winding, although it has steel losses and losses due to the current of magnetization, which strongly influence the efficiency. In AC motors, two types of three-phase winding are used: star and delta connection. Star - reduces starting currents, but the power is lost, the delta - allows you to get full power, but has high starting currents. Often, a combined starred-delta motors is used, which makes it possible to avoid high starting currents, however, the starting torque is reduced twice.

The new technology of three-phase stator winding

There is a new technology of three-phase stator winding, which combines the benefits of both compounds and eliminates their shortcomings [1]. It is called «Slovyanka». Such connection involves the use of two sets of windings, star and delta, connected in parallel. According to [2], this method of winding allows to obtain a number of significant advantages, such as:

1) reduction of starting currents down to 2-3 nominal values;
2) increase of starting and minimum moments by 30-40%;
3) reduced magnetization current, due to reduction of losses in steel in 2,7-3,0 times;
4) the efficiency is close to the nominal in the range from 0,3 to 1,4 of the nominal loads;
5) reduction of the level of electromagnetic noise and vibration;
6) reduction of start-up switching equipment and absence of the additional power supply cable for starting the "star-delta";
7) savings of electric energy by 15-40%.

Techno-economic comparison of the AC motor with regular winding and winding «Slovyanka»

In order to analyze the feasibility of using a motor with new winding, it was conducted a research on such intensively developed recently mechanism as electric vehicle.

Electric vehicles are becoming more and more popular. Electro mobiles, such as Tesla, use AC motors instead of brushless direct current motors (BLDC). These AC motors are specialized for using in electric vehicles – they are made from electrotechnical steel for input voltage frequency of 200-300 Hz. Although they are cheaper than BLDC, but still expensive. The new technology, Slovyanka, enables to use industrial motors with regular electro-technical steel in electric cars.

Comparative studies between windings were made under normal environmental conditions for the same vehicle which was driven according to Japanese "10-15 driving mode" (Fig. 1) [3]. This standard "10-15 driving mode" was commonly used for fuel economy testing. As a vehicle it was selected car "Slavuta", with weight 850 kg and frontal area is 2.002 square meters.

Main force balance question for electric cars looks the following:

$$F_{tp} = F_{frw} + F_{lr} + F_{ar} + F_i, \quad (1)$$

where F_{tp} – traction power; F_{frw} - strength of rolling resistance of wheels; F_{lr} – strength of of lifting resistance; F_{ar} - strength of air resistance; F_i – strength of inertia.

Based on Eq.(1) the torque to provide "10-15 driving mode" (Fig. 1) can be calculated:

$$M = \frac{\left(F_{frw} + F_{lr} + F_{ar} \mp F_i\right) \cdot r}{\eta_{tr} \cdot k_{tr}}, \qquad (2)$$

where r - wheel radius; η_{tr} – transmission efficiency; k_{tr} - transmission number of the transmission.

Fig. 1 shows velocity according to the «10-15 driving mode» and torque, which required for driving vehicle. Multiplying speed by the torque, we can receive power *P* (Fig. 2). As follows, performed calculations showed, that to provide "10-15 driving mode" "Slavuta" requires a motor with nominal power of 26.4 kW and 49 kW maximum power. According to this requirement the following motors were selected for comparison: specialized motor for electric cars AC-15 (price is 1393$ [4]) and AYR100S8 with winding «Slovyanka» (final price is 465 $ [5]). In order to study efficiency of two motors with different windings a comparative graph of efficiency as function of mechanical power for two motors (regular and winding «Slovyanka») [2] was used. This graph was interpolated to more powerful motor, assuming that proportion of difference would be the same. This way a graph of efficiency change during «10-15 driving mode» for vehicle with motors with different windings where obtained - Fig. 2.

Fig.2 shows power, which is needed for vehicle moving and efficiency of AC-15 ($\eta 1$) and AYR100S8 with winding «Slovyanka» ($\eta 2$). The analysis of this graph shows that the integral value of the efficiency of the motor AYR100S8 with winding «Slovyanka» is 0.86% higher than of the AC-15.

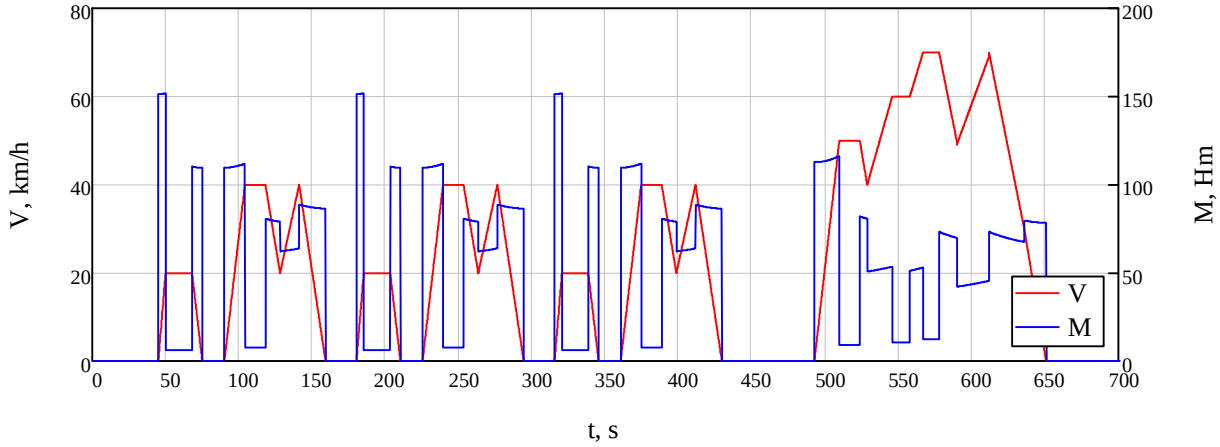

Fig.1. Velocity and torque of “Slavuta” for «10-15 driving mode».

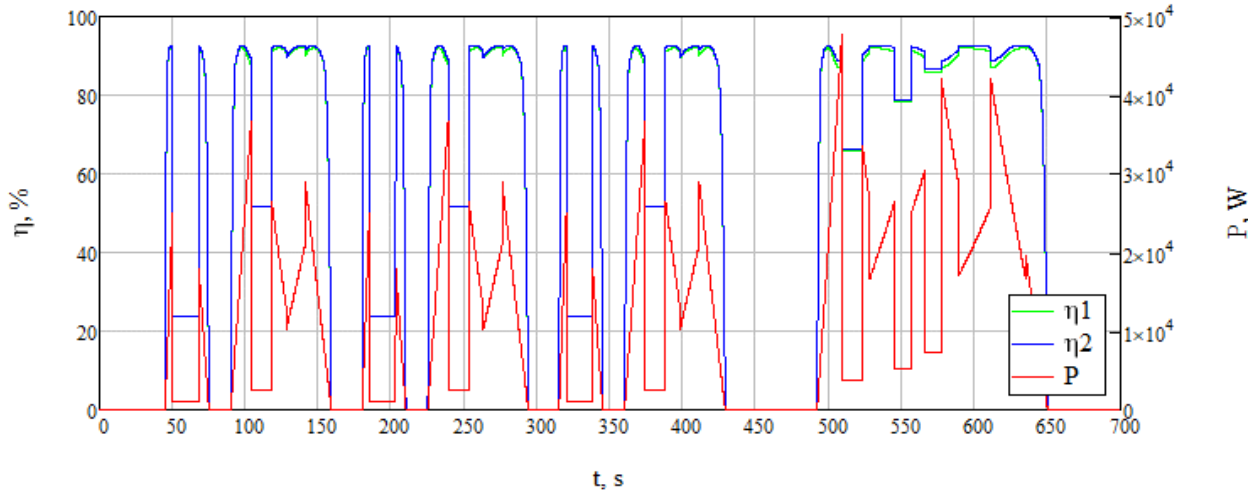

Fig.2. Power and efficiency graph: η_1 – AC-15 motor, η_2 - AYR100S8 with winding «Slovyanka».

Conclusion

There is new type of winding for AC motors that combines star and delta - «Slovyanka». Performed researches showed, that being 3 times cheaper it provides 0.86 % higher efficiency on electrical vehicle. This enables to produce more effective and cheaper electric vehicles.

References

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