New Generation (9G) Alternator

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1. Introduction

To meet the demands of major automobile manufacturers for high-performance products, we have developed a new generation (9G) alternator with higher output and efficiency without sacrificing quietness, by using state-of-the-art manufacturing technologies for improving the fill factor of the stator coil for which conventional methods had reached their limit, This report introduces technological aspects of the stator used for the new generation (9G) alternator.

2. Trends of Alternators

Alternators for automobiles in general are driven via belt by engines for AC generation, and the current thus generated is converted into DC by built-in rectifiers to provide electric power to the various electric loads on the vehicle and also to recharge its battery. Recently, electric loads on automobiles have increased further as the number of electronics-based systems have increased to meet demands related to the environment, safety and security, and information and entertainment.

As for environmental needs, after the Kyoto Protocol, which was adopted at the Third Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) in 1997, announced legally binding reduction targets for greenhouse gas emissions for respective advanced nations, controls on automobile fuel consumption have been tightened worldwide in order to reduce CO_2 emissions. [(1)] In order to satisfy these regulations on improving fuel economy, the electrical loads on automobiles, directly or indirectly have rapidly increased. As a result, technological requirements for alternators have become much more complicated.

3. Challenges for Alternators

The recent technological challenges for alternators are described below. The development themes listed below are trade-offs to each other yet must be solved simultaneously.

(1) High outputs for increased electrical loads

As mechanical engine accessories are increasingly motorized to improve fuel economy, the output of alternators will need to be increased by 30 amperes by the year 2015.

(2) High power generation efficiency

Even if mechanical engine accessories are motorized, its merits would be offset if alternator power generation efficiency were low, because driving torque will increase for higher output.

(3) Compact and light-weight

The high outputs of alternators must be attained without increasing the size of alternators, due to vehicle requirement for weight reduction and limited underhood space.

(4) Quietness

Quietness of each engine part is strongly required in order to increase product value of the vehicle. Therefore, power generation noise, which tends to increase when alternator output is enhanced, must be lowered.

4. Technological Features of New Generation (9G) Alternator

4.1 Outline of new generation (9G) alternator

We have solved the above problems and completed the development of the new generation (9G) alternator (Fig. 1) by simultaneously improving the fill factor of the stator coils and increasing both the cooling performance and noise suppression required for increased output levels. The technological features are described below.

Fig. 1 9G Alternator

(1) Output current: Increased by 54% (against the conventional model 6GA)
(2) Power generation efficiency: Increased by 12% (against the conventional model 6GA)
(3) Electromagnetic noise: Reduced by 10 dB (against the conventional model 6GA)

4.2 Improvement of stator fill factor

The factor that most influences the power genera-

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tion efficiency of an alternator is the copper loss of the stator. With the conventional model 6GA series, the copper loss accounts for approximately 67% of the total loss under full load and temperature saturated condition. One effective way to reduce the copper loss of a stator is to increase the cross section area of the coil by making the most of the available stator coil winding space, that is to say, increasing coil fill factor (∑ copper wire cross-section/stator coil winding space). For example, Mitsubishi developed and commercially produced the 8GM alternator with higher fill factor by applying coil forming only to the portion to be inside the slots of the stator core, whereas no coil forming was conducted on 6GA stator.

However, the scope for improving the fill factor by this method is limited since the copper wires in the conventional models must be inserted axially into the stator core in the manufacturing process.

Meanwhile in 1993, we developed a stator structure called "Poki-Poki motor", and this structure has since been employed in various information devices, factory automation equipment, electric home appliances, automobile devices, and elevators. This original technology of Mitsubishi can improve the fill factor without sacrificing productivity. [2]

Under these circumstances, we have developed a new stator manufacturing method that combines the conventional 8GM technology (partial coil forming for copper lines in the slot) with the Poki-Poki motor technology. The stator cores, which are ring-shaped in conventional models, are now flat bands. Furthermore, band shaped strands of continuous copper wires, to which coil forming is conducted, are inserted into the opening of the slot (see Figs. 2 and 3). This method has dramatically improved the fill factor of the stator coil (Fig. 4) and reduced the coil resistance remarkably by reducing the height of the coil end.

Fig. 2 9G Stator

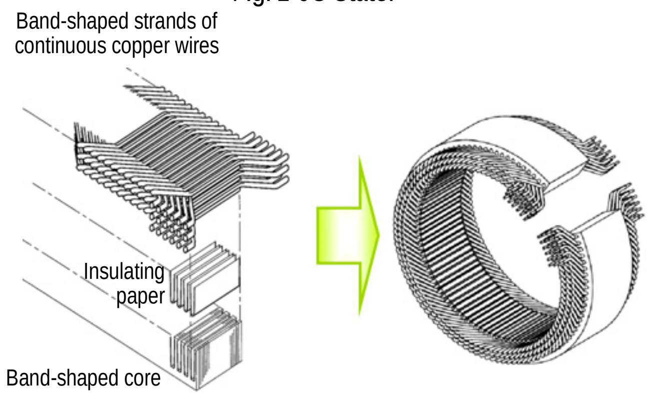


Fig. 3 Manufacturing method of 9G stator

4.3 Improved cooling performance

Higher output without changing the size of an alternator increases the temperature of the alternator components. When designing the alternator, it is desir-

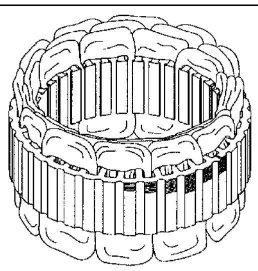
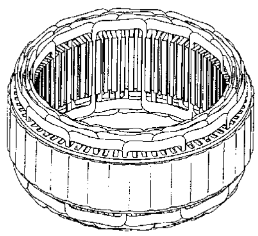
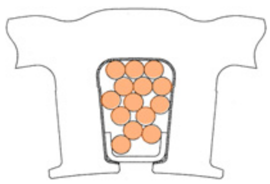
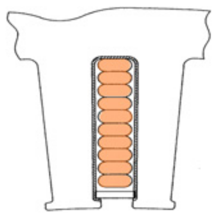
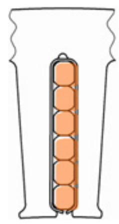
	Conventional models		New generation model
	6GA	8GM	9G
Appearance			
Slot cross section	 Fill factor: 60%	 Fill factor: 72%	 Fill factor: 85%

Fig. 4 Comparison of stator structure

able to improve the cooling performance as far as is practical, to minimize the use of heat-resistant parts that increase material costs. Figure 5 shows the improved heat transfer performance of the bracket as an example of the cooling performance improvements we have incorporated in the new 9G alternators.

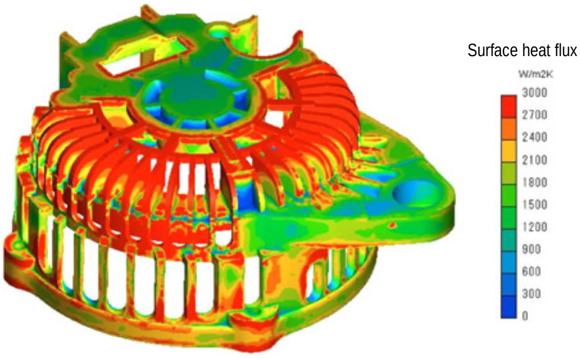


Fig. 5 Case example of heat transfer analysis

5. Conclusion

This report has introduced stator manufacturing technology that remarkably improves the fill factor, and design technology for the cooling mechanism on the basis of thermo-fluid analysis. These technologies have contributed to the successful development of alternators that feature high output, high efficiency, compact size, reduced weight, and low noise. We will continue to develop technologies for higher outputs and efficiencies.

References:

(1) Data from the web page of the Ministry of Environment (published information)

(2) N. Miyake: New Motor Manufacturing Technologies, Mitsubishi Denki Giho, 76, No. 6, pp. 426-430 (2002)