NanoMax – (TAIHNM)
Corona Resistant Magnet Wire

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ABSTRACT

This paper is provided as documentation of market research, engineering development, and production trials to create a new premium corona resistant wire offering by Rea Magnet Wire.

Market research was conducted with customer surveys sent to over 375 motor repair shops. The feedback shared by the 70 respondents identified opportunities and focused the performance improvements to the following characteristics: mechanical insertion force, corona resistance, damage resistance, thermal class and varnish compatibility. In addition, an extensive benchmarking study was conducted to validate performance of competitive product against those characteristics. Rea Magnet Wire then combined the best available manufacturing techniques and enamel materials to successfully create a premium best-in-class, inverter-grade magnet wire. We proudly introduce our new premium performance product, NanoMax, which is the best corona resistant magnet wire available in the market.

Background – Market Needs

Rea Magnet Wire initially surveyed customers informally at the 2017 EASA Conference in Tampa, Florida. EASA participants were asked to rate the importance of scrape resistance, windability, and termination in their manufacturing process on a scale of 1 to 5, with 1 equating to "Unimportant" and 5 equating to "Important."

The results–while not statistically significant due to the number of responses–suggested that scrape resistance and windability were the most important characteristics, with an average score of 4.7 for both. The results of this initial survey led Rea Magnet Wire to pursue a broader market-wide survey.

Rea Magnet Wire then partnered with a distributor to coordinate a survey to the motor repair market. The survey was initially sent to over 375 motor repair shops and over 70 individuals responded.

The questions rated the importance of different aspects of magnet wire across two quality measurements–voltage endurance and scrape resistance–as well as two ease-of-use measurements–windability and packaging.

The results of the survey data validated earlier findings and are included below. The survey population was asked to "Rate the importance of each attribute below with 1 being most important, and 5 being least important."

Characteristic	1	2	3	4	5	Count	Avg
Voltage Endurance	32%	16%	25%	14%	13%	69	2.61
Windability	22%	20%	29%	20%	9%	65	2.75
Scrape Resistance	13%	37%	11%	26%	13%	62	2.89
Packaging	9%	15%	10%	21%	46%	68	3.79

Voltage endurance was concluded to be the most important factor with an average rank of 2.61 on the scale and the most total respondents ranking this factor as one of their top three. Windability (2.75), scrape resistance (2.89), and packaging (3.79) rounded out the survey responses.

The survey also asked, "In order to make the wire easy-to-use, which would you say is the wire characteristic you think is the most important?"

Characteristic	1	2	3	4	5	Count	Avg
Wire Softness	31%	26%	28%	7%	8%	74	2.35
Scrape Resistance	22%	28%	29%	17%	4%	69	2.55
Inception Voltage	26%	24%	29%	14%	7%	70	2.53
Packaging	6%	19%	10%	42%	23%	69	3.58

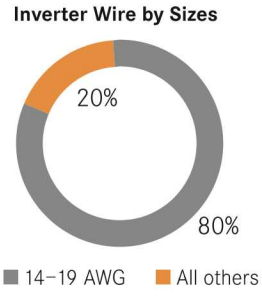
Wire softness was concluded to be the most important factor with an average rank of 2.35 on the scale. Scrape resistance (2.55), inception voltage (2.53) and packaging (3.58) rounded out the survey responses.

With the understanding that our customers are voicing a need for a higher performing, highly specific inverter-grade magnet wire, Rea Magnet Wire set out to design and develop this new product.

Current Situation

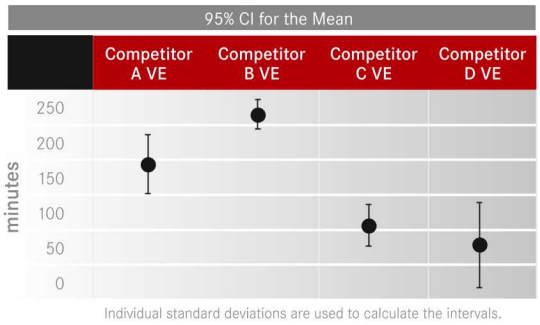
The survey data validated what the motor market deemed to be the most important performance characteristics of inverter-grade magnet wire. In order to create a superior product, Rea Magnet Wire completed a benchmarking study of the various competitor products available.

Rea Magnet Wire sourced over 28 different spools of competitive products across three different sizes of wire: 15.0 AWG, 18.0 AWG, and 22.0 AWG from three different competitors. The testing range would cover more than 80% of the total inverter-grade wire sizes used by the magnet wire market.



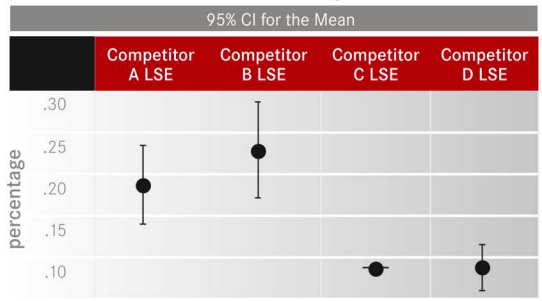
The study showed performance gaps in corona resistance, conductor softness, and damage resistance. The graphs below show the corona resistance and low stress elongation results on 15.0 AWG. These characteristics show variation among the suppliers with no product clearly leading the market in all performance characteristics. With no clear market leader, an opportunity to fill this gap in market needs exists.

Interval Plot of Voltage Endurance on 15.0 AWG



Individual standard deviations are used to calculate the intervals.

Interval Plot of Low Stress Elongation on 15.0 AWG



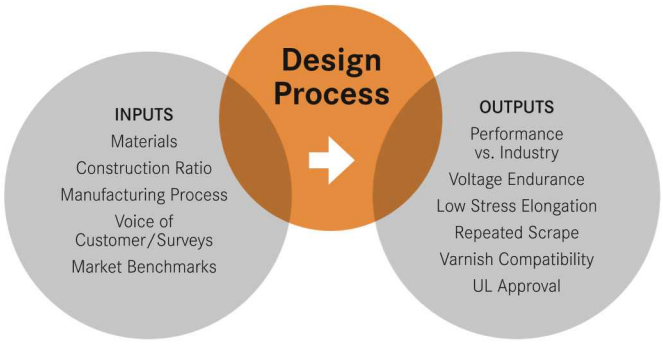
Individual standard deviations are used to calculate the intervals.

Development Goal

The goal of the effort was to develop a product that is a clear market leader with features of:

1. Best corona resistance performance
2. Softest conductor properties
3. Leading damage resistance
4. Higher thermal class

To accomplish this, the design effort can be modeled as shown below:



Several input factors were considered. External inputs representing the voice of the customer were obtained along with an understanding of the competitive performance environment. Business inputs representing the readiness of the technology, product structure, and internal culture for development were included. These external and business inputs along with the product inputs for material types, material ratios, manufacturing processes, technical knowledge base and other options factored into the design process.

The design outputs were voltage endurance, low stress elongation, repeated scrape, varnish compatibility, and thermal class.

Analysis

The design method utilized was:

1. Evaluation of materials to create the best corona resistance and the best damage resistance
2. Knowledge of key manufacturing processes to create the softest conductor properties
3. Knowledge of material construction ratios to create the best product features

These factors were utilized to produce prototypes for testing. The test results of the prototypes were used to identify the critical materials, processes, and construction ratios to create a premium performing product. The results are as follows:

Corona Resistance: Voltage Endurance Testing

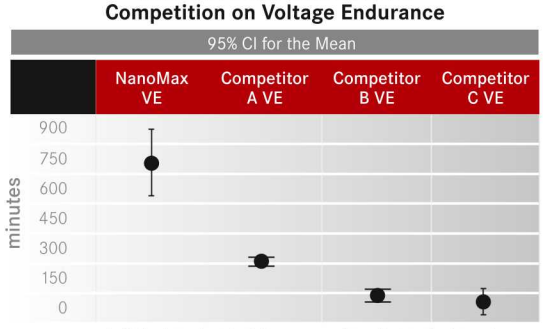
Test Equipment: Ampac Model MP-1000 High Voltage Endurance Tester with 3500V Upgrade

Testing Process: NEMA twisted pairs tested using 3500 VAC at 120°C until failure

Product Improvement: In order to improve corona resistance, several material suppliers were asked to submit their recommendations and sample enamels for evaluation. These materials were used to produce magnet wire for evaluation. Then voltage endurance testing was conducted to determine the material which produced the best performance. This material was then utilized for the final product design.

Test Results: NanoMax achieved best in class corona resistance versus the competition.

Interval Plot of NanoMax vs. Competition on Voltage Endurance



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Mechanical Insertion Force: Low Stress Elongation (LSE)

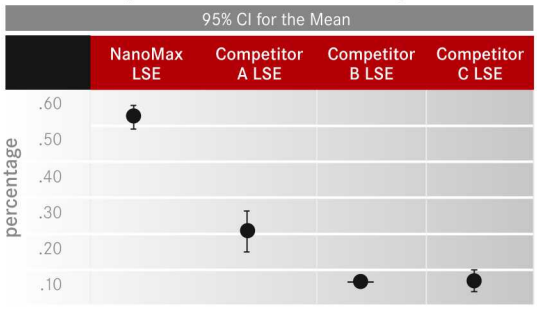
Test Equipment: Tinius Olsen H5K-S Mechanical Properties Tester

Testing Process: ASTM B279

Product Improvement: In order to achieve softer mechanical properties, Rea Magnet Wire utilized multiple production improvements to create wire with the highest LSE value on the market.

Test Results: NanoMax achieved best in class conductor softness versus the competition.

Interval Plot of NanoMax vs. Competition on Low Stress Elongation



Individual standard deviations are used to calculate the intervals.

Damage Resistance: Repeated Scrape

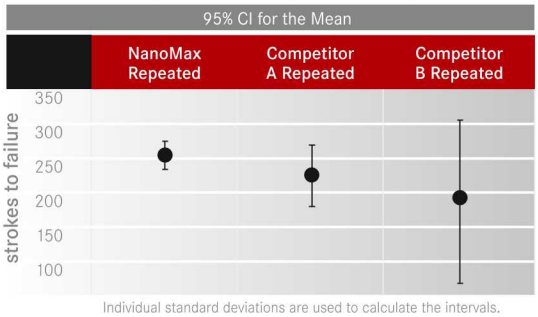
Test Equipment: Ampac Model Nova 600 Repeated Scrape Tester

Testing Process: Repeated scraping of the wire enamel until short circuit due to conductor exposure

Product Improvement: Damage resistance was enhanced through the introduction of a high molecular weight and internally lubricated Polyamide-imide (PAI) topcoat. The corona resistant enamel also utilized a PAI polymer carrier.

Test Results: NanoMax achieved dramatic improvement in damage resistance.

Interval Plot of NanoMax vs. Competition on Repeated Scrape



Individual standard deviations are used to calculate the intervals.

Varnish Compatibility

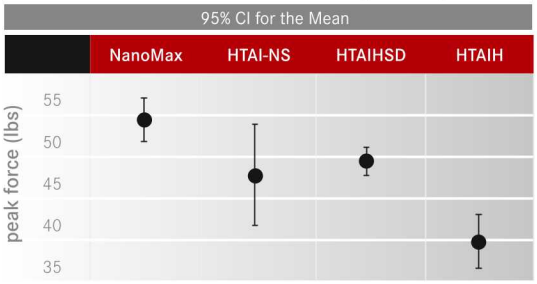
Test Equipment: Tinius Olsen H5K-S Mechanical Properties Tester with 3 point break fixture

Testing Process: Varnished Helical Coil Peak Break Force

Product Improvement: Varnish compatibility is important to insure motor windings retain varnish build and strength. With the material changes developed in NanoMax, varnish compatibility and strength are retained, which provides further improvement to the overall application insulation system.

Test Results: NanoMax retained excellent varnish compatibility with no loss of varnish adhesion strength when compared to other Rea products.

Interval Plot of NanoMax vs. Alternatives on Varnish Compatibility



Individual standard deviations are used to calculate the intervals.

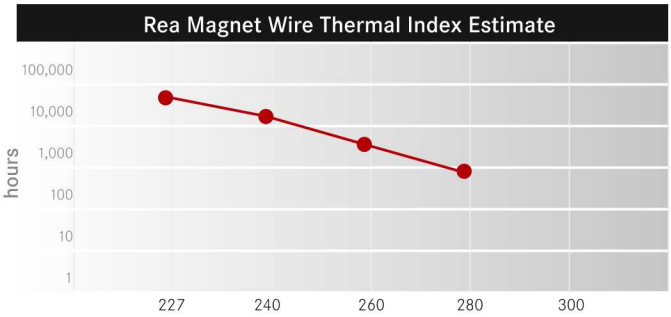
Thermal Class

Test Equipment: UL Testing Laboratory Oven and Proof Tester

Testing Process: ASTM 2304/UL 1446

Product Improvement: NanoMax increases the percentage of PAI. As a result of the high percentage of PAI in the construction, the team believed the thermal class of the wire would potentially also increase and this was validated by UL—an independent third party.

Test Results: NanoMax achieved a 220°C thermal rating from UL and is listed in the Rea Magnet Wire file number E37683.



Conclusion

The performance of NanoMax has proven to be superior and is the market leader in several key performance features. The new design was intended to improve the corona resistance, conductor softness and damage resistance, as well as increase the thermal class of the wire. In all four cases, these design goals have been met or exceeded to the point that NanoMax is the best product available in the market today.

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