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Tightness Tests of Lamination-Bonded Electric Sheet Stacks

Abstract: The article presents the results of tightness tests involving specimens of lamination-bonded electric sheet stacks exposed to water pressure restricted within the range of 2 bars to 14 bars. Cylindrical specimens were made of NO27 SURALAC 9000 electric sheets with adhesive, some of which were directly exposed to a pressure test after stacking, whereas some were additionally impregnated with resin prior to testing. The test results indicated that the specimens additionally impregnated with resin did not reveal any signs of leakage when exposed to a water pressure of up to 10 bar for 10 minutes. During the tests, the pressure in the measurement system remained constant throughout the entire 10-minute period (no pressure drop in the measurement system was observed).

Key words: tightness test, electric steel sheet, lamination bonding technology, tightness of electrical steel stack

DOI: 10.32730/mswt.2024.68.6.6

1. Introduction

The most popular technologies for stacking electrical sheets into stator/rotor cores include welding, clamping, riveting and (adhesive) bonding. The effect of the above-named technologies on individual magnetic properties of cores is presented, among other things, in publications [1, 2]. The conclusion drawn from these works is that when stacking the stator and rotor (because of the lowest increase in losses), the most advantageous method involves adhesive bonding with thermosetting adhesive [2]. If compared to other stacking technologies, adhesive bonding used for the fabrication of stator/rotor stacks has various advantages, including:

- joining of individual sheets of the stack over the entire area (in comparison with spot joining as is the case with welding or clamping),
- no clenching of sheets in the joint area (as in welding).

In addition to the above-presented advantages, the mechanical properties of adhesive-bonded sheet stacks are also interesting from the electrical machine design engineers' point of view. The lamination bonding technology is enjoying increasing popularity. A particularly interesting advantage from a mechanical point of view is the formation of a joint over the entire sheet area, reducing the risk of local delamination and positively affecting the strength of the entire package. The question which arises is whether the joint over the entire area of the sheet is (at least to a minimal degree) tight to the pressure of liquid (e.g. from the electric machine cooling system).

The objective of the tests discussed in the article was the performance of tightness tests involving specimens of lamination-bonded stacks exposed to water under increasing pressure.

2. Preparation of specimens for tightness tests

The tightness tests involved the preparation of cylindrical specimens made of electric sheets NO27. The sheets were characterised by a layer of epoxy adhesive applied by the manufacturer (Cogent Power). The stacking was performed in accordance with the technology specified by the manufacturer. The cylindrical specimens used in the tests were characterised by a wall thickness of 5 mm with an internal hole having a diameter of Ø10 mm, through which water was supplied under pressure ($Ø_{ext.}$ 20 mm/$Ø_{int.}$ 10 mm). The specimen height amounted to 55 mm. Nuts with an internal thread of 1/4" (stainless steel A2) were adhesive-bonded to the outer sheets on both sides of the stack using TEROSON MS 939 flexible sealant (in order to screw the specimen to the measurement system). An example of a stack specimen used in the tests is presented in Figure 1. The tests involved the making of two specimens:

- specimen no. 1 was subjected to tightness tests immediately after stacking,
- specimen no. 2 after stacking was additionally impregnated with resin Dolphon CC 1180 HiR.

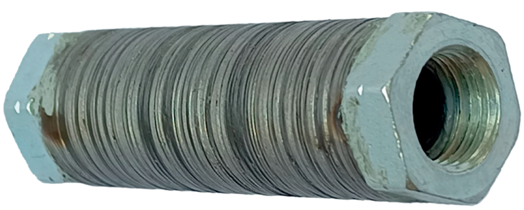

Fig. 1. Test specimen after additional impregnation

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The measurement system consisted of a water tank, amanual pump with a pressure gauge, shut-off valves, hoses with DN10 STECKO plug-in ends, STECKO DN10--GZ 1/2” socket connectors with adapters for 1/4” external threads and metal-rubber seals for 1/2” and 1/4" threads. The initial stage involved the preparation of specimens having a wall thickness of 10 mm ($Ø_{ext.}$ 30 mm/$Ø_{int.}$ 10 mm) and a height of 40 mm (specimens nos. 3 and 4). In the above-presented specimens, 1/4" internal threads were made directly in the internal hole of the stack, on both sides. However, the initial tests revealed that threading weakened the stacks in the threaded part, leading to water leaks in the threaded part of the specimens (threading was probably the reason for the leaks during the tests). As a result, the results concerning specimens nos. 3 and 4 were considered unreliable and ignored.

3. Tightness tests

The tightness tests were performed by filling the measurement system with water (without setting the pressure) followed by the closing of the outlet valve and slowly increasing the pressure in the system to the target value. After reaching the desired pressure value, the inlet valves were closed and the pressure in the system was set at a constant target value. The behaviour of the measurement system with the specimen (affected by the previously set pressure) was observed for 10 minutes. Afterwards, the valves were opened and a new target pressure was set. During the test, observations involved the water pressure value on the pressure gauge and the outer surface of the cylindrical stack where the appearance of water droplets (if any) would indicate a leak. If no leakage was observed on the specimen surface and the water pressure value on the pressure gauge remained unchanged throughout the 10-minute test period, the specimen was considered to be tight in terms of a given water pressure value. The tests were performed for a target pressure of 2 bar, 6 bar, 10 bar and 14 bar. An example of a leak test in relation to a pressure of 10 bar is presented in Figure 2.

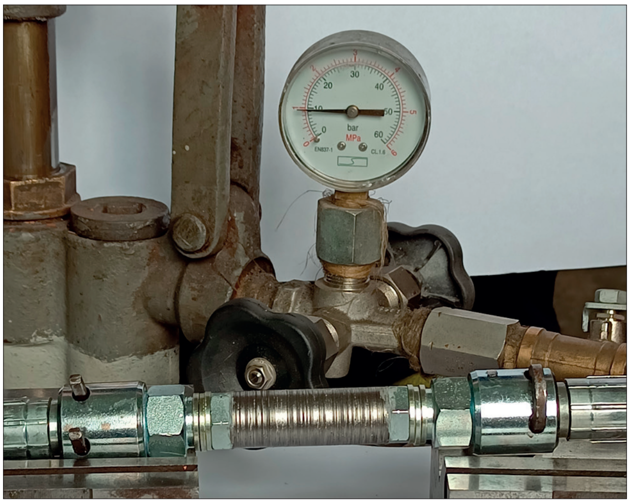

Fig. 2. Tightness tests (10 bar) of the additionally impregnated specimen

4. Results

The tightness test results in relation to specimens 1 and 2 are presented in Table 1.

Próbka pakietu blach klejonych, która bezpośrednio po pakietowaniu została poddana testom nie wykazała szczelności nawet przy najmniejszej zastosowanej podczas testów wartości ciśnienia (2 bary). Wycieki wody na powierzchni próbki pojawiły się już podczas wzrostu ciśnienia do wartości docelowej równej 2 bary, w związku z czym niemożliwe było przeprowadzenie prób przy większych wartościach ciśnienia. Natomiast próbka nr 2 poddana dodatkowej impregnacji żywicą po pakietowaniu pomyślnie przeszła testy szczelności do wartości ciśnienia wynoszącej 10 barów (włącznie).

Przy próbie 14 barów w układzie pomiarowym pojawił się spadek ciśnienia, ale nie zaobserwowano wycieku na powierzchni zewnętrznej samej próbki. Prawdopodobnie wyciek pojawił się w innym miejscu w układzie pomiarowym (na uszczelkach metalowo-gumowych lub w miejscu połączeń węży z zaworami).

Table 1. Tightness test results for the test specimens ($Ø_{ext.}$ 20/$Ø_{int.}$ 10)

Water pressure [bar]	Time [min]	Specimen 1 stack of adhesive-bonded sheets – not impregnated	Specimen 2 stack of adhesive-bonded sheets impregnated with resin
2	10	× (leak during exerting pressure)	√
6	10	– (test not performed)	√
10	10	– (test not performed)	√
14	10	– (test not performed)	× (pressure drop in the measurement system after 30 s)

5. Summary

The stack of adhesive-bonded sheets could withstand a pressure of up to 10 bar, yet after the additional impregnation of the stack with resin and on condition that, following the impregnation procedure, the stack was not weakened by additional machining (e.g. threading). Immediately after stacking, the stacks did not show any signs of tightness, even at low-pressure values in the measurement system.

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The article was presented at the 32nd Scientific and Technical Conference "Problems of Exploitation of Electric Machines and Drives" – PEMINE (Słok near Bełchatów, 2–4.10.2024)