Hybrid curing systems to improve rotational machine resin impregnation efficiency

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In modern rotational machine manufacturing plants production rate, energy efficiency and ease of maintenance must be obtained from each production machine.

Existing resin impregnation machines used to impregnate secondary insulation onto rotating machines still rely on outdated curing methods. Where energy efficiency and high production rates are required, a possible combination of resin curing systems to overcome one another’s shortcomings could result in greater energy efficiency, production rates and ease of maintenance.

During the manufacturing of rotational machines such as electrical motors and alternators, the rotor is impregnated with a resin as secondary insulation [1]. This resin impregnation is crucial to the performance of the rotational machine as it keeps the copper coils together when in operation up to 18 000 rpm. This prevents coils loosening due to vibration and causing internal machine damage. Resin impregnation also increases the thermal conductivity of the rotor coil, thereby conducting heat away from the core while protecting the coil from water damage. During curing of the impregnation resin, the curing time can be decreased using a number of curing methods [2]. It is possible to use a number of different curing methods depending on the part, cycle time and preferred resin. This research will focus on the possibility of combining existing curing methods into a hybrid curing system in order to determine if decreased curing times, increased production rates and increased electrical efficiency can be achieved while the resin’s mechanical properties do not decrease. Figure 1 is an illustration of secondary insulation, also called ground insulation, on an alternator rotor where the impregnated resin can be seen.

During the resin curing process, internal crosslinking, which transforms the structure of the resin from a liquid to an infusible solid structure, takes place. This process is also called polymerisation. Figure 2 is a graphical illustration of typical resin curing phases. It can be seen from this illustration that resin, typically, has three curing stages where it crosses from one stage to another with the addition of heat.

The heat required to cure resin can be supplied by an external source or heat created by the polymerisation process. The external process of curing resin is an exothermal process, which can be initiated by an initiator. To cure resin, a number of processes have been developed over the years. Some processes cure by increasing the temperature of the resin, while the addition of a photo initiator makes it possible to cure resin with UV radiation [4]. Curing resin with a microwave is also possible – as the microwaves heat up, the resin polymerisation takes place. As the resin is subjected to additional external thermal heat contributing to the existing thermal heat generated by the polymerisation process, the resin curing speed is increased and the curing time decreased.

Each of these technologies has its own advantages and disadvantages. When early impregnation machines where developed, energy was relatively inexpensive and readily available. This led to most of the early impregnation machines making use of thermal curing as a preferred curing method.

Impregnation machines, typically, have four stages: initial heating of the part; impregnating of the part with resin; curing of the resin; and cooling of the part. Figure 3 shows an existing impregnation machine where the process flow is from left to right. Thermal curing requires a large amount of energy to cure resin – typically in the region of 190 °C. These early impregnation machines require a large amount of maintenance due to a high number of internal moving parts and elevated temperatures, which cause parts to fail prematurely. Traditional thermal convection ovens have to heat up large volumes of air in order to heat the resin for curing. Alternative curing sources such as UV radiation can be focused directly on to the part, limiting unwanted energy being consumed.
Later developments allowed resin to be cured by UV radiation thanks to the addition of a photo initiator into the resin. The photo initiators produce free radicals when exposed to a UV radiation source, thus cross-linking and curing the resin. The benefit of curing resin with UV radiation is that it cures from the surface, limiting run-off after the resin dipping process. Emissions released during curing are now trapped beneath the already cured resin surface, limiting the need for cumbersome and energy consuming emission control systems such as extraction fans. Some currently available UV curable resins, such as a product produced by Elantas called UP 142 UV, has the capability to be cured with either UV radiation or thermal heat. Once the photo initiators have been irradiated by the UV source and the polymerisation process started, the process of cross-linking produces external thermal energy as a by-product of the polymerisation process. This thermal energy, in turn, continues the polymerisation process, ensuring that resin not exposed to the UV source will still fully cure. During the curing process using a UV radiation source a large amount of heat, up to 600 °C, is generated. This additional heat can be utilised to increase the curing rate. Further technologies capable of curing resin include microwave oven curing where the exposure to the microwave source can be controlled.

Resin can also be fully cured with a microwave source. It heats up the resin, thus initiating the polymerisation process. This additional microwave source heat, added to the exothermal heat produced by polymerisation, increases the curing rate. Heat transfer to the resin by microwave is direct and evenly distributed throughout the resin, unlike thermal heating which initiates heating at the surface of the resin. Tests conducted show that it is ideal to reduce the wattage of the microwave down to 120 W. This will avoid sparking inside of the microwave oven [5].

The benefit of using microwave curing is that the resin can be directly targeted, thus reducing energy consumption. Researchers studying the possibility of using microwave curing found that the cross linking density is higher with microwave curing than existing thermal curing systems. A higher cross-linking density will contribute to the fully cured resin having increased mechanical properties. It was also found that, typically, curing time is reduced when using a microwave source. The test conducted was, unfortunately, not done to optimise the curing time only in order to show that microwave curing can be used as an alternative curing method [5]. During the author’s research project, tests will be conducted to determine if the presence of metal in the resin to be cured will cause sparking and a potential fire hazard. The tests will also be used to optimise the curing time while still achieving a good high-density cross-linked resin.Beside resin impregnation of the rotational machine, the part is pre-heated to reduce curing time. When the part is dipped in a resin tub, the pre-heat ensures that gelation of the resin can be achieved as soon as possible. Once the resin has reached the gel curing point, resin run-off is reduced and the part can be further processed. After the part has been fully cured in the curing oven, it will travel through a cooling tunnel where excess heat is removed – it is possible to extract excess heat from both the pre-heating and cooling phases. This additional excess heat, which would traditionally be dumped into the environment, can now be funnelled back into the curing oven greatly reducing heat loss and increasing efficiency. Although the current scope of the research project does not cover extraction and re-use of excess heat, it would be a natural next step to greatly reduce energy loss in impregnation machines.

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Bibliography


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