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Effect of Moisture Content and Density on Thermal Conductivity and the Diffusivity of Abrasive Agglomerates

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Abstract
Aluminum oxide grinding wheels are among the most common and durable abrasive materials, boasting high hardness. They are primarily used for grinding and sharpening metals with high tensile strength, such as steel and wrought iron, and for removing burrs. As is well known, grinding wheels made of aluminum oxide were used in the early twentieth century (around 1900–1910) as a manufactured and durable alternative to natural abrasives such as sandpaper. These wheels were developed to meet the need for grinding metals with high tensile strength, such as steel and iron, providing fast cutting and high durability in industrial processes. When grinding temperatures rise, the moisture absorbed by the grinding wheels turns to steam, generating internal pressure that can lead to wheel cracking or a decrease in the strength of the bond (glass bond), thus accelerating wheel wear. However, this also has a positive effect, as the moisture (water) within the wheel pores increases the overall heat capacity of the body (wheel + water) because water has a very high heat capacity, temporarily reducing the temperature rise of the grinding surface. This work aims to highlight two material properties by studying this effect on the thermal and physical performance of abrasive materials using modulated differential scanning calorimetry (MDSC) 2920 to determine specific heat capacity and the flash diffusion method to evaluate thermal conductivity derived from the quantified thermal diffusion. The study was conducted on laboratory-prepared samples in dry and wet states, 38A120LVS and 38A60LVS, with specific mass compositions. A microstructure model was used to analyze the experimental data, demonstrating how heat capacity and thermal conductivity depend on the composition and moisture content, as determined by apparent density. The series-parallel model was used to describe the conductivity of the dry and wet samples. The results demonstrated the accuracy of the specific heat models for the additives, providing essential information for developing heat and mass transfer models used during the drying process of the primary grinding wheels. These results confirmed the validity of the mathematical equations developed to determine the thermophysical properties of these materials.

Keywords: Aluminum oxide (Al_2O_3) wheels, mass composition, moisture content, flash method, porous abrasive.

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1. Introduction

The thermophysical properties of the working of grinding wheel materials in their unprocessed and green state have a substantial impact on the optimization of industrial drying processes, as well as the subsequent dimensional and mechanical integrity of the final product. In the manufacturing industries, bonded abrasive wheels are commonly used for sharpening, grinding, and cutting operations where precision and thermal stability are of extreme importance. These wheels are usually composed of minerals such as aluminum oxide, zirconium oxide, or silicon carbide that are also bonded using phenolic resin or vitrified ceramic systems. The grinding wheels are available in different types based on the application requirements, and they are geared towards mechanical and thermal requirements [1].

The present research is dedicated to vitrified-bond grinding wheels that often contain fine grains of aluminum oxide with a diameter of approximately 100 mm, as shown in Figure 2, and an average cylindrical shape based on the intended application in the industries. Such scenarios involve, but are not limited to, crankshaft journal grinding, where single-dimensional accuracy and thermal degradation boundaries are among the key performance indicators [1].

The manufacturing process of such abrasive materials resembles the conventional manufacturing process of ceramics and follows four significant steps, i.e., mixing, pressing, drying, and vitrification. The initial step involves mixing abrasive grains with primary binders and a vitrifiable binder so as to form a wet granular blend. The mixture is pressed in molds to form an annular-shaped green body of the desired density. It is dried in a kiln under specific conditions to eliminate moisture without any structural degradation and subsequently undergoes high-temperature vitrification to provide the final mechanical and thermal properties [1].

This work is incorporated into the research on modeling the phenomenon of coupled heat and mass transfer in porous media, particularly the experimentalization of thermophysical properties of abrasive agglomerates in their original state. The paper is founded on earlier studies of hygrothermal and mechanical characteristics of hygroscopic bonded abrasives, which are further developed into quantitative thermal models [1]. Two agglomerate mixtures are examined. The steps include the description of materials, thermal capacity through the use of differential calorimetry, thermal diffusivity using flash procedures, and the analytical modeling of effective thermal conductivity [2, 3, 4–10].

Although real density has relatively little variation, binder chemistry and compaction can change the pore structure, and that affects both diffusivity and conductivity. This provides a prediction of the behavior during the drying of green grinding wheels through experimental measurements and microstructural modeling that would be applied in optimizing the process and achieving gains in energy efficiency [11].

The thermal performance of vitrified abrasive agglomerates seems to be driven by how moisture content, apparent density, and material composition work together, not just by one factor at a time. When moisture changes, it can also shift the effective heat capacity and thermal conductivity, mainly because pore saturation is altered. Meanwhile, apparent density is a proxy for the internal pore arrangement, which then controls the heat transfer pathways. At the same time, grain size distribution and binder composition differences play a role too, and they influence the way the material behaves during drying and vitrification. Even though the thermal properties of ceramic materials have been studied before, there has not been much focus on the combined effect of these three variables, especially for porous abrasive grinding wheels. Therefore, in this work, the coupled impact of moisture content, apparent density, and material composition on thermal conductivity and thermal diffusivity is examined, with laboratory-prepared abrasive samples tested under controlled dry and wet conditions. The results should help to refine predictive thermal models and also support industrial drying process optimization while reducing cracking defects and lowering energy consumption [1,11,13,17].

1.1 Research Problem

Although many vitrified abrasive grinding wheels have been used in industrial applications, there is still limited knowledge about how the combination of moisture content, apparent density, and material composition affects their thermophysical behavior. So far, these parameters have been studied separately; however, in practical manufacturing, it is essential to study the interaction of these parameters. Therefore, an inadequate understanding of these combined effects can limit the validity of thermal models that are used for the prediction of drying/vitrification heat transfer, increasing the risk of thermal stresses, cracking, defect formation, and energy losses during production [1,11,13,17].

1.2 Research Objectives

The present study seeks to investigate the interactive effects of moisture content, apparent density, and material composition on the thermal behavior of vitrified abrasive agglomerates through an experimental approach. In particular, the study aims to calculate the specific heat capacity and thermal diffusivity by means of Differential Scanning Calorimetry (MDSC 2920) and the Laser Flash Method, to compute thermal conductivity, and to validate the obtained results by involving microstructural thermal models in the calculations, and to determine their applicability for improving drying performance in the industry and minimizing manufacturing defects.

2. Materials and Methods of Measurements Specific Heat Capacity.

The overall manufacturing technique of grinding wheels involves four key processes, namely, mixing, pressing, drying, and vitrification, as shown in Figure 1.

In the first step, abrasive grains are mixed with primary binders and a vitrifiable binder to create a damp-sand-like powder. The mixture is pressed into a mold to achieve the required density and give the wheel its annular shape.

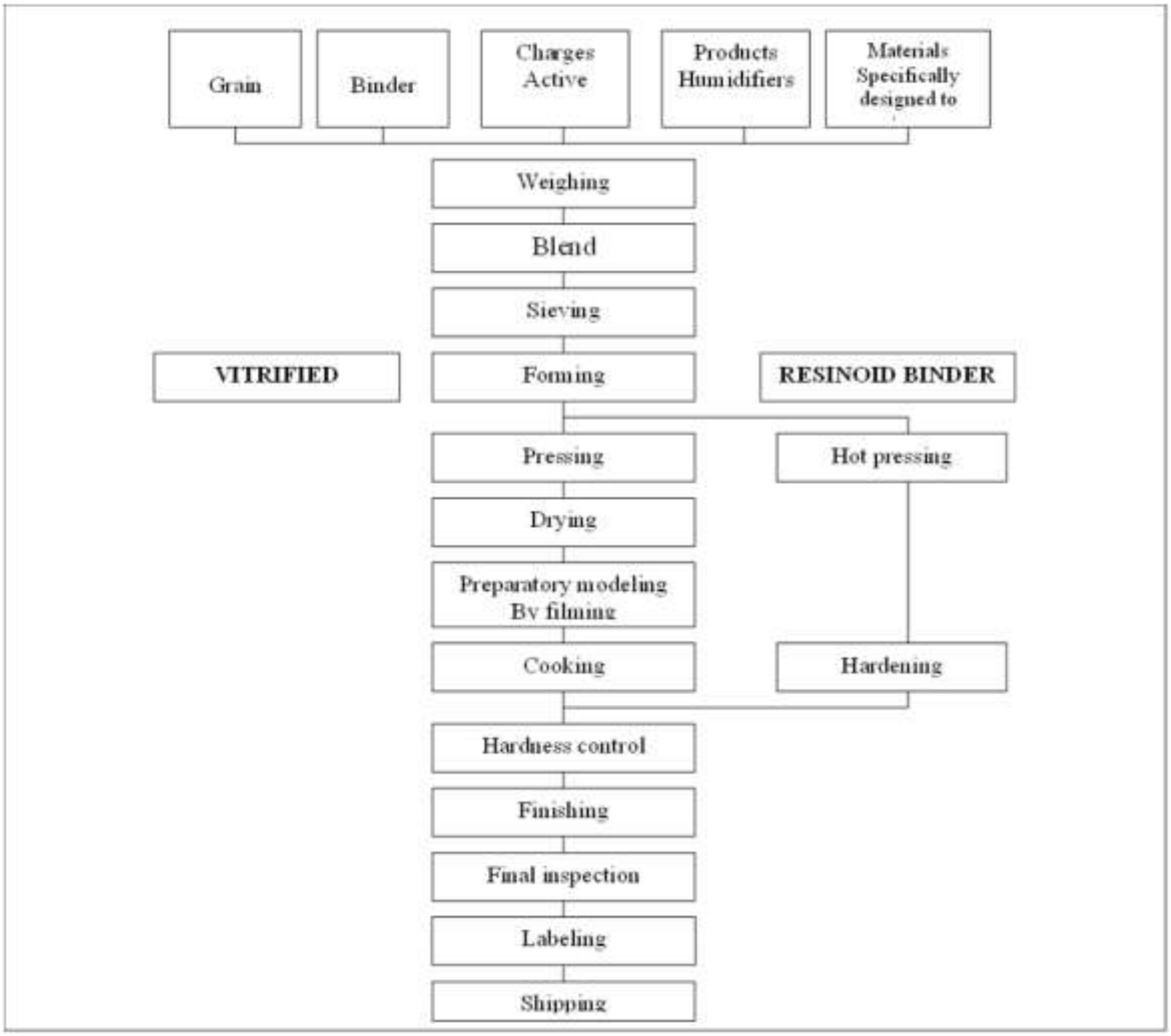


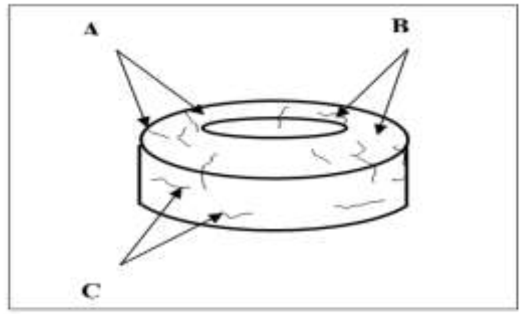
Figure 1. General scheme of production of vitrified and resinoid grinding wheels

The wheel is then dried using hot air in a kiln. Lastly, high-temperature firing is an essential part of vitrification that provides the wheel with its specific mechanical and thermal characteristics [1]. Figure 1 displays the essential production processes, which include weighing, mixing, sieving, pressing, drying, firing, and final inspection. The drying stage serves as a vital component because it accounts for most of the cracking defects that occur during the process.

The final structure of the grinding wheels is obtained by firing (up to 1280 °C) for grinding wheels with ceramic bonding (vitrifiable). Approximately 5% of the vitrified wheels produced have structural defects. Many of the manufacturing steps, as well as handling, can be the cause of these defects.

However, in about 40% of damaged wheels, these defects are in the form of singular and reproducible cracks. The drying step, which induces the deformation of the material, is essentially the main cause of concern. The nature of the cracks observed is shown schematically in Figure 2.

(1)



(2)

Figure 2. Schematic representation of grinding wheel cracking (2): A – circumferential cracks, B – radial cracks, C – axial cracks

2.1 Preparation of Samples

The samples studied in bulk powder form were conditioned at room temperature (**25 °C**), and their relative humidity **was** variable.

The formulations of the prepared abrasive grinding wheels consist of alumina grains (Al_2O_3) and vitrifiable binders (FA443 or B5US), dextrin, citric acid, and calcium lignosulfonate according to their specific composition. The tests were conducted on all samples using both dry and wet testing methods to investigate how moisture affected their thermophysical properties. The chemical compositions of the specifications studied are shown in Table 1.

Table 1. Chemical Composition of samples studied

Common Name	Composition	weight proportion %
Abrasive	Alumine α- Al_2O_3	87,718
Vitrifiable binder	FA443 -33,10 % TiO_2 -24 ,68 % SiO_2 -13,37 % Fe_2O -11,60 % Cao -10,67 % Al_2O_3 -06,58 % *Another*	12,282
Primer binder	Dextrine	0,096
	Acide Citrique Anhydre $C_5H_8O_7$	0,3
Wetting agent	Acide Citrique Monohydraté $C_6H_8O_7H_2O$	1,021

This study was limited to two standard products, or two specifications, whose denominations are as follows: 38A120LVS wet and 38A60LVS dry. Powders are classified according to the characteristics of the grain, the binder, and the structure of the grinding wheel. Thus, each element of the nomenclature represents:

The 38A120LVS and 38A60LVS samples have the same constituents and the same mass fractions constituting them, but are differentiated by the initial grain volume.

38A = represents the physical (alumina) and geometric (shape ratio of the cutting edge) characteristics.

120,60 = represent the gain size (mesh size).
L = Symbolizes the hardness and the structure of the wheel.
VS= is the type of clumping agents used.
The first and second specifications include the components shown in Table 2, which are in powder form at room temperature (25 °C).

Table 2. Constituents and mass fractions of both specifications 38A120LVS and 38A60LVS.

Constituents	Mass Fraction
Alumina (small grain) - 38A60LVS	0,877
Alumina (coarse grain) - 38A120LVS	0,877
Vitrifiable binder (FA443)	0,122
Dry dextrin	0,00096
Dry citric acid	0,003
Liquid water	0,00924

2.2 Experimental Equipment

The experimental work was conducted using a laboratory-scale measurement setup designed for the thermophysical profiling of porous abrasive materials. The specific heat capacity was established using a Modulated Differential Scanning Calorimeter (MDSC 2920), and thermal diffusivity was measured using the Laser Flash Method. Apparent density was then obtained from the measured mass together with the geometric dimensions of each specimen. For moisture conditioning, specimens were dried in a laboratory oven under controlled conditions. After that, both dry and wet samples were prepared following the same manufacturing routine, so the only difference was moisture content. Every measurement was carried out at a controlled laboratory temperature in order to ensure the repeatability and reliability of the results, as reported earlier [1,2,5,7].

2.3 Measurement of Specific

The heat capacity of each constituent of the two sintered abrasive specifications (38A120LVS and 38A60LVS**)** was measured and represented in Figure 3.

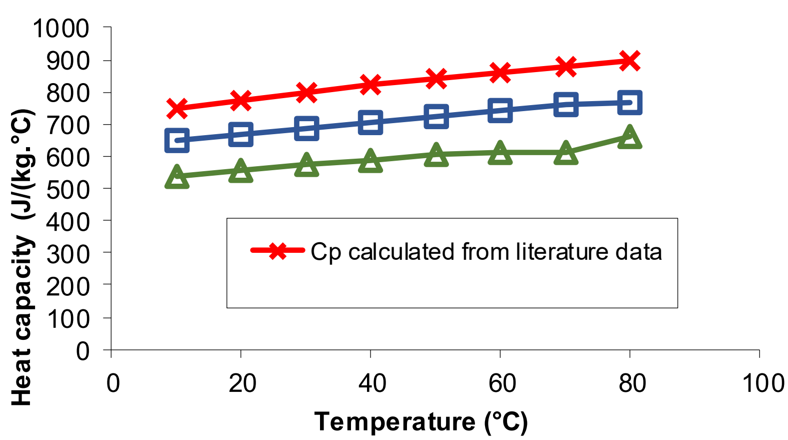


Figure 3. Thermal capacity of Al_2O_3 for two grain sizes

For each constituent, the measurements were repeated three or four times, as well as for the thermal capacity of the sintered abrasive (38A120LVS) in both dry and wet conditions. Each experiment provided the evolution of Cp with temperature between 10 and 80 °C. For the same component, the experimental curves were averaged and then smoothed by straight lines. When we measured the experimental thermal capacities of the constituents (dextrin, citric acid), we observed that the thermal capacity evolved unpredictably because of the residual water content, which was itself uncontrolled. We therefore decided to condition our samples by placing them in an oven at a temperature of 120 °C for 2 weeks to completely dehydrate them.

In the second step, we referred to the data in the literature in the (Handbook of Chemistry and Physics [7]) to obtain the correlation (1) for alumina:

$$C_{p_{Al2O3}} = \left(26.12 + \left(4.39.10^{-3}\right)\times T - \frac{7.27.10^{5}}{T^{2}}\right)\frac{4183}{102} \qquad \textbf{(1)}$$

$C_{P,\ AL_2O_3}$ in (J/ (Kg.°C)), et T en K

Figure 4 shows that Differential Scanning Calorimetry (DSC) was used to measure the specific heat of the constituents of 38A120LVS and 38A60LVS. The difference between the two formulations is based on the differences in the composition of the binder and the ratio of organic additives. As an example, a higher fraction of small-grain alumina in the 38A60LVS formulation results in a slightly higher heat capacity at lower temperatures, which is in line with the trend in Figure 3. The results of these measurements can be used as essential input data to model the energy balance during the drying process, especially to forecast the time-temperature profile needed to obtain homogeneous drying without creating thermal stresses [1,6].

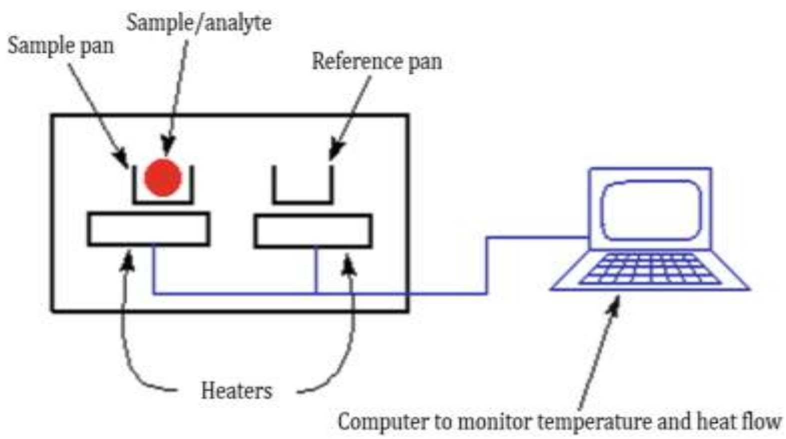


Figure 4. Differential Scanning Calorimetry (DSC)

Figure 4 shows the temperature dependence of the specific heat capacity of each major constituent (alumina, vitrifiable binder FA443, dextrin, and citric acid) of the 38A120LVS and 38A60LVS formulations.

2.4 Measurement of Thermal Diffusivity

In the study, a flash method was used to determine the thermal diffusivity of grinding wheel samples in dry and wet conditions [4,5,8,9], as shown in Figure 5. In this method, a brief pulse of energy is incident on one side of a thin sample, and the temperature response of the other face is measured. The temperature increase with time can be used to measure the thermal diffusivity. It is especially appropriate for small cylindrical specimens, e.g., vitrified-bond grinding wheels, where it offers a high degree of accuracy and a low level of experimental contamination [2,4].

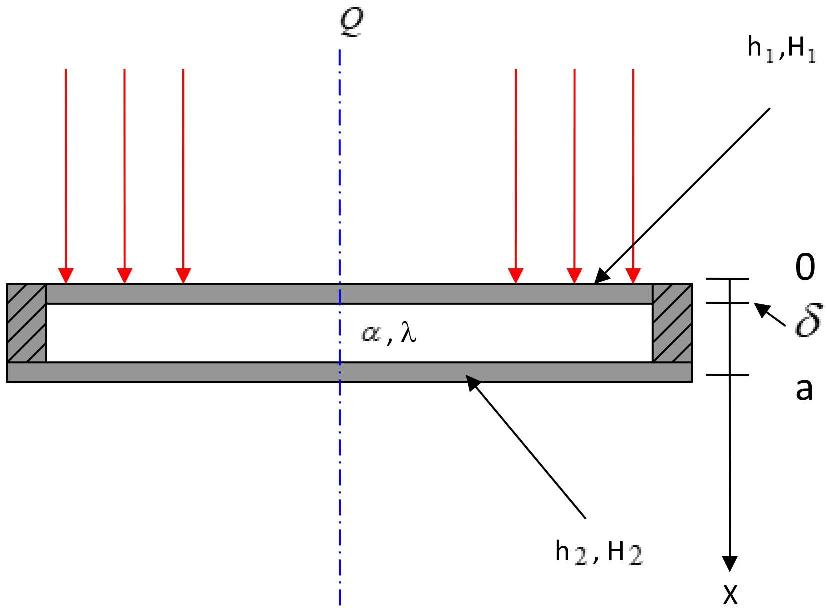


Figure 5. Laser flash method for thermal diffusivity measurement

The measured diffusivity and the experimentally determined specific heat capacity and density
were then used to deduce thermal conductivity using the following relationship:

$$\lambda = \alpha \cdot \rho \cdot Cp \quad (2)$$

where ρ is the apparent density and Cp is the special heat capacity.

2.5 Mathematical Modeling of Thermophysical Properties

Fourier's Law: $q = -\lambda \nabla T$ (3)

Other advanced addition equations were used to calculate relationship between thermal properties. The following equations were used to calculate transient heat conduction:

$$\frac{\partial T}{\partial t} = \alpha \nabla^2 T \quad (4)$$

$$T = T(x,t) \quad (5)$$

$$P_{app} = \rho Cp \quad (6)$$

To calculate Temperature-Dependent Specific Heat Model the following equation was used

$$Cp = \left(26.12 + (4.39 \times 10^{-3})e^{T} - \frac{7.27 \times 10^{5}}{T^{2}}\right)\frac{4183}{102} \quad (7)$$

Parker's flash method was employed to calculate the thermal diffusivity:

$$\alpha = \frac{1.38\, e^2}{\pi^2 t_{1/2}} \quad \text{or, to put it simply} \quad \alpha = \frac{0.138 L^2}{t_{1/2}} \quad (8)$$

Where: L = sample thickness and $t_{1/2}$ = half-rise time

Equations for boundary and initial conditions $T(x,0) = T_0$ (9)

$$\frac{dT}{dX} = 0 \quad at \quad x = 0$$

$$\frac{dT}{dX} = 0 \quad at \quad x = a$$
$$0 < X < a$$

Analytical exponential solution:

$$T(x,t) = T_0 + Ae^{-kt}$$

Heat flow via porous agglomerates was described using two models.

Air Phase Resistance

$$R_{air} = \frac{y_{air} - \Delta y}{2\lambda_{air}} \quad (10)$$

$$R_{air} * = \frac{1}{3\lambda_{eq}} \quad (11)$$

Combined Thermal Resistance

$$R_{total} * = Rs + \frac{RsR_{air}}{Rs+2R_{air}} \quad (12)$$

$$R *= \frac{R_s^2}{Rs+2R_{air}} \quad (13)$$

$$Req = Rs + \frac{(Rs+R_{air})^2}{Rs+R_{air}} \quad (14)$$

Effective Thermal Conductivity

$$\lambda_{eff} = \frac{1}{Req*} \quad (15)$$

2.6 Summary of Experimental Procedure

To conclude, the experimental results of specific heat capacity indicate that: Alumina grain size has a great influence on low- and mid-temperature heat capacity. The temperature dependence of Cp is adjusted by binder composition and organic additives. The wet materials have a greater effective heat capacity because of the presence of water.

These observations are in line with literature research on ceramic and composite materials and provide a foundation for modeling the thermal characteristics of grinding wheels during realistic drying and vitrification conditions [1,10]. The addition of these experiments is appropriate.

Conversion of Cp values into thermal models facilitates a precise forecast of the energy requirements, drying kinetics of the treatment, and temperature gradient in the wheel throughout industrial processing.

3. Results

The results of the experiment, graphical interpretation, and model validation are presented in this section. Thermal diffusivity (α) and thermal conductivity (λ) are important thermophysical characteristics that govern heat transfer in the materials used in grinding wheels. These properties are critical to the drying process, as accurate knowledge of them is required to model the drying process and predict the temperature gradient to avoid defects such as cracking or internal stresses [1,2,4,5].

3.1 Specific Heat Capacity (Cp)

This was evidenced by the experimental results, which showed that Cp increased as temperature increased for all constituents and composite formulations, as is observed in ceramic and organic materials, where higher degrees of freedom of vibration are encountered at high temperatures. Moreover, grain size and binder composition also had a strong effect on Cp values: formulations with smaller grain fractions of alumina showed a small difference in heat capacity at low temperatures, whereas hydrophilic organic binders (e.g., lignosulfonate) increased effective Cp in intermediate temperature regions more than silicones because of the effect of desorption and water [13].

3.2 Thermal Conductivity microstructural Model

To model the effective thermal conductivity of grinding wheel agglomerates, two microstructural models were used: the series-parallel model and the triangular model. Series-Parallel Model (Figure 7): The model considers the grinding wheel as a structure where heat moves through the grain-binder combinations sequentially, while the other solid-air phases are considered to be in parallel. It describes the key attributes of the heterogeneous microstructure, such as porosity and solid-phase distribution [6,14,10].

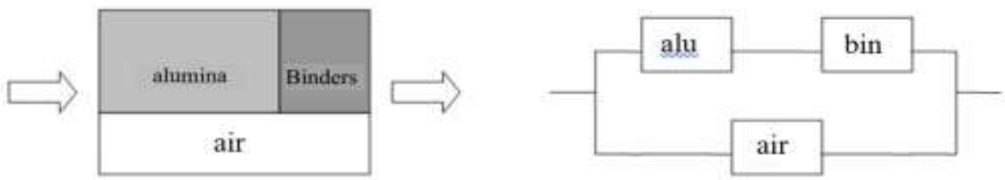


Figure 7. Schematic of series-parallel arrangement

Schematic of the series-parallel microstructural model where grains + binder and solid + air are considered in series and parallel respectively.

3.3. Fitting of a Model and Experimental Results

The experimentally obtained thermal conductivity data as a function of apparent density for the dry and wet samples are shown in Figure 8.

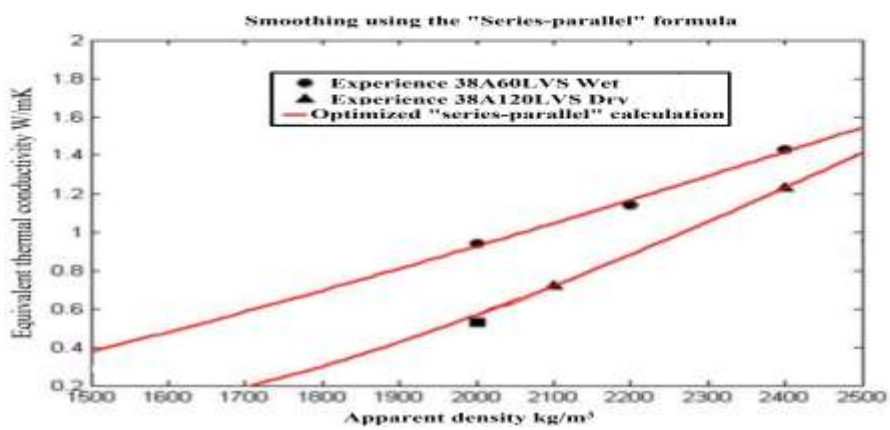


Figure 8. Thermal conductivity vs. apparent density for 38A60LVS specification (experimental and model predictions)

The fitted curves of the series-parallel model are superimposed. The findings indicate that the conductivity is proportional to the density, as the air fraction is lower and there is better contact between the solid phases, whereas moisture content decreases thermal conductivity slightly because water-filled pores have lower conductivity than the solid body [1,2,6].

3.4. Optimal Model parameters

The best parameters of both microstructural models are summarized in Table **1**, which was fitted to the experimental data**.** Δy represents the influence of microstructural porosity, and λlia represents the thermal conductivity of the binder phase. The parameters in these studies were calculated in dry and **wet** environments, and these results indicate the effect of moisture content on heat transfer [6-10].

Table 3; Optimal values of adjustable parameters (Δy and λ_lia) for thermal conductivity modeling in 38A120LVS and 38A60 LVS specifications

Agglomérâtes	Formule 'série-parallèle' Formula	
	Δy	λ_{bin}
38A120LVS Wet	-0.239	0.605
38A60LVS Dry	-0.254	1.107

Optimal fitted parameters. Δy and λlia the series-parallel and triangular microstructural models

in the dry and humid conditions. These two approaches of flash method examination and microstructural modeling can be used as a solid structure to forecast the thermal performance of grinding wheels under varying operating and processing circumstances. Combining these data with numerical models, engineers are able to optimize the process of drying, decrease the use of energy and sustain the product quality in order to make sure that the grinding wheels will perform the required mechanical and thermal conditions [1-10].

4. Discussion

In the present research, the thermophysical behavior of two types of porous vitrified agglomerates **(**38A120LVS and 38A60LVS**)** in dry and wet conditions was examined. Specific heat capacity (Cp), thermal diffusivity (α), and thermal conductivity (λ) were investigated. Cp and α were obtained using a Differential Scanning Calorimetry instrument (MDSC 2920) and a laboratory flash system instrument, respectively, followed by the calculation of **λ**. Also, two empirical microstructural models (series-parallel and triangular) were presented in order to correlate **λ** with apparent density and moisture content.

4.1 Specific Heat Capacity (Cp): Effects on Temperature and Composition.

These tendencies coincide with the quantified Cp trends in larger porous ceramic structures. As an illustration, porous mullite oxide ceramics (e.g., ZrO_2 and Sm_2O_3) demonstrate a strong temperature dependence of Cp at high temperatures, with changes in Cp associated with intrinsic phase transitions in ceramic materials [13]. This literature supports the finding that non-linear changes in heat capacity can be driven by complex compositions and phase interactions, as in the present case of abrasive agglomerate binders. Notably, moisture **is** present to increase the effective Cp of both grinding wheel agglomerates and other porous substances. Greater porosity was also related to greater Cp in porous silicon thin films, with a greater amount of water absorbed or retained in pore structures, proving that fluid content essentially determines thermal storage properties [17]. These results confirm the finding in the present work that moisture content cannot be disregarded in the process of modeling thermal dynamics during drying and processing.

4.2 Thermal Diffusivity (α): Dependences of Density and Porosity.

Results of thermal diffusivity in this experiment demonstrated a progressive rise in diffusivity

with density: dry samples with a higher apparent density had higher values of alpha and wet samples had lower diffusivity due to the presence of water-filled pores with lower heat propagation rates. These experimental results can be explained in terms of thermal transport in porous media because, in the case of air- or water- filling pore spaces, a process of thermal diffusion is hindered not only by a lack of solid connectivity but also by the fact that gases and liquids have lower thermal conductivity than solids do [17].

This trend has been supported by contemporary literature on porous composites. Recent research on yttria-partially stabilized zirconia (YPSZ) composites indicates that thermal diffusivity increases with the proportion of more conductive phases because of an improved percolation network, but high porosity has a systematic and predictable negative effect on thermal diffusion [14]. This supports the role played by pore-mediated connectivity in determining alpha, which confirms the correlation between density and diffusivity in the current study.

More evidence for this found in the work on porous thermal storage ceramics which are based on industrial wastes, in which high porosity (e.g., 60-80 vol%) leads to much lower thermal conductivity and related diffusivity values. These experiments highlight the fact that large pore volume weakens the solid network and reduces both reduces both α and λ [16], which is similar to the relative damping of diffusivity in wet abrasive composites in this paper.

4.3 Effective Thermal Conductivity (λ): Modelling and Empirical Correlations.

The relationship $\lambda = \alpha\rho Cp$ is an intermediary between the thermophysical parameters and the macrosystem of a porous material in terms of the capability of the material to transfer heat. In the experiment, λ rose with density and fell with moisture level owing to the decreased inherent conductivity of the pore-filled water and air gaps.

Experiments on porous mullite composite ceramics have compared thermal conductivity values and found that they decrease sharply at high porosity levels (e.g., 63–73%) compared to dense ceramics (5.1 W/m·K for fully dense mullite vs. 0.285–0.50 W/m·K for porous forms) [13]. These absolute values are significantly lower than those of the constituents of dense grinding wheels but similar to highly porous abrasive bodies when normalized for density variation. This illustrates the principle of porosity being a predominant factor governing λ in all porous ceramic systems. The empirical models proposed here, namely the series-parallel and triangular microstructural formulations, are representative of modern-day porous media modeling, which usually builds on the use of effective medium theories. As an example, research on porous binary composites explains the relevance of effective medium models, such as the Bruggeman model, in determining the effect of pore volume and phase connectivity on **λ** [12]. Despite the difference in the physical microstructures of abrasive agglomerates and bulk composites, both of these models are connected by the fact that their theoretical foundation depends on the structural arrangement and connection of the conductive and insulating phases.

These comparative studies indicate that the modeling accuracy obtained in this paper is not unrealistic with respect to the general literature expectation, particularly when the effects of heterogeneous microstructures and moisture are taken into account.

4.4 Effects of Moisture and Water on Thermal Transport.

The significant effect of moisture on Cp and λ is one of the important finding of this study. Thermal conductivity is reduced as effective Cp increases significantly due to latent heat and extra pathways of heat storage whereas thermal conductivity is lowered due to the addition of water, which lowers the λ of the water-filled pores compared to solid matrix linkages. Similar results have been observed in studies of porous silicon films, where water uptake changes Cp and effective λ**,** and problems with the more basic assumptions of pure solid-phase heat transfer have been identified [17]. Other studies on porous materials indicate that confined liquids may even become more effective thermal conductors under some microstructural circumstances because of augmented interfacial transport, but such impacts are material-specific and depend on pore structure and liquid interface behavior [17]. These subtle behaviors highlight the importance of the effects of moisture and demonstrate the importance of modeling systems, such as those presented in the current work.

The The moisture absorbed by grinding wheels (especially vitrified-bonded wheels) increases their overall heat capacity, allowing them to absorb larger amounts of operating heat before heating up, but it can cause structural weakness and a decrease in wheel life due to water evaporation under thermal pressure [2,6,3]. The moisture (water) present inside the pores of the wheel increases the overall heat capacity of the body (wheel + water) because water has a very high heat capacity, which temporarily reduces the rise in the temperature of the grinding surface [2,3,6].

The experimental temperature-dependent specific heat capacities of the main constituents of the two formulation systems**,** 38A120LVS and 38A60LVS, are presented in Table 4. These constituents are alumina, vitrifiable binder FA443, dextrin, and citric acid. The temperature dependence of the specific heat capacity of all constituents is typical, as it tends to rise with temperature, which is common to all ceramic and organic materials due to the gradual increase in the number of vibrational and rotational modes with temperature [2,4,8].

4.5 Drying Modeling and Drying Industrial Processing Implications.

Numerical/analytical comparative studies of thermal performance during grinding and other associated ceramic operations (e.g., dynamic heat source models that take into account both dry and wet conditions during grinding) justify the significance of incorporating realistic thermal properties into simulation models to control thermal gradients and avert thermally induced damage [14]. Although these works focus on heat generation and distribution during material removal, they contribute to the broader idea that precise thermal properties are essential for developing accurate predictive models. The empirical models derived in this case, together with the experimental evidence, can thus make a great contribution towards process optimization. This is in line with current state-of-the-art research on porous material modeling, which focuses on customized modeling methods that capture real microstructural complexities [11].

6. Conclusions

This study focused on the experimental determination of the thermal properties of a porous abrasive. The specific heat capacity and thermal conductivity were measured for different compositions, porosities, moisture **c**ontents, and temperatures of the porous material. Thermal conductivity was derived from thermal diffusivity. In this work, we not only performed and reported the measurements but also attempted to develop equations to calculate the thermal properties for other compositions, moisture contents**,** and porosities outside the experimental scope.

To correlate the thermal conductivity values, we opted to test two formulas based on a predefined thermal path rather than applying a polynomial or exponential formula. The proposed formula was matched to the experimental data through numerical optimization of two coefficients. Good smoothing of the experimental points was achieved, but the smoothed curves do not appear to be usable outside the experimental range.

7. Recommendations

In light of the findings of the current investigation, it is suggested that future studies examine a broader set of moisture contents and different apparent density levels so that the prediction performance of the thermophysical models can be improved. In addition, it would be beneficial to test more abrasive compositions along with alternative binder systems because their effects on thermal conductivity and thermal diffusivity might not be fully captured yet. Also, advanced thermal characterization techniques should be used, and at the same time, numerical simulation approaches could be applied in order to validate the developed models under industrial operating conditions. Lastly, combining the proposed thermophysical models with industrial drying process control might help reduce energy usage, lower the likelihood of crack formation, and improve the overall quality of vitrified grinding wheels [11–17].

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N.	Author Name and Emai and ORCID link	Study Conception / Idea	Data Collection or Contribution to Data Collection	Contribution to Previous Studies / Literature Review	Study Methodology	Conducting Analyses (Practical Aspect)	Data Analysis	Interpretation and Discussion of Results	Approval of Final Version
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