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SIMULATION OF KINETIC PARAMETRS OF VYNYL ESTER RESIN SAMPLES WITH DIATOMITE AND DIMETHYL METHYLPHOSPHONATE FILLERS

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Abstract. This article presents the results of predicting the kinetic properties of composite materials based on vinyl ester resin (VER) with the addition of diatomaceous earth and dimethyl methylphosphonate (DMMP) using the Netzsch Kinetics Neo software based on the results of thermogravimetric analysis (TGA). The VER samples were synthesized at the University of Science and Technology of China (Hefei, China) as part of a project funded under a targeted grant program. The kinetic characteristics of four samples were predicted based on the results of thermogravimetric analysis: Pure VER, VER + DE – a VER sample with a diatomite concentration of 25%, VER+DE/DMMP – VER with physically mixed DMMP and diatomite at concentrations of 12.5% and 12.5%, respectively, and VER + DE@DMMP – a sample with DMMP immobilized in the pores of diatomite (25%). Based on the TGA curves, models were selected in the Netzsch Kinetics Neo software, which allow for the prediction of the samples' kinetic properties under specific conditions over a defined period of time—something that is not feasible under laboratory conditions. Models were selected in the Netzsch Kinetics

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Neo software. For the pure sample, the model corresponded to a simple first-order reaction; for VER with diatomite, independent reactions (simple and diffusion); for VER+DE/DMMP and VER+DE@DMMP, autocatalytic A2 and A3, and diffusion D3.

The results of the analysis showed that pure VER decomposes very slowly at low temperatures, but quite rapidly at high temperatures, compared to the other samples. The VER+DE/DMMP and VER+DE@DMMP samples exhibit a higher decomposition rate in the initial stages, whereas mass loss slows down at high temperatures.

In the dynamic mode, the pure VER sample showed the shortest decomposition time and the lowest temperature. In the immobilized sample, decomposition proceeds slightly faster than in the diatomite sample. The composite with physically mixed diatomite and DMMP demonstrated intermediate decomposition temperatures and times.

The results obtained open up opportunities for the development of new fire-resistant materials with controllable functional properties.

Keywords: vinyl ester resin, diatomite, DMMP, thermogravimetric analysis, Netzsch Kinetics Neo, degradation, decomposition time

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ДИАТОМИТ пен ДИМЕТИЛ МЕТИЛФОСФОНАТ ТОЛТЫРҒЫШТАРЫ БАР ВИНИЛЭФИР ШАЙЫР ҮЛГІЛЕРІНІҢ КИНЕТИКАЛЫҚ ПАРАМЕТРЛЕРІНІҢ МОДЕЛЬДЕУ

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Аннотация. Бұл мақала Netzsch Kinetics Neo бағдарламасын пайдалана отырып, термогравиметриялық талдау (ТГА) нәтижелеріненің негізінде диатомит пен диметил метилфосфонат (DMMP) қосылған винил эфир шайыры (VER) негізіндегі композиттік материалдардың кинетикалық қасиеттерін болжау зерттеуінің нәтижелерін ұсынады. VER үлгілері Қытай Ғылым және технология университетінде (Хэфэй, Қытай) мақсатты бағдарлама аясында қаржыландырылған жоба шеңберінде синтезделді. Термогравиметриялық талдау нәтижелері негізінде төрт үлгінің кинетикалық сипаттамаларын болжау жүргізілді: таза VER, VER + DE – диатомит концентрациясы 25% болатын VER үлгісі, VER+DE/DMMP – DMMP пен диатомит 12,5% және 12,5% концентрацияда физикалық араласқан VER; VER + DE@DMMP – диатомит тесіктерінде бекітілген DMMP-і бар үлгі (25%). ТГА қисықтарына сүйене отырып, Netzsch Kinetics Neo бағдарламасы арқылы модельдер таңдалды; бұл модельдер үлгілердің белгілі бір жағдайларда белгіленген уақыт аралығындағы кинетикалық қасиеттерін болжауға мүмкіндік береді, ал зертханалық жағдайларда мұны жүзеге асыру мүмкін емес. Модельдер Netzsch Kinetics Neo бағдарламасында таңдалды. Таза үлгі үшін модель қарапайым бірінші реттік реакцияға сәйкес келді; диатомит қосылған VER үшін – тәуелсіз реакциялар (қарапайым және диффузиялық); VER+DE/DMMP және VER+DE@DMMP үшін – автокаталитикалық A2 және A3, диффузиялық D3.

Талдау нәтижелері таза VER-дің төмен температурада өте баяу ыдырайтынын, ал жоғары температурада басқа үлгілерге қарағанда салыстырмалы түрде тез ыдырайтынын көрсетті. VER+DE/DMMP және VER+DE@DMMP үлгілері бастапқы кезеңдерде ыдырау жылдамдығы жоғары болса, жоғары температурада массаның жоғалуы бәсеңдеді.

Динамикалық режимде таза VER үлгісі ыдырау уақытының ең қысқа болуын және ең төменгі температураны көрсетті. Иммобилизацияланған үлгіде ыдырау диатомит қосылған үлгіге қарағанда сәл жылдам жүреді. Физикалық жолмен араластырылған диатомит пен DMMP қоспасы ыдыраудың орташа температурасы мен уақытын көрсетті.

Алынған нәтижелер басқарылатын функционалдық қасиеттері бар жаңа отқа төзімді материалдарды әзірлеуге мүмкіндік береді.

Түйін сөздер: винил эфир шайыры, диатомит, DMMP, термогравиметриялық талдау, Netzsch Kinetics Neo, деградация, ыдырау уақыты

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МОДЕЛИРОВАНИЕ КИНЕТИЧЕСКИХ ПАРАМЕТРОВ ОБРАЗЦОВ ВИНИЛЭФИРНЫХ СМОЛ С НАПОЛНИТЕЛЯМИ ИЗ ДИАТОМИТА И ДИМЕТИЛМЕТИЛФОСФОНАТА

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Аннотация. В статье представлены результаты прогнозирования кинетических характеристик композитных материалов на основе винилэфирной смолы (VER), модифицированной диатомитом и диметилметилфосфонатом (Dimethyl Methylphosphonate, DMMP), с использованием программного комплекса Netzsch Kinetics Neo на основе данных термогравиметрического анализа (ТГА). Образцы винилэфирной смолы были синтезированы в Университете науки и технологий Китая (г. Хэфэй, КНР) в рамках выполнения проекта программно-целевого финансирования. Проведено моделирование кинетических параметров четырех типов образцов: Pure VER (чистая винилэфирная смола), VER + DE (образец с содержанием диатомита 25 %), VER + DE/DMMP (образец с физически смешанными диатомитом и DMMP в концентрациях по 12,5 %), а также VER + DE@DMMP (образец с DMMP, иммобилизованным в порах диатомита, с общим содержанием наполнителя 25 %).На основании кривых ТГА в программе Netzsch Kinetics Neo были подобраны кинетические модели, позволяющие прогнозировать поведение материалов при различных температурных режимах и продолжительности воздействия, что затруднительно реализовать в лабораторных условиях. Для чистой смолы наиболее адекватной оказалась модель простой реакции первого порядка. Для образца VER + DE установлена комбинация независимых реакций первого порядка и диффузионного механизма. Для образцов VER + DE/DMMP и VER + DE@DMMP наиболее соответствующими оказались автокаталитические модели A2 и A3 в сочетании с диффузионной моделью D3. Результаты показали, что чистая винилэфирная смола характеризуется медленным разложением при низких темпера-

турах и более интенсивной деградацией при высоких температурах по сравнению с модифицированными образцами. Композиты VER + DE/DMMP и VER + DE@DMMP демонстрируют повышенную скорость разложения на начальных стадиях процесса, тогда как при высоких температурах скорость потери массы снижается. В динамическом режиме чистая смола характеризуется минимальным временем термического разложения и наиболее низкой температурой деструкции. Для образца с иммобилизованным DMMP процесс разложения протекает несколько быстрее, чем для композита, содержащего только диатомит. Образец с физически смешанными диатомитом и DMMP характеризуется промежуточными значениями температуры и времени разложения. Полученные результаты свидетельствуют о перспективности использования диатомита и диметилметилфосфоната для создания новых огнестойких полимерных материалов с регулируемыми эксплуатационными свойствами.

Ключевые слова: винилэфирная смола, диатомит, DMMP, термогравиметрический анализ, Netzsch Kinetics Neo, деградация, время разложения

Introduction. Polymer composites are a special class of materials that combine a polymer matrix with reinforcing or functional fillers, enabling the production of materials with predetermined physical, chemical, mechanical, and performance properties. Due to their low weight, low cost, and desirable thermal properties, they are widely used in industries such as construction, transportation, aviation, energy, and the chemical industry (Wu et al., 2023).

A significant drawback is the rapid flammability and combustibility of the polymer matrix, as well as rapid heat release. To address this issue, the development of flame retardants that create a protective barrier during combustion and prevent the formation of carbon residue is becoming increasingly relevant (Wang et al., 2023).

Vinyl ester resins (VER) are unsaturated polyester resins with enhanced chemical resistance and strength (Pączkowski et al., 2022). These materials are produced by reacting epoxy resin with methacrylic acid. The resulting epoxyacrylates dissolve in monomers. The resulting liquid resins can be used similarly to unsaturated polyester resins (UPR) (Nodehi et al., 2022).

Vinyl ester resins can be viewed as a compromise between unsaturated polyester and epoxy resins (Todjiyev et al., 2026).

However, due to their polymer matrix, ECMs are not sufficiently fire-resistant, which limits their application (Hu et al., 2022). This problem has been partially solved by physically adding fire-retardant substances to the resins or chemically introducing fire-retardant groups into their network structure (Zhang et al., 2020). However, while flame retardants increase the material's fire resistance, they simultaneously contribute to the deterioration of certain physicochemical properties (Li et al., 2022).

One of the fillers that minimally degrades the properties of the polymer matrix of the fire-retardant material is dimethyl methylphosphonate (DMMP), which possesses flame-retardant properties through

the interaction of the generated radicals with H• and OH• radicals (Xavier et al., 2025). Due to its volatility, DMMP does not remain in the polymer matrix for long, and its effect is short-lived.

Scientists from the University of Science and Technology of China have found a way to ensure the long-term flame-retardant properties of DMMP by immobilizing DMMP in the micro- and nanoporous channels of diatomaceous earth (DE) and then incorporating it into vinyl ester resin (VER) (Xie et al., 2026).

The choice of diatomite was justified, first, by its widespread occurrence in Kazakhstan (Aktobe Region), and second, by its porous structure, which stems from its origin in sedimentary rocks and algae (Xu et al., 2019). The fire-retardant and flame-suppressing properties of diatomite are well known (Bi et al., 2024).

When characterizing new materials using analytical methods to determine thermal properties, thermogravimetric analysis is employed, which allows for the determination of mass loss at various temperatures under a specified heating rate. In the Netzsch Kinetics Neo software, based on the analysis data, it is possible to determine predictive kinetic characteristics, such as the degree of degradation over a very long period of time that cannot be analyzed under laboratory conditions, the calculation of the degradation temperature, the degradation time at very high heating rates that cannot be set on a laboratory instrument, and other characteristics (Harter et al., 2022).

This study presents data on the prediction of kinetic characteristics of VER-based composites with diatomite and DMMP additives based on thermogravimetric analysis using the Netzsch Kinetics Neo software.

Materials and Methods. Composite materials based on vinyl ester resin with the addition of diatomaceous earth and DMMP were prepared at the University of Science and Technology of China (Hefei, China) as part of a project funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR28712729) [[16]].

Four VER samples were used to record and study the kinetic characteristics:

Pure VER, VER + DE – a VER sample with a diatomite concentration of 25%, VER+DE/DMMP – VER with physically mixed DMMP and diatomite at concentrations of 12.5% and 12.5%, respectively, VER + DE@DMMP – a sample with DMMP immobilized in the pores of diatomite (25%).

The composite containing DE@DMMP was prepared by first vacuum-immobilizing DMMP within the pores of DE (producing DE@DMMP), after which the resulting filler was incorporated into vinyl ester resin (VER) with stirring until a homogeneous dispersion was achieved. The mixture was degassed under vacuum, then a curing accelerator and initiator (each at 1.5 wt.% relative to the resin) were added, poured into molds, and cured at room temperature until the composite was fully formed.

Thermogravimetric analysis was performed on a NETZSCH TG 209 F1 Libra (Germany) instrument, dynamically heating the sample in a 40 mL/min flow of inert nitrogen gas from room temperature to 800 °C. The heating rate was 10 °C/min.

Kinetics analysis was performed using the NETZSCH Kinetics-Neo (Germany) software. The program works as follows: first, TGA data obtained under real-world conditions—that is, up to a temperature of 800 °C with a heating rate of 10 °C/min—are

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loaded into the program. Then, based on the TGA data, the program selects a model corresponding to a single reaction or several parallel reactions. Using this program, it is possible to predict the thermal properties of a material under certain conditions that cannot be replicated in a laboratory, such as very high temperatures, high heating rates, isothermal conditions, and the behavior of the material over an unlimited period of time.

Results and Discussion. We obtained the thermogravimetric analysis results of the four samples and performed modeling in the NETZSCH KINETIC NEO program. The following figures show the models (Figures 1, 2, 3, and 4).

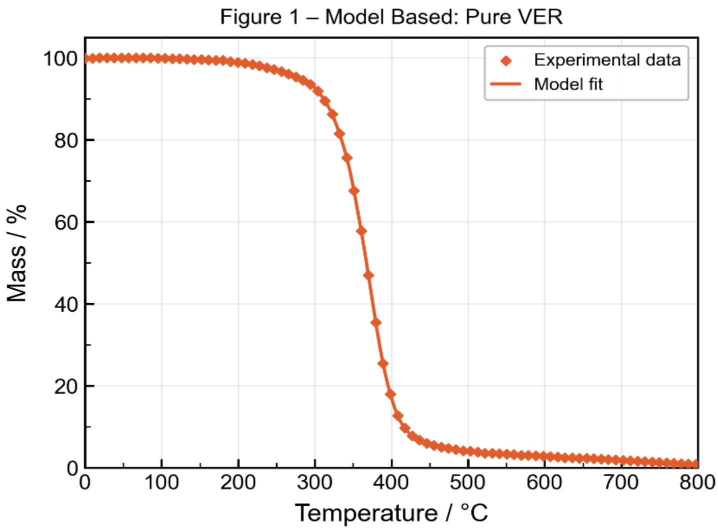

Figure 1. Model of pure VER.

The TGA curve shows that significant mass loss in the pure VER sample begins at 300 degrees, and by 400 degrees, half of the sample's mass has already been lost. From 440 degrees onward, the mass begins to decrease only slightly. Accordingly, degradation begins after 27 minutes, 50% of the mass is lost after 36 minutes, and the rate of loss slows down after 42 minutes. It takes about an hour for the mass to be completely lost.

The reaction model of the pure sample corresponds to a simple first-order F_n reaction, and the activation energy is 103.5 kJ/mol.

The reaction follows the following formula

$$d\alpha/dt = k\cdot(1-\alpha)^1$$

here α conversion degree, k – rate constant.

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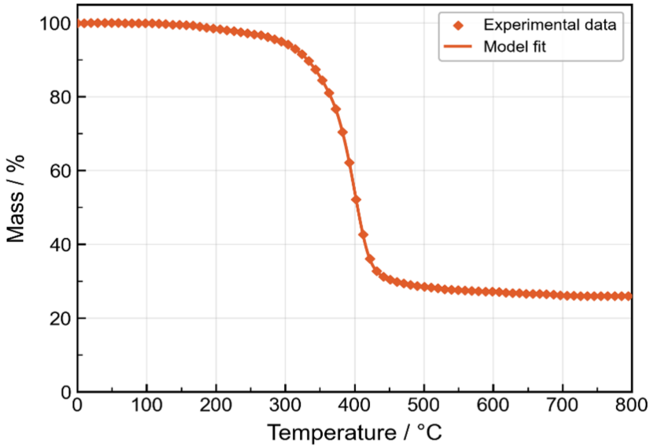

Figure 2. Model of VER + DE.

A significant loss of mass in the VER sample containing diatomite also begins at a temperature of 300 degrees, reaching 50% decomposition at 419 degrees. From 454 degrees onward, the mass begins to decrease slightly. At a temperature of 800 degrees, approximately 30% of the mass remains. Accordingly, degradation begins at 29 minutes, 50% of the mass is lost by 39 minutes, and the rate of loss slows down after 45 minutes. It takes 77 minutes for the mass to decrease by 30%.

The model for the diatomite-added sample consists of two independent reactions – a first-order F_n reaction and a D3 reaction (181 kJ/mol and 13 kJ/mol, respectively).

D3 — Diffusion model (3D: Jander model). This model describes diffusion-controlled processes in solid materials. The reaction equation is:

$$1 - \frac{2}{3}\alpha - (1 - \alpha)^{2/3} = kt$$

Here, the speed is highly dependent on the product being generated.

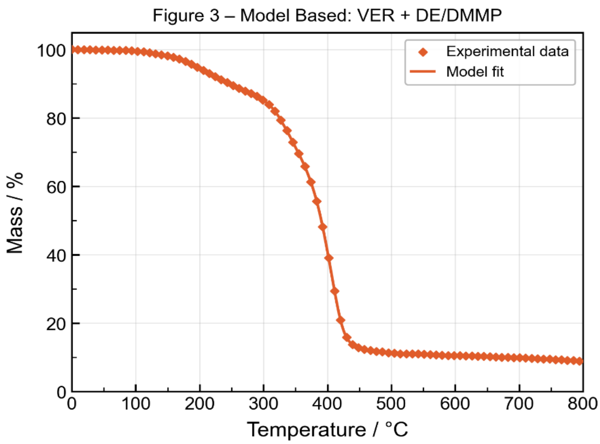

Figure 3. The model of VER+DE/DMMP.

A significant loss of mass in the VER sample, which contains physically mixed DMMP and diatomite, begins at a temperature of 303 degrees, reaching 50% decomposition at 408 degrees. From 458 degrees onward, the mass begins to decrease slightly. At a temperature of 800 degrees, approximately 20% of the mass remains. Accordingly, degradation begins at 28 minutes, 50% of the mass is lost by 38 minutes, and the rate of loss slows down after 43 minutes. It takes 77 minutes for the mass to decrease by 20%.

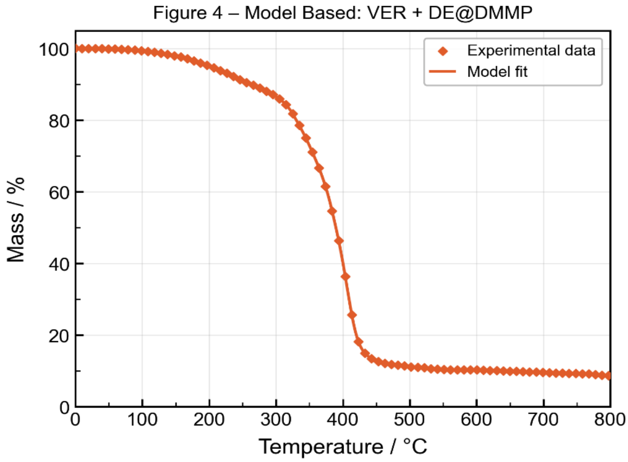

Figure 4. The model of VER + DE@DMMP.

A significant loss of mass in the VER sample, with DMMP mobilized in the diatomite pores, begins at a temperature of 313 degrees, reaching 50% decomposition at 405 degrees. From 453 degrees onward, the mass begins to decrease slightly. At a temperature of 800 degrees, approximately 15% of the mass remains. Accordingly, degradation begins at 29 minutes, 50% of the mass is lost by 38 minutes, and the rate of loss slows down after 43 minutes. It takes 75 minutes for the mass to decrease by 15%.

The VER+DE/DMMP and VER + DE@DMMP models correspond to three independent parallel reactions: A2 (21–48 kJ/mol), A3 (52–129 kJ/mol), D3 (164–40 kJ/mol). The activation energies for the VER+DE/DMMP and VER + DE@DMMP models are shown in parentheses.

A2 — Autocatalytic reaction model, corresponding to equation

$$d\alpha/dt = k\cdot\alpha\cdot(1-\alpha).$$

According to the equation, the reaction starts slowly, then accelerates sharply, and finally slows down.

A3 — Autocatalytic reaction model

$$d\alpha/dt = k\cdot\alpha^2\cdot(1-\alpha),$$

here, the rate is highly dependent on the product being generated.

It can be observed here that in the VER sample containing physically mixed diatomite and DMMP, autocatalysis is initiated more readily compared to the immobilized sample, whereas diffusion, conversely, proceeds more slowly. In the sample with immobilized DMMP, there is a protective barrier, which slows down the chemical reactions.

After importing the TGA data into the NETZSCH Kinetics-Neo software, we predicted the kinetic characteristics of the samples under isothermal conditions. In doing so, we estimated the rate of mass loss for the samples at specific temperatures.

The results are shown in Table 1, which presents data on the time of mass loss at specific fractions and at different holding temperatures.

Table 1. Time of mass loss at different temperatures.

	Time of 10% mass lost		Time of 50% mass loss	
Pure VER	100^0	17 month	100^0	11 years
	200	90 hours	200	3 days
	300	1.5 hours	300	35 min
	400	18 min	400	2 min
VER+DE	100^0	2.9 year	100^0	23 years
	200	1 day	200	9 days
	300	12 min	300	3.6 hour
	400	0.7 min	400	6 min
VER+DE/DMMP	100^0	3 days	100^0	11 days
	200	1.8 hours	200	7 hours
	300	3 min	300	37 min
	400	36 sec	400	6.8 min
VER + DE@DMMP	100^0	4.8 hour	100^0	4.5 days
	200	29 min	200	4 hour
	300	5 min	300	33 min
	400	1.2 min	400	5.7 min

According to the program data, the maximum mass loss for pure VER is 82%, for the VER+DE sample it is 68%, for VER+DE/DMMP it is 79%, and for VER+DE@DMMP it is 84%.

The rate of mass loss depends heavily on temperature, and as the temperature rises, the degradation rate increases sharply.

VER+DE is the least thermally stable at low temperatures (2.9 years to 10% loss at 100°C—longer than Pure), but at high temperatures (300–400°C), degradation occurs more rapidly.

VER+DE/DMMP loses 10% of its mass very quickly at 300–400 °C (3 min and 36 sec). The thermal stability of VER+DE@DMMP is intermediate.

At 100 and 200 degrees, pure VER and VER with diatomaceous earth degrade over years, whereas VER+DE/DMMP and VER + DE@DMMP degrade over days and hours. However, at high temperatures, the difference in degradation time disappears (minutes and hours).

The degradation rate depends on temperature; the higher the temperature, the faster the rate. Effect of additives:

VER+DE/DMMP and VER + DE@DMMP samples show a higher decomposition rate in the initial stages, while at high temperatures, mass loss slows down (6–7 min to 80%).

Samples with DMMP/diatomite (3 and 5) show a faster initial rate of degradation but sometimes slow down mass loss at high temperatures.

Pure VER degrades slowly at low temperatures but rapidly at 300–400 °C. For example, at 400 °C, 50% of the mass of the pure sample is lost in 2 minutes, while for the sample with a physical mixture of diatomaceous earth and DMMP it takes 6.8 minutes, and for the sample with immobilized diatomaceous earth it takes 5.7 minutes.

The next step in predicting the kinetic characteristics was to estimate the temperature-time degradation profile of the samples under dynamic conditions. While we obtained the TGA results in the laboratory at a heating rate of 10°C/min, the software allows users to select any heating rate.

The simulation in the software using the dynamic mode was done, setting the heating rate to 120 K/min, which simulates the material's behavior under fire conditions (Lyon et al., 2000) (Fig. 5).

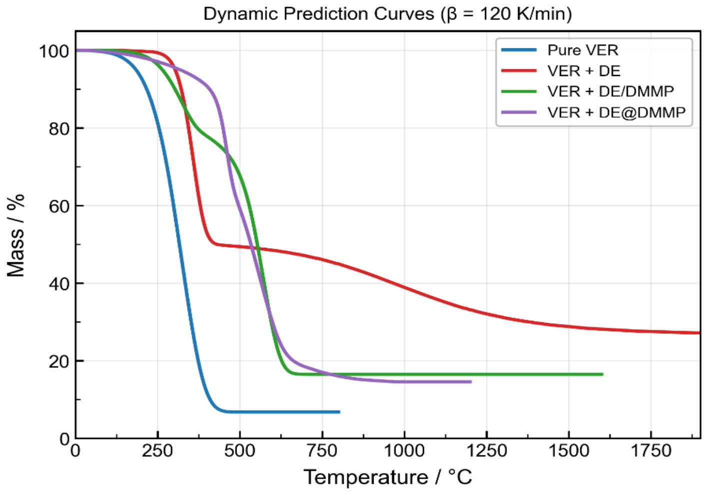

Figure 5. Dynamic prediction curves at a heating rate of 120 K/min.

The dynamic mode allows us to determine the time and temperature at which various degrees of material decomposition occur.

The graphs show that pure VER begins to decompose at 346 degrees, with diatomite at 370 degrees, and the sample with physically mixed DE and DMMP at a temperature slightly below 271 degrees. The immobilized sample showed the highest decomposition onset temperature—454 degrees.

At the same time, for all samples except the pure one, the decomposition is non-uniform; in the sample with diatomite, decomposition occurs very rapidly in the 400–500°C range and slows down significantly above 500°C. In the physically mixed sample, decomposition also proceeds in two stages at different rates, though the difference is not as significant. In the immobilized sample, the difference is almost negligible—

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decomposition proceeds faster in the 200–400°C range and slightly slower from 400°C onward. It is likely that the interaction of DMMP with the diatomite surface provides partial stabilization of the system and slows down decomposition processes at elevated temperatures.

The half-decomposition temperatures for the samples are as follows: Pure VER—472 degrees, VER+DE—801, VER+DE/DMMP—600 degrees, VER+DE@DMMP—572 degrees. Here, the sample with diatomite showed the highest temperature. In the immobilized sample, however, the 50% decomposition temperature is still higher compared to the pure resin.

The temperatures at which the samples completely decompose are 560, 1500, 678, and 852 °C, respectively. Here, too, the sample containing diatomite exhibited the highest temperature, followed by the immobilized sample.

Time-dependent modeling showed that VER+ DE@DMMP begins to decompose after just 1.2 minutes, while the pure sample remains stable for a long time (2.5 min). The other two samples showed decomposition times intermediate between these two. Half of the mass remains in the pure sample after 3.8 minutes, in the diatomite sample after 6.2 minutes, in the physically mixed sample after 4.9 minutes, and in the immobilized sample after 4.6 minutes. Complete decomposition is significantly slower in the diatomite sample, taking 20 minutes, while the pure sample degrades completely in 4 minutes, VER+DE/DMMP in 5 minutes, and VER+DE@DMMP in 7.6 minutes.

If we analyze the comparative degradation temperatures of the samples under actual TGA experimental conditions at a rate of 10°C/min and according to the simulation at a rate of 120°C/min in the NETZSCH KINETIC NEO software, it can be observed that at 10°C/min, the temperature range from the onset of degradation to its slowdown varies from 300°C to 400°C, with times ranging from 29 min to 45 min. Complete degradation occurs approximately 70 minutes after the start of heating. Meanwhile, under conditions of 120°C/min, according to the simulation, the times of degradation onset vary significantly among samples in the range from 271°C to 454°C, and the slowing down occurs from 470°C to 720°C, which is significantly higher than at 10°C/min. The onset times of degradation at high heating rates range from 1 to 3 min, and complete degradation occurs within a wide range from 1 min to 20 min.

Conclusion. This article presents a simulation of the kinetic parameters of four VER-based composites with added diatomite and DMMP, based on TGA results: Pure VER, VER + DE – a VER sample with a 25% diatomite concentration, VER+DE/DMMP – VER with physically mixed DMMP and diatomite at concentrations of 12.5% and 12.5%, respectively, VER + DE@DMMP – a sample with DMMP immobilized in the pores of diatomite (25%).

To determine the kinetic parameters of the samples, the TGA results were exported to the NETZSCH Kinetics-Neo software, and models were constructed based on which predictions were made in isothermal and dynamic modes. The selected reactions are as follows: pure VER – a simple first-order Fn reaction; VER with diatomite – two independent reactions (Fn and D3); VER+DE/DMMP and VER+DE@DMMP – A2, A3, D3.

A prediction was made of the degradation time of the composites in isothermal mode at temperatures ranging from 100 to 400 degrees.

According to the program data, the maximum mass loss for pure VER is 82%, for the VER+DE sample—68%, for VER+DE/DMMP—79%, and for VER+DE@DMMP—84%.

The rate of mass loss depends heavily on temperature: as temperature increases, the decomposition rate rises sharply.

The times required for 10%, 50%, and 80% mass loss of the samples were predicted. The analysis results showed that pure VER decomposes very slowly at low temperatures but relatively quickly at high temperatures compared to the other samples. The VER+DE/DMMP and VER+DE@DMMP samples exhibit a higher decomposition rate in the initial stages, whereas at high temperatures, mass loss slows down (6–7 minutes to 80%).

In the dynamic mode, the time and temperature at which various degrees of material decomposition are reached were predicted at a heating rate of 120 K/min, which corresponds to a simulated fire scenario.

The immobilized sample exhibited the highest decomposition onset temperature, while the sample with physically mixed diatomite and DMMP exhibited the lowest. For all samples except the pure one, the decomposition rate is non-uniform; for VER+DE@DMMP, the rate slows down as the temperature increases. The interaction of DMMP with diatomite leads to partial stabilization of the system and a slowing of decomposition as the temperature rises.

The VER+DE sample (801°C) decomposes the slowest, while half of the pure vinyl ester resin sample (472°C) degrades very quickly.

Complete decomposition of the diatomaceous earth sample occurs at a very high temperature.

Time-dependent modeling showed that decomposition occurs rapidly in the pure sample, most slowly in the diatomaceous earth sample, and slightly faster in the immobilized sample than in the diatomaceous earth sample. A dynamic comparison revealed an increase in the degradation temperature and a significant reduction in the degradation time at a rate of 120°C/min compared to the actual conditions of the TGA experiment.

Predictions of kinetic characteristics can be applied to the development of new polymer composites with functional properties that maintain stability under the influence of various factors, as well as fire-resistant structures that exhibit an extremely low degradation rate under fire conditions.

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