

SYSTEM AND METHOD FOR PROCESSING EXTRUSION DATA DURING AN EXTRUSION PROCESS

Cross Reference to Related Application(s)

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The present disclosure claims the benefit of Singapore Patent Application No. 10202012761V filed on 18 December 2020, which is incorporated in its entirety by reference herein.

10 Technical Field

The present disclosure relates to extrusion data processing. More particularly, the present disclosure describes various embodiments of a system and method for processing extrusion data during an extrusion process performed by an extruder.

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Background

Plastics are widely used in many products because they are lightweight, durable, flexible, inexpensive to produce, and can be manufactured into solid objects of various shapes. Plastics comprise polymers as the main ingredient and their plasticity makes it possible for plastics to be formed into various shapes using manufacturing processes such as moulding and extrusion. Plastic extrusion is a manufacturing process in which plastic material, such as in the form of pellets, is fed into an extruder through a feeder. The plastic material is conveyed forward through a barrel in the extruder by a rotating screw and forced through a die to form elongated products with constant cross-sections, such as rods and pipes. Heating elements are disposed along the barrel to melt and soften the plastic material as it moves through the barrel.

The plastic material may be mixed with other materials, such as additives, fillers, or reinforcing materials, to form a plastic compound with a diverse range of intrinsic material properties. This is done using a compounding extruder, such as a twin-screw extruder, in a compound extrusion process. The extrusion material or extrudate may undergo a qualification test to determine whether the extrudate is within the required

- specifications. In the qualification test, extrusion data is processed and the extrudate is characterized to obtain their intrinsic material properties, but this is always performed away from the compounding line by manual sampling of the extrudate. This material characterization process is often time consuming and there is a significant time lag between the manual sample collection and analysis of the samples. If the data analysis shows that the samples do not meet the required specifications and thus failing the qualification test, the batch of extrudate from which the samples were collected would need to be embargoed, resulting in material wastage.
- Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved system and method for processing extrusion data during an extrusion process.

Summary

- According to a first aspect of the present disclosure, there is a system for processing extrusion data during an extrusion process performed by an extruder under predefined extrusion parameters. The system comprises: a set of pre-extrusion instruments for measuring, during the extrusion process, pre-extrusion properties of an extrudate within the extruder; a set of post-extrusion instruments for measuring, during the extrusion process, post-extrusion properties of the extrudate after exiting the extruder; and a processor for collecting the extrusion data comprising the extrusion parameters and the measured pre-extrusion and post-extrusion properties of the extrudate, wherein the processor is configured for building a materials database using the extrusion data.

- According to a second aspect of the present disclosure, there is a method for processing extrusion data during an extrusion process. The method comprises: performing the extrusion process using an extruder under predefined extrusion parameters; measuring, during the extrusion process, and using a set of pre-extrusion instruments, pre-extrusion properties of an extrudate within the extruder; measuring, during the extrusion process and using a set of post-extrusion instruments, post-extrusion properties of the extrudate after exiting the extruder; collecting, using a

processor, the extrusion data comprising the extrusion parameters and the measured pre-extrusion and post-extrusion properties of the extrudate; and building a materials database using the processor and the extrusion data.

5 According to a third aspect of the present disclosure, there is a computerized method for determining material properties of an extrudate. The method comprises: providing a machine learning model trained with training data comprising a pre-established set of extrusion parameters and material properties of extrudates; receiving, by the trained machine learning model, an input set of extrusion parameters for an extruder to create
10 the extrudate; processing the input set of extrusion parameters using the trained machine learning model; and generating, by the trained machine learning model in response to said processing of the input set of extrusion parameters, an output set of the material properties of the extrudate.

15 According to a fourth aspect of the present disclosure, there is a computerized method for determining extrusion parameters for an extruder to create an extrudate. The method comprises: providing a machine learning model trained with training data comprising a pre-established set of extrusion parameters and material properties of extrudates; receiving, by the trained machine learning model, an input set of material
20 properties of the extrudate; processing the input set of material properties using the trained machine learning model; and generating, by the trained machine learning model in response to said processing of the input set of material properties, an output set of the extrusion parameters for the extruder to create the extrudate.

25 A system and method for processing extrusion data during an extrusion process according to the present disclosure are thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

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Brief Description of the Drawings

Figure 1 is an illustration of a system for processing extrusion data during an extrusion process performed by an extruder, according to embodiments of the present disclosure.

5 Detailed Description

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a system and method for processing extrusion data during an extrusion process, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims.

10 Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the

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embodiments of the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith. References to "an embodiment / example", "another embodiment / example", "some embodiments / examples", "some other embodiments / examples", and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore,

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repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

5 The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment. As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless
10 otherwise indicated. The term “set” is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions.

15 In representative or exemplary embodiments of the present disclosure, there is a system 50 for processing extrusion data during an extrusion process performed by an extruder 100 as shown in Figure 1. The extruder 100 is configured to manufacture extrusion material or extrudate 200 from suitable raw material such as plastic material. The plastic material may be referred to as polymer material wherein polymer is an
20 ingredient of plastic. The extruder 100 includes a feeder 102 for receiving feed stock for producing the extrudate 200 in the extrusion process. The feed stock includes the raw material such as in the form of plastic or polymer nurdles or pellets. The feed stock may further include additional material, such as additives, fillers, or reinforcing materials, to mix with and enrich the raw material to impart the extrudate 200 with a
25 diverse range of intrinsic material properties. For example, the additional material may include colorants and ultraviolet inhibitors and may be in either liquid, powder, fibre, or paste form. The extrudate 200 may be referred to as a plastic or polymer compound, blend, or composite.

30 The extruder 100 includes a barrel 104 having a proximal end 104a and a distal end 104b. The extruder 100 further includes a set of rotating screws inside the barrel 104. In one embodiment, the extruder 100 is a single screw extruder. In another embodiment, the extruder 100 includes a pair of rotating screws and may be referred

to as a twin-screw extruder 100 suitable for compounding the raw material with the additional material to form a compound extrudate 200, such as a plastic or polymer compound. The extruder 100 includes a motor 106 for driving the rotating screws to convey the raw material through the barrel 104.

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The extruder 100 is configured to perform the extrusion process under predefined extrusion parameters which include the rotational speed and torque of the rotating screw, and the desired extrusion temperature and pressure. To achieve the desired extrusion temperature, the extruder 100 includes a set of heating elements disposed
10 at one or more heating zones between the proximal end 104a to the distal end 104b of the barrel 104 for heating the raw material as it moves through the barrel 104, thereby softening and melting the raw material. The heating zones may be coupled with PID controllers to gradually increase the temperature of the barrel 104 from the rear to the front. This allows the raw material to melt gradually as they are driven
15 forward through the barrel 104 towards the distal end 104b, reducing the risk of overheating which may degrade the extrudate 200, especially for polymers.

The raw material experiences intense pressure and friction inside the barrel 104 as it is being pushed through the barrel 104 by the rotating screws. This contributes to
20 increased heating of the raw material and in some cases, the heating elements may be turned off if the melt temperature of the raw material can be sustained by the pressure and friction inside the barrel 104. The extruder 100 may include cooling elements to maintain the temperature below a predefined value if the raw material is excessively heated.

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The extruder 100 includes a die 108 disposed at the distal end 104b of the barrel 104. At the distal end 104b of the barrel 104, the raw material has passed through the heating zones and has been heated sufficiently into a molten state. The molten raw material is forced through the die 108 to form the extrudate 200. The extrudate 200 is
30 a continuous elongated product with a constant cross-section depending on the configuration of the die 108. For example, the extrudate 200 can be in the form of a strand with circular, trapezoid, rectangular, or other shaped cross-sections. After exiting the die 100, the extrudate 200 is still hot and needs to undergo a cooling

process before the next manufacturing stage. The extrudate 200 can be cooled by air or a liquid coolant. For example, the extrudate 200 is pulled through and quenched in a water bath or cooled slowly through a conveyor system.

- 5 The extrudate 200 may be subjected to a qualification test to determine whether the extrudate 200 is within the required specifications. Particularly, the extrudate 200 is characterized to obtain or measure their intrinsic material properties. Notably, material characterization is the process of measuring and determining intrinsic material properties such as but not limited to physical, chemical, mechanical, and
- 10 microstructural properties of materials. More specifically, the material properties may include rheological, morphological, and chemical composition properties of the materials.

The extrudate 200 is characterized using extrusion data obtained during the extrusion

15 process performed by the extruder 100. The system 50 for processing the extrusion data includes a set of pre-extrusion instruments and a set of post-extrusion instruments. The pre-extrusion instruments are disposed before the die 108, such as at the distal end 104b of the barrel 104, for measuring, during the extrusion process, pre-extrusion properties of the extrudate 200 within the extruder 100, i.e. specifically

20 within the barrel 104 before the extrudate 200 exits the die 108. The post-extrusion instruments are disposed after the die 108 for measuring, during the extrusion process, post-extrusion properties of the extrudate 200 outside the extruder 100, i.e. after the extrudate 200 exits the die 108. The system 50 further includes a processor 300 for collecting the extrusion data including the predefined extrusion parameters of the

25 extruder 100, the measured pre-extrusion properties of the extrudate 200, and the measured post-extrusion properties of the extrudate 200.

In various embodiments of the present disclosure, there is a method for processing extrusion data during the extrusion process. The method includes a step of performing

30 the extrusion process using the extruder 100 under predefined extrusion parameters. The method includes a step of measuring, during the extrusion process, and using the set of pre-extrusion instruments, pre-extrusion properties of the extrudate 200 within the extruder 100. The method includes a step of measuring, during the extrusion

process and using the set of post-extrusion instruments, post-extrusion properties of the extrudate 200 after exiting the extruder 100. The method includes a step of collecting the extrusion data using the processor 300.

- 5 In some embodiments, the pre-extrusion instruments and/or post-extrusion instruments are configured to measure the rheological properties of the extrudate 200. The pre-extrusion instruments may include a set of pre-extrusion rheological sensors 202 configured for measuring rheological properties of the extrudate 200 before exiting the die 108. The pre-extrusion rheological sensors 202 may include one or more of a
10 temperature sensor, pressure sensor, volume sensor, and torque sensor. The pre-extrusion rheological sensors 202 may be disposed at various segments of the barrel 104 for measuring the rheological properties of the extrudate 200 as it moves through the barrel 104 towards the distal end 104b before exiting the die 108. The segments where the pre-extrusion rheological sensors 202 are disposed may coincide with the
15 heating zones of the barrel 104. Particularly, the pre-extrusion rheological sensors 202 are configured to measure the flow and viscosity of the extrudate 200 in response to the shear rate that is controlled by the rotational speed of the rotating screws.

- In some embodiments, the pre-extrusion instruments and/or post-extrusion
20 instruments are configured to measure the morphological and/or chemical composition properties of the extrudate 200. The pre-extrusion instruments may include a set of pre-extrusion optical sensors 204 configured for measuring the morphological and/or chemical composition properties of the extrudate 200 before exiting the die 108. The post-extrusion instruments may include a set of post-extrusion
25 optical sensors 206 configured for measuring the morphological and/or chemical composition properties of the extrudate 200 after exiting the die 108. The pre-extrusion optical sensors 204 and/or post-extrusion optical sensors 206 may include one or more spectrometers, such as a Raman spectrometer, Fourier transform infrared (FTIR) spectrometer, colour spectrometer, or ultraviolet spectrometer. Additionally or
30 alternatively, the pre-extrusion optical sensors 204 and/or post-extrusion optical sensors 206 may include one or more of an X-ray scanner and computed tomography (CT) scanner.

The Raman spectrometer, colour spectrometer, and ultraviolet spectrometer are configured to respectively measure the Raman spectra, colour spectra, and ultraviolet spectra of the extrudate 200. In one embodiment, the extrudate 200 comprises a blend of a polymer material and a filler material. The measured spectra can be used to
5 determine the homogeneity of the polymer blend as well as the dispersion state of the filler material that is added to the polymer material. Specifically, the Raman spectra can be used to evaluate filler-matrix as well as filler-filler interactions.

The FTIR spectrometer is configured to measure the infrared spectra of the extrudate
10 200. The infrared spectra can be used to evaluate the crystallinity of the extrudate 200, especially for polymers, by establishing the signatures of the crystalline and amorphous phases and determining the peak height ratios of the corresponding spectra. The infrared spectra can also be used to determine the chemical composition of the extrudate 200, including the compound ingredients that constitute the extrudate
15 200. The Raman and infrared spectroscopies can provide chemical and physical information that can be used to determine the extent of chemical reactions that have taken place in the extrudate 200, as well as the state of nanoparticle dispersion in the extrudate 200, such as between the polymer and filler materials.

20 The post-extrusion optical sensors 206 may include an optical sensor disposed at the exit of the die 108 for measuring the die swell of the extrudate 200 after exiting the die 108. The optical sensor may be a distance sensor or an infrared sensor. Die swell or extrudate swell is a common phenomenon in polymer extrusion wherein the polymer extrudate 200 partially recovers or swells back to its former shape after being forced
25 out through the die 108. Alternatively, the extruder 100 includes a chamber placed after the die 108 and the extrudate 200 is collected in the chamber after exiting the die 108. Once the chamber is filled with the extrudate 200, a piston will push the extrudate 200 out through another die and the force exerted on the piston will be measured. The speed of the piston can be varied to simulate different shear rates and the respective
30 forces are measured accordingly during the extrusion process.

In some embodiments, the pre-extrusion instruments and/or post-extrusion instruments are configured to measure the mechanical performance properties of the

extrudate 200. The post-extrusion instruments may include a melt tension instrument 208 configured for measuring melt tension properties of the extrudate 200 after exiting the die 108. The post-extrusion instruments include a set of rollers 210 disposed after the die 108 and configured for rolling the extrudate 200 to facilitate measurement of the melt tension properties. The melt tension properties are measured by performing a set of melt tension tests on the extrudate 200 at various stages of the cooling process after the extrudate 200 exits the die 108. Particularly, as the extrudate 200 cools through the cooling process, such as by water quenching, the extrudate 200 changes from the molten state to the semi-solid state and eventually to the solid state. The measured melt tension properties represent the tensile strength of the extrudate 200 at the various states.

The extrusion data includes the predefined extrusion parameters of the extruder 100, the pre-extrusion properties of the extrudate 200 measured by the pre-extrusion instruments, and the post-extrusion properties of the extrudate 200 measured by the post-extrusion instruments. The pre-extrusion properties and post-extrusion properties include one or more of temperature, pressure, volume, torque, Raman spectra, infrared spectra, colour spectra, ultraviolet spectra, X-ray images, CT images, die swell, and melt tension properties. The extrusion data collectively characterizes one or more of the rheology, morphology, chemical composition, and mechanical performance properties of the extrudate 200. In one embodiment, the extrudate 200 is a polymer compound and these properties can provide information about the polymer compound, including but not limited to, the type(s) of polymer used, type(s) of additives / fillers / reinforcements used, compatibility and homogeneity of polymer compound, dispersion of additives / fillers / reinforcements in the polymer compound, flow characteristics of the polymer compound under different shear rates, and simulated mechanical performance of the polymer compound.

As stated above, the processor 300 is configured for collecting the extrusion data. The extrusion data is collected automatically and in real-time during the extrusion process. Additionally, the processor 300 is configured for building a materials database 310 using the extrusion data. The automated collection of extrusion data in real-time enables the materials database 310 to be built in a fast and cost-effective manner.

Correspondingly, the method for processing the extrusion data further includes a step of building the materials database 310 using the processor 300 and the extrusion data.

5 The materials database 310 records the material properties of the extrudate 200 derived from the measured pre-extrusion properties and post-extrusion properties. The material properties are associated with the predefined extrusion parameters and the raw materials, as well as any additives / fillers / reinforcements, used to create the extrudate 200. The information recorded in the materials database 310 can allow for future replication of the extrudate 200 if such material properties are desired. Moreover,
10 if the desired material properties of the extrudate 200 are known, any deviations or inconsistencies can be detected from the measured pre-extrusion properties and post-extrusion properties during the extrusion process so that there can be immediate intervention if necessary. This would provide better performance to the extruder 100 such as feed precision, material dosing, mixing efficiency, and real-time quality
15 management.

Using the materials database 310, material properties of the extrudate 200 can be correlated with each other as well as with the extrusion parameters of the extruder 100. For example, colour changes of the extrudate 200 can be indicative of
20 homogeneity and crystallinity of the extrudate 200. These properties can be combined with other measurements such as from melt tension, die swell, and temperature to obtain a thermo-mechanical correlation of the extrudate 200. Reaction kinetics data from the chemical reactions can be used to determine the response of various chemical compounds and catalysts to the extrusion parameters and then correlate to
25 the rheological properties (such as pressure, volume, and temperature) to predict material properties such as the crosslink density in polymers. The melt tension properties can be correlated with the rheological properties (such as pressure, volume, and temperature) to provide insights and better understanding of the viscoelastic properties of the extrudate 200.

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In some embodiments, the processor 300 is configured for reducing dimensionality of the extrusion data. The dimensionality of the extrusion data can be reduced using various functions and algorithms such as clustering techniques, leave-one-out cross-

validation, feature importance in forest / decision tree regressors, principal component analysis, and the like. Other dimensionality control techniques include restricting the features based on domain knowledge, such as unifying multiple related features. For example, the spectra where the peak height and location characteristics may sufficiently describe the material properties. For example, several physical parameters can be combined using pre-established physical correlations to fewer or singular parameters describing the material properties.

In some embodiments, the processor 300 is configured for training a machine learning model using the materials database 310. Extrusion data from the materials database 310 is fed to the machine learning model which can be used to correlate material properties with each other. These property correlations can be used to establish an active feedback control loop for automated intervening / self-correction of the extrusion parameters without human intervention to optimize the extrusion process. The processor 300 is thus configured for receiving feedback from the machine learning model and to adjust the extrusion parameters based on the feedback. For example, the speed and temperature of the extruder 100 and feeding of materials into the feeder 102 / barrel 104 can be tuned to control homogeneity and reaction times in the materials in the barrel 104, depending on the colour change and spectroscopy properties of the extrudate 200. The speed of the extruder 100 can be adjusted and the cooling process after extrusion can be controlled to obtain the desirable crystallinity of the extrudate 200.

The machine learning model is trained to determine a set of output data based on a set of input data. The input data may include the extrusion parameters for an extrusion process and the output data may include the material properties of the extrudate 200 created by the extrusion process. Alternatively, the input data may include the desired material properties of the extrudate 200 and the output data may include the extrusion parameters for an extrusion process to create the extrudate 200.

The machine learning model may be used to search the materials database based on a set of extrusion parameters for an extrusion process to create an extrudate and a set of material properties of the extrudate. If an existing extrudate corresponding to

- the set of extrusion parameters and the set of material properties can be found in the materials database, then details of the existing extrudate can be retrieved from the materials database for recreating the extrudate. If such existing extrudate cannot be found in the materials database, a new extrudate corresponding to the extrusion
- 5 parameters and material properties is added to the materials database. Accordingly, the machine learning model can be used to automatically create new extrudates and retrieve details of existing extrudates in the materials database without human intervention.
- 10 In some embodiments, the input data includes the extrusion parameters for the extrusion process and the output data includes the material properties of the extrudate 200 created by the extrusion process. The processor 300 is configured to perform a computerized method for determining the material properties of the extrudate 200. The method includes a step of providing the machine learning model trained with training
- 15 data from the materials database 310, the training data including a pre-established set of extrusion parameters and material properties of extrudates 200. The method includes a step of receiving the input data by the trained machine learning model, the input data including an input set of extrusion parameters for the extruder 100 to create the extrudate 200. The method includes a step of processing the input set of extrusion
- 20 parameters using the trained machine learning model. The method includes a step of generating the output data by the trained machine learning model in response to said processing of the input set of extrusion parameters, the output data including an output set of material properties of the extrudate 200.
- 25 In some embodiments, the input data includes the material properties of the extrudate 200 and the output data includes the extrusion parameters for the extrusion process to create the extrudate 200. The processor 300 is configured to perform a computerized method for determining the extrusion parameters for the extruder 100 to create the extrudate 200. The method includes a step of providing the machine
- 30 learning model trained with training data from the materials database 310, the training data including a pre-established set of extrusion parameters and material properties of extrudates 200. The method includes a step of receiving the input data by the trained machine learning model, the input data including an input set of material properties of

the extrudate 200. The method includes a step of processing the input set of material properties using the trained machine learning model. The method includes a step of generating the output data by the trained machine learning model in response to said processing of the input set of material properties, the output data including an output
5 set of extrusion parameters for the extruder 100 to create the extrudate 200.

The machine learning model is trained to determine the output data from the input data using various suitable machine learning or artificial intelligence algorithms, such as but not limited to, a Bayesian optimization algorithm (or its variants), a reinforcement
10 learning algorithm, or a regression algorithm. For example, the machine learning model may be based on a neural network. It will be appreciated that the machine learning model is not limited to any software platform or programming language, and the machine learning model may be executed using any number of known platforms and/or languages.

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In some embodiments, the machine learning model is trained using a Bayesian optimization algorithm or reinforcement learning algorithm. This is an active learning approach where the algorithm gives immediate feedback to alter the input parameters so as to arrive at the input conditions that will result in predefined output material
20 properties of the extrudate 200. This approach does not require a large initial dataset and can be used even when there is minimal or no existing data. The algorithm trains itself on the first few iterations, and by a combination of exploration and exploitation, converges to the input parameters that are required for the desired output material properties.

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In some embodiments, the machine learning model is trained using a regression algorithm. A large initial dataset from the materials database 310 is required to train the machine learning model and the entire parameter space of the extrusion process is accurately captured and represented. The machine learning model can be used to
30 predict the output material properties of the extrudate 200 based on the input parameters. The machine learning model can also be inversely used to suggest the input parameters that are required for the desired output material properties.

By training the machine learning model with the materials database 310, the machine learning model can be used to predict critical extrusion parameters to create extrudates 200 with desired material properties. Particularly, predicting the critical extrusion parameters can control the consistency and morphology polymer compounds. The machine learning model can also be used to design and develop new materials, particularly to formulate new polymeric blends and composites, without running various trial batches of the new materials.

In the foregoing detailed description, embodiments of the present disclosure in relation to a system and method for processing extrusion data during an extrusion process are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

Claims

1. A system for processing extrusion data during an extrusion process performed by an extruder under predefined extrusion parameters, the system comprising:
- 5 a set of pre-extrusion instruments for measuring, during the extrusion process, pre-extrusion properties of an extrudate within the extruder;
- a set of post-extrusion instruments for measuring, during the extrusion process, post-extrusion properties of the extrudate after exiting the extruder; and
- 10 a processor for collecting the extrusion data comprising the extrusion parameters and the measured pre-extrusion and post-extrusion properties of the extrudate,
- wherein the processor is configured for building a materials database using the extrusion data.
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2. The system according to claim 1, wherein the pre-extrusion instruments and/or post-extrusion instruments are configured for measuring rheological properties of the extrudate.
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3. The system according to claim 2, wherein the pre-extrusion instruments comprise one or more of a temperature sensor, pressure sensor, volume sensor, and torque sensor.
4. The system according to any one of claims 1 to 3, wherein the pre-extrusion
- 25 instruments and/or post-extrusion instruments are configured for measuring morphological and/or chemical composition properties of the extrudate.
5. The system according to claim 4, wherein the pre-extrusion instruments and/or post-extrusion instruments comprise optical sensors including one or more of a Raman
- 30 spectrometer, Fourier transform infrared spectrometer, colour spectrometer, ultraviolet spectrometer, X-ray scanner, and computed tomography scanner.

6. The system according to claim 5, wherein the post-extrusion instruments comprise an optical sensor for measuring die swell of the extrudate.

7. The system according to any one of claims 1 to 6, wherein the pre-extrusion instruments and/or post-extrusion instruments are configured for measuring mechanical performance properties of the extrudate.

8. The system according to claim 7, wherein the post-extrusion instruments comprise a melt tension instrument configured for measuring melt tension properties of the extrudate.

9. The system according to claim 13, wherein the post-extrusion instruments comprise a set of rollers configured for rolling the extrudate to facilitate measurement of the melt tension properties.

10. A method for processing extrusion data during an extrusion process, the method comprising:

performing the extrusion process using an extruder under predefined extrusion parameters;

measuring, during the extrusion process, and using a set of pre-extrusion instruments, pre-extrusion properties of an extrudate within the extruder;

measuring, during the extrusion process and using a set of post-extrusion instruments, post-extrusion properties of the extrudate after exiting the extruder;

collecting, using a processor, the extrusion data comprising the extrusion parameters and the measured pre-extrusion and post-extrusion properties of the extrudate; and

building a materials database using the processor and the extrusion data.

11. The method according to claim 10, further comprising reducing dimensionality of the extrusion data.

12. The method according to claim 10 or 11, further comprising training a machine learning model using the materials database.

13. The method according to claim 12, further comprising adjusting the extrusion
5 parameters based on feedback received from the machine learning model.

14. The method according to claim 12 or 13, further comprising training, using the processor, the machine learning model to determine a set of output data based on a set of input data, the input data comprising extrusion parameters for an extrusion
10 process and the output data comprising material properties of an extrudate created by the extrusion process.

15. The method according to claim 12 or 13, further comprising training, using the processor, the machine learning model to determine a set of output data based on a set of input data, the input data comprising material properties of an extrudate and the
15 output data comprising extrusion parameters for an extrusion process to create the extrudate.

16. The method according to any one of claims 12 to 15, wherein the machine
20 learning model is trained using a Bayesian optimization algorithm, a reinforcement learning algorithm, or a regression algorithm.

17. The method according to any one of claims 10 to 16, further comprising searching, using the machine learning model, the materials database based on a set
25 of extrusion parameters for an extrusion process to create an extrudate and a set of material properties of the extrudate.

18. The method according to claim 17, further comprising adding, to the materials database, a new extrudate if an existing extrudate corresponding to the set of
30 extrusion parameters and the set of material properties cannot be found in the materials database.

19. A computerized method for determining material properties of an extrudate, the method comprising:

- 5 providing a machine learning model trained with training data comprising a pre-established set of extrusion parameters and material properties of extrudates;
- receiving, by the trained machine learning model, an input set of extrusion parameters for an extruder to create the extrudate;
- processing the input set of extrusion parameters using the trained machine learning model; and
- 10 generating, by the trained machine learning model in response to said processing of the input set of extrusion parameters, an output set of the material properties of the extrudate.

20. The method according to claim 19, wherein the machine learning model is
15 trained using a Bayesian optimization algorithm, a reinforcement learning algorithm, or a regression algorithm.

21. A computerized method for determining extrusion parameters for an extruder to create an extrudate, the method comprising:

- 20 providing a machine learning model trained with training data comprising a pre-established set of extrusion parameters and material properties of extrudates;
- receiving, by the trained machine learning model, an input set of material properties of the extrudate;
- 25 processing the input set of material properties using the trained machine learning model; and
- generating, by the trained machine learning model in response to said processing of the input set of material properties, an output set of the extrusion parameters for the extruder to create the extrudate.

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22. The method according to claim 21, wherein the machine learning model is trained using a Bayesian optimization algorithm, a reinforcement learning algorithm, or a regression algorithm.