

METHOD FOR PREDICTING TOOL SERVICE LIFE, ELECTRONIC DEVICE, AND STORAGE MEDIUM

TECHNICAL FIELD

[0001] The present application relates to an intelligent manufacturing field, and in particular, to a method for predicting tool service life, an electronic device, and a storage medium.

BACKGROUND ART

[0002] When designing tools, it is often necessary to predict service life of the tools to ensure their quality. In related technologies, the service life of the tool is often determined by conducting a large number of experiments using the tool on a large number of workpieces. This approach is not only time-consuming and labor-intensive but also consumes a large number of workpieces, resulting in resource waste.

SUMMARY

[0003] In view of the above, it is necessary to provide a method for predicting tool service life, an electronic device, and a storage medium, which can solve the technical problem of predicting tool service life with a poor efficiency.

[0004] In a first aspect, the present application provides a method for predicting tool service life. The method includes: obtaining simulation data by performing simulated machining on a simulated workpiece using simulation parameters of a simulated tool; obtaining thermo-mechanical coupling parameters corresponding to the simulated tool by performing feature analysis on the simulation data; and determining a predicted service life of the simulated tool according to the thermo-mechanical coupling parameters, a life coefficient corresponding to the simulated tool, and preset material property parameters.

[0005] In a second aspect, the present application further provides an electronic device. The electronic device comprises: a storage device storing at least one instruction; and a processor executing the at least one instruction to implement the method for predicting tool service life according to the first aspect.

[0006] In a third aspect, the present application further provides a computer-readable storage medium, wherein computer-readable instructions are stored in the computer-readable storage medium, and the computer-readable instructions are executed by a processor of an electronic device to implement the method for predicting tool service life according to the first aspect.

5 **[0007]** In the solution of predicting tool service life provided by the embodiments of the present application, simulated machining is performed on a simulated workpiece using simulation parameters of a simulated tool to obtain simulation data, enabling the simulation data to prospectively reflect potential issues such as tool wear that may occur during actual cutting processes. Through simulated machining, reliance on physical resources in tool development can be reduced, thereby lowering the
10 development cycle and trial-and-error costs of tools. Feature analysis is performed on the simulation data to obtain thermo-mechanical coupling parameters, enabling these parameters to accurately characterize the actual working condition where force and temperature interact during the cutting process of the tool. According to the thermo-mechanical coupling parameters, the life coefficient corresponding to the simulated tool, and the preset material property parameters, the influences of
15 multiple factors such as temperature, stress, rotational speed, and thermodynamic properties of the simulated tool can be comprehensively considered, thereby enabling rapid and accurate determination of the predicted service life. In this way, workpiece consumption can be avoided, resource waste can be reduced, and the prediction efficiency of tool life can be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

20 **[0008]** FIG. 1 is a flowchart of a method for predicting tool service life according to an embodiment of the present application.

[0009] FIG. 2 is a schematic diagram of a simulated tool according to an embodiment of the present application.

[0010] FIG. 3 is a schematic diagram of tool design parameters and material grades of simulated
25 tools according to an embodiment of the present application.

[0011] FIG. 4 is a schematic diagram of tool material property parameters of simulated tools according to an embodiment of the present application.

- [0012] FIG. 5 is another schematic diagram of tool material property parameters of a simulated tool according to an embodiment of the present application.
- [0013] FIG. 6 is a schematic diagram of machining parameters according to an embodiment of the present application.
- 5 [0014] FIG. 7 is another schematic diagram of machining parameters according to an embodiment of the present application.
- [0015] FIG. 8 is a schematic diagram of orthogonal cutting machining according to an embodiment of the present application.
- [0016] FIG. 9 is a schematic diagram of simulation data according to an embodiment of the present application.
- 10 [0017] FIG. 10 is a schematic diagram of thermo-mechanical coupling parameters according to an embodiment of the present application.
- [0018] FIG. 11 is a matching table of material grades of simulated tools and performance constants according to an embodiment of the present application.
- 15 [0019] FIG. 12 is a comparison chart of predicted service lives corresponding to multiple tool design schemes according to an embodiment of the present application.
- [0020] FIG. 13 is a flowchart of a method for determining a cutting cycle number according to an embodiment of the present application.
- [0021] FIG. 14 is another flowchart of a method for determining a cutting cycle number according to an embodiment of the present application.
- 20 [0022] FIG. 15 is a flowchart of a generation method for a life coefficient and preset material property parameters corresponding to a simulated tool according to an embodiment of the present application.
- [0023] FIG. 16 is a schematic diagram of actual service life and predicted service life of a real tool according to an embodiment of the present application.
- 25 [0024] FIG. 17 is a structural schematic diagram of an electronic device according to an embodiment of the present application.

DETAILED DESCRIPTION

[0025] It should be noted that "at least one" in the present application refers to one or more, and "a plurality of" refers to two or more than two. "And/or" describes an association relationship between associated objects, indicating that three relationships may exist. For example, A and/or B may indicate: A exists alone, both A and B exist, or B exists alone, where A and B may be singular or plural. The terms "first", "second", "third", "fourth", etc. (if present) in the specification, claims, and drawings of the present application are used to distinguish similar objects and are not intended to describe a specific order or sequence.

[0026] In the embodiments of the present application, terms such as "exemplary" or "for example" are used to indicate examples, illustrations, or explanations. Any embodiment or design scheme described as "exemplary" or "for example" in the embodiments of the present application should not be construed as being more preferred or advantageous than other embodiments or design schemes. Rather, the use of terms such as "exemplary" or "for example" is intended to present related concepts in a specific manner. The embodiments described below and features in the embodiments may be combined with each other if no conflict arises.

[0027] As shown in FIG. 1, it is a flowchart of a method for predicting tool service life according to an embodiment of the present application. Depending on different requirements, sequence of steps in this flowchart may be adjusted according to actual requirements, and some steps may be omitted. The method for predicting tool service life is applied to an electronic device, such as the electronic device 10 shown in FIG. 17.

[0028] S11, simulated machining is performed on a simulated workpiece using simulation parameters of a simulated tool, and simulation data is obtained.

[0029] In some embodiments, a simulation software of the electronic device performing simulated machining on the simulated workpiece using simulation parameters of the simulated tool to obtain the simulation data, in other words, the simulation software performs the following steps:: S111: obtaining simulation parameters of the simulated tool; S112: determining the simulated workpiece according to the simulated tool; S113: performing a simulation operation on the simulated workpiece based on the simulated tool and the simulation parameters, and obtaining simulation result data; S114: performing simulation analysis on the simulation result data to obtain analysis result data; S115: performing noise filtering processing on the analysis result data to obtain the simulation data. The

simulation parameters of the simulated tool may include tool design parameters, tool material property parameters, machining parameters, and workpiece material property parameters.

[0030] Each of the simulated tool and the simulated workpiece may include a three-dimensional geometric model. The three-dimensional geometric model may include geometric information, such as points, lines, surfaces, etc., which can accurately present features such as a tool profile and a tool shape. The simulated tool may have 1 to 16 cutting flutes. In one embodiment, as shown in FIG. 2, it is a schematic diagram of the simulated tool according to an embodiment of the present application. The simulated tool shown in FIG. 2 has 4 cutting flutes. The simulated workpiece may be a three-dimensional geometric model of a blank (e.g., a cube, cylinder, sphere, cone, etc.), which, after simulated machining by the simulated tool, becomes a three-dimensional geometric model of a target part shape (e.g., a metal plate with grooves, a mobile phone housing, etc.).

[0031] The tool design parameters may include angle parameters such as an axial rake angle, an axial relief angle, an axial relief angle of corner radius, a radial relief angle of corner radius, a radial rake angle, a radial relief angle, etc. Units of these angle parameters may be degrees, and they can be used to indicate features such as the shape and structure of the simulated tool. Cutting performance of the simulated tool can be controlled through the tool design parameters.

[0032] The tool material property parameters include tool physical property parameters and tool mechanical property parameters of the simulated tool. The tool physical property parameters may include parameters such as density, thermal conductivity, specific heat capacity, etc. The tool mechanical property parameters may include parameters such as Young's modulus, Poisson's ratio, cobalt content, hardness, transverse rupture strength, etc. The material of the simulated tool may include carbide, ceramic, glass, and the like.

[0033] For example, as shown in FIG. 3, it is a schematic diagram of tool design parameters and material grades of simulated tools according to an embodiment of the present application. In FIG. 3, L108, K44UF, CTS24Z, F6, etc., represent material grades of simulated tools. The tool design parameters corresponding to each material grade corresponding to the simulated tool include an axial rake angle and an axial relief angle. Units and specified values of the axial rake angle and axial relief angle can be referred to in FIG. 3.

[0034] For example, as shown in FIG. 4, it is a schematic diagram of tool material property parameters of simulated tools according to an embodiment of the present application. FIG. 4 shows the tool material property parameters for a total of four material grades of simulated tools: L108, K44UF, CTS24Z, F6. Each material grade corresponding to the simulated tool corresponds to a total of five tool material property parameters: density, Young's modulus, Poisson's ratio, thermal conductivity, and specific heat capacity. Specified values and units of density, Young's modulus, Poisson's ratio, thermal conductivity, and specific heat capacity can be referred to in FIG. 4.

[0035] In some embodiments, the material grades of different simulated tools can be distinguished by different tool material property parameters. The tool material property parameters are defined by material composition. Materials corresponding to the four material grades of simulated tools shown in FIG. 3 and FIG. 4 may all be carbide material (i.e., tungsten carbide). The material compositions corresponding to different material grades of simulated tools may be the same, but proportions may differ.

[0036] For example, as shown in FIG. 5, it is another schematic diagram of tool material property parameters of a simulated tool according to an embodiment of the present application. As shown in FIG. 4, if the material grade corresponding to the simulated tool obtained by the electronic device is CTS24Z, based on CTS24Z, a total of five tool material property parameters corresponding to the simulated tool having the material grade CTS24Z can be obtained. The five tool material property parameters includes the density, Young's modulus, Poisson's ratio, thermal conductivity, and specific heat capacity. As shown in FIG. 5, based on CTS24Z, a total of eight tool material property parameters corresponding to the simulated tool having the material grade CTS24Z can be obtained, the eight tool material property parameters include the density, Young's modulus, Poisson's ratio, thermal conductivity, specific heat capacity, cobalt content, hardness, transverse rupture strength.

[0037] The machining parameters may include parameters such as a rotational speed, a total feed amount, a cutting depth (abbreviated as depth of cut), a cutting width (abbreviated as width of cut), a number of cutting flutes, a feed per tooth, a cutting fluid concentration, etc., which can be used to guide a cutting process. Among them, the number of cutting flutes defines a number of cutting flutes the simulated tool has. The number of cutting flutes can be an integer greater than or equal to 1, indicating that the simulated tool has at least one cutting flute.

[0038] For example, as shown in FIG. 6, it is a schematic diagram of machining parameters according to an embodiment of the present application. FIG. 6 shows the specified values and units for a total of four machining parameters: the rotational speed, the feed per tooth, the cutting width, and the cutting depth.

5 **[0039]** For example, as shown in FIG. 7, it is another schematic diagram of machining parameters according to an embodiment of the present application. FIG. 7 shows the specified values and related units for a total of seven machining parameters: a rotational speed, a total feed amount, a number of cutting flutes, a feed per tooth, a cutting width, a cutting depth, and a cutting fluid concentration.

[0040] The workpiece material property parameters include physical property parameters and
10 mechanical property parameters of the simulated workpiece. The physical property parameters may include parameters such as density, thermal conductivity, specific heat capacity, etc. The mechanical property parameters may include parameters such as Young's modulus, Poisson's ratio, yield strength, tensile strength, thermal conductivity, specific heat capacity, hardness, etc.

[0041] The simulation software can be AdvantEdge, Abaqus, AnyLogic, or other tools. The
15 embodiments of the present application do not limit a type of simulation software.

[0042] In some embodiments, the electronic device can select and/or generate a simulated workpiece compatible with the simulated tool through the simulation software. Exemplarily, step S112, determining the simulated workpiece according to the simulated tool, includes: S1121: obtaining information such as a type of the simulated tool and size information of a cutting flute of
20 the simulated tool; S1122: based on the type of the simulated tool and the size information of the cutting flute of the simulated tool, determining workpiece size information compatible with the simulated tool using a preset matching table of simulated tools and simulated workpiece size information to determine workpiece size information compatible with the simulated tool; S1123: generating or selecting a corresponding geometric body as the simulated workpiece according to the
25 workpiece size information. In one embodiment, the preset matching table defines the workpiece size information that can be machined for simulated tools with different types and different sizes of cutting flute.

[0043] Among them, the type of the simulated tool can be one of a flat end mill, a ball nose end mill, a bull nose end mill, etc. Since the three-dimensional geometric models of different types of

simulated tools are not the same, the electronic device has a tool type mapping table, the tool type mapping table defines corresponding relationships between geometric shape features and types of simulated tools. Therefore, the electronic device can extract geometric features (e.g., geometric shape features) from the three-dimensional geometric material grade corresponding to the simulated tool and determine the type of the simulated tool according to the tool type mapping table.

[0044] The size information of the cutting flute can include parameters such as a length and/or a diameter of the cutting flute. Since the geometric features of different types of simulated tools are not the same, the electronic device can also determine the size of the cutting flute of the simulated tool according to the geometric features. In one embodiment, the preset matching table of simulated tools and simulated workpiece size information can be a matching table of cutting flute sizes of the simulated tool and simulated workpiece size information. When the simulated tool has multiple cutting flutes of different sizes, the workpiece size information can be determined by first synthesizing sizes of multiple cutting flutes (e.g., averaging the sizes of the cutting flutes), and then searching the matching table according to the synthesized size, or the workpiece size information can be determined by first selecting one size from the sizes of multiple cutting flutes, and then searching the matching table based on the selected size. Exemplarily, the electronic device can determine the workpiece size information based on an average size of multiple cutting flutes (e.g., an average length and/or an average diameter) of the simulated tool, and then determine the workpiece size information by searching the matching table according to the average size ; or, the electronic device can select a largest size from the sizes of multiple cutting flutes (e.g., the greatest length and/or the largest diameter), and then determine the workpiece size information by searching the matching table based on the largest size.

[0045] In some embodiments, the workpiece size information may include cube parameters such as a length, a width, and a height, or the workpiece size information may include cylinder parameters such as a radius and a height, or the workpiece size information may also include sphere parameters such as a radius, etc., to facilitate generating a corresponding geometric body as the simulated workpiece.

[0046] For example, in the matching table of simulated tools and workpiece size information, if the cutting flute size is within a range of 11mm to 12mm in length, it can be obtained from the matching

table that the type of the corresponding simulated tool is flat end mill, and the corresponding simulated workpiece size is length 16mm, width 16mm, height 6mm; or, in the matching table, if the cutting flute size is within a range of 24mm to 26mm in length and within a range of 9mm to 10mm in diameter, it can be obtained from the matching table that the type of the corresponding simulated tool is flat end mill, and the corresponding simulated workpiece size is length 50mm, width 30mm, height 12mm.

[0047] The above examples of methods for determining the simulated workpiece are for illustration only and are not limited in practical applications. For example, in other embodiments, the electronic device can also select and/or generate a corresponding simulated workpiece through the simulation software, according to the type of the simulated tool, the size of the cutting flute of the simulated tool, and the number of cutting flutes. Among them, the preset matching table of simulated tools and workpiece size information predefines workpiece size information that can be processed corresponding to simulated tools of different types, different cutting flute sizes, and different numbers of cutting flutes. For example, in the matching table, a six-flute bull nose end mill with a length in the range of 23mm to 25mm and a diameter in the range of 40mm to 50mm can correspond to a cubic simulated workpiece with a length of 200mm, a width of 150mm, and a height of 10mm. In one embodiment, the number of cutting flutes of the simulated tool can be obtained based on geometric feature analysis of the simulated tool, or obtained from the simulation parameters of the simulated tool. The embodiments of the present application do not limit this.

[0048] In another embodiment, the simulated workpiece or the simulated tool can be obtained through user input, or obtained directly or indirectly from three-dimensional (3D) software (e.g., 3ds MAX, rhino, cinema 4D, Softimage XSI 5.01, Pro/E, UG, AutoCAD, etc.), without needing to be determined through the simulated tool as in step S112.

[0049] In some embodiments, the electronic device uses the simulation software to perform simulation operation based on the simulated tool, using the simulation parameters and the simulated workpiece, to restore or simulate the actual cutting process, thereby obtaining raw simulation result data. The simulation result data may include a large amount of physical field data such as mechanical data, thermal data, and motion data generated during the simulated cutting process.

[0050] Taking orthogonal cutting as an example, as shown in FIG. 8, it is a schematic diagram of orthogonal cutting machining according to an embodiment of the present application. In FIG. 8, "tool" can represent the simulated tool, "workpiece" can represent the simulated workpiece, "chip" can represent a simulated chip formed by cutting action of the simulated tool on the simulated workpiece, "shear plane" represents a shear plane. FIG. 8 shows an interaction relationship between the simulated tool, the simulated workpiece, and the simulated chip. In FIG. 8, V_c represents a cutting speed, V_{ch} represents a chip speed, a represents a undeformed chip thickness, α_{ch} represents a chip thickness, p and τ represent a normal stress and a shear stress respectively, S represents a resultant stress formed by p and τ , ℓ_{cp} and ℓ_{ce} correspond to the chip length, representing a plastic contact zone and an elastic contact zone respectively, α represents the axial relief angle of the simulated tool, γ represents the axial rake angle of the simulated tool, α represents the axial relief angle of the simulated tool, F_c and F_t represent the cutting force and thrust force respectively, and Φ represents the shear angle. The normal force p , shear stress τ , and resultant stress S will be explained in step S12 below.

[0051] In some embodiments, the electronic device can use the simulation software to extract, from the simulation result data, shear stress data generated by the cutting force applied by the cutting flute of the simulated tool to the simulated workpiece, contact pressure data between the cutting flute of the simulated tool and the simulated workpiece, temperature data of the cutting flute of the simulated tool, etc., as the analysis result data.

[0052] For example, the shear stress data can be signal data of the shear stress generated by the cutting force applied by the cutting flute of the simulated tool to the simulated workpiece changing over time. The temperature data can be signal data of the temperature of the cutting flute of the simulated tool changing over time. The contact pressure data can be signal data of the contact pressure between the cutting flute of the simulated tool and the simulated workpiece changing over time. For ease of distinction, signal data of the shear stress generated by the cutting force applied by the cutting flute of the simulated tool to the simulated workpiece changing over time can be set as first signal data; signal data of the temperature of the cutting flute of the simulated tool changing over time can be set as second signal data; and signal data of the contact pressure between the cutting flute of the simulated tool and the simulated workpiece changing over time can be set as third signal data.

[0053] In some embodiments, noise data can be filtered from the analysis result data to obtain high-quality simulation data. The noise data may come from non-steady-state stages such as a start and an end of the simulation process. Data in these intervals is not representative and can be filtered out.

[0054] In other embodiments, to further improve a quality of the simulation data, the electronic device can perform anomaly detection on the simulation data and delete abnormal data from the simulation data caused by reasons such as numerical oscillation or simulation convergence failure.

[0055] In this embodiment, the simulated machining is performed on the simulated workpiece using the simulated tool, enabling the simulation data to prospectively reflect potential issues such as tool wear that may occur during actual cutting processes. Through the simulated machining, reliance on physical resources in tool development can be reduced, thereby lowering the development cycle and trial-and-error costs of tools.

[0056] It should be noted that characteristics of the simulated tool and the simulated workpiece reflected by parameters such as the aforementioned simulation parameters and the thermo-mechanical coupling parameters, life coefficient, preset material property parameters, etc., also characterize real characteristics of the real tool corresponding to the simulated tool and the real workpiece corresponding to the simulated workpiece. The interaction process between the simulated tool and the simulated workpiece can also reflect the interaction process between the real tool corresponding to the simulated tool and the real workpiece corresponding to the simulated workpiece. However, for ease of explanation, the present application only uses the simulated tool and the simulated workpiece as examples for description.

[0057] S12, feature analysis is performed on the simulation data to obtain thermo-mechanical coupling parameters corresponding to the simulated tool.

[0058] In some embodiments of the present application, the thermo-mechanical coupling parameters may include a target shear stress and target temperatures. A preset algorithm of the electronic device performing feature analysis on the simulation data to obtain the thermo-mechanical coupling parameters corresponding to the simulated tool, in other words, the preset algorithm performs the following steps: S121: determining, based on the simulation data, shear stresses generated by cutting forces applied by a cutting flute of the simulated tool to the simulated workpiece; S122: determining the target shear stress corresponding to the simulated tool based on the shear

stresses corresponding to the cutting flute; S123: determining the target temperatures corresponding to the simulated tool based on temperatures of the cutting flute.

[0059] Among them, the shear stress can characterize the shear stress endured by the simulated workpiece in a direction parallel to the shear plane due to the action of the simulated tool (the action of the cutting force applied by the simulated tool). The shear stress can cause the simulated workpiece to undergo shear deformation along the shear plane, forming chips. For example, the shear stress can refer to the arrow pointing to τ in FIG. 8.

[0060] In some embodiments, the simulation data may include first signal data of the shear stresses generated by the cutting forces applied by the cutting flute of the simulated tool to the simulated workpiece changing over time. The electronic device performs feature analysis on the first signal data to determine the shear stresses corresponding to peaks of the first signal data, and selects the target shear stress from the shear stresses corresponding to peaks. For example, when the simulated tool has one cutting flute, there is only one first signal data. The feature analysis performed by the electronic device on the first signal data may include selecting the largest shear stress from the shear stresses corresponding to peaks of the first signal data as the target shear stress.

[0061] In some embodiments, if the simulated tool corresponds to multiple cutting flutes, the simulation data may include first signal data corresponding to each cutting flute, i.e., there are multiple first signal data. The electronic device can select the largest shear stress from all shear stresses corresponding to the peaks of the multiple first signal data as the target shear stress.

[0062] In some embodiments of the present application, the target temperature may include a first target temperature and a second target temperature, where the first target temperature may be higher than the second target temperature. The simulation data may include second signal data of the temperatures of the cutting flute of the simulated tool changing over time. The electronic device performs feature analysis on the second signal data to determine temperatures corresponding to peaks and valleys of the second signal data, selects the first target temperature from the temperatures corresponding to peaks, and selects the second target temperature from the temperatures corresponding to valleys. For example, when the simulated tool has one cutting flute, there is one second signal data. The electronic device performing feature analysis on the second signal data specifically includes: selecting the highest temperature from the temperatures corresponding to peaks

of the second signal data as the first target temperature, and selecting the lowest temperature from the temperatures corresponding to valleys of the second signal data as the second target temperature.

[0063] In some embodiments, if the simulated tool has multiple cutting flutes, the simulation data may include second signal data corresponding to each cutting flute, i.e., there are multiple second signal data. The electronic device can select the highest temperature from all temperatures corresponding to the peaks of the multiple second signal data as the first target temperature, and select the lowest temperature from all temperatures corresponding to all valleys of the multiple second signal data as the second target temperature.

[0064] In other embodiments of the present application, besides the target shear stress and the target temperatures, the thermo-mechanical coupling parameters may further include target contact pressure. The electronic device performing feature analysis on the simulation data to obtain the thermo-mechanical coupling parameters corresponding to the simulated tool further includes: determining, based on the simulation data, contact pressures between the cutting flute of the simulated tool and the simulated workpiece; and determining the target contact pressure corresponding to the simulated tool based on the contact pressures corresponding to the cutting flute.

[0065] Among them, the contact pressure can characterize a normal force endured by the simulated workpiece in a direction perpendicular to the shear plane due to the action of the simulated tool (the action of the cutting force applied by the simulated tool), which can be regarded as a normal stress component perpendicular to the shear plane. The contact pressure can cause local compressive deformation of the simulated workpiece in the direction perpendicular to the shear plane. For example, the contact pressure can refer to the arrow pointing to p in FIG. 8.

[0066] In some embodiments, the simulation data may further include third signal data of the contact pressures between the cutting flute of the simulated tool and the simulated workpiece changing over time. The electronic device performs feature analysis on the third signal data to determine the contact pressures corresponding to the peaks of the third signal data, and selects the target contact pressure from the contact pressures corresponding to peaks. For example, when the simulated tool has one cutting flute, there is one third signal data. The feature analysis performed by the electronic device on the third signal data may include selecting a largest contact pressure from the contact pressures corresponding to peaks of the third signal data as the target contact pressure.

[0067] In some embodiments, if the simulated tool corresponds to multiple cutting flutes, the simulation data may include third signal data corresponding to each cutting flute, i.e., there are multiple third signal data. The electronic device can select the largest contact pressure from all contact pressures corresponding to the peaks of the multiple third signal data as the target contact pressure.

5 [0068] As shown in FIG. 9, it is a schematic diagram of simulation data according to an embodiment of the present application. FIG. 9 shows signal data of the contact pressures (contact pressure values) between the cutting flute of the simulated tool and the simulated workpiece changing over time, where the horizontal axis represents time and the vertical axis represents the value of contact pressure (values). In FIG. 9, different symbols are used to mark the contact pressures
10 corresponding to peaks and valleys, where a dashed line corresponding to contact pressure 2175.75 represents a mean of the contact pressures.

[0069] As shown in FIG. 10, it is a schematic diagram of thermo-mechanical coupling parameters according to an embodiment of the present application. FIG. 10 shows thermo-mechanical coupling parameters corresponding to eight simulation tasks. In FIG. 10, simulation numbers are used to
15 represent corresponding simulation tasks. Each simulation task corresponds to a material grade corresponding to the simulated tool. Each material grade corresponding to the simulated tool has corresponding tool design parameters (the axial rake angle and the axial relief angle) and thermo-mechanical coupling parameters. The thermo-mechanical coupling parameters corresponding to the simulated tool in each simulation task include the target contact pressure, the target shear stress, the
20 first target temperature, and the second target temperature. The specified values and units of each parameter can be referred to in FIG. 10.

[0070] In this embodiment, by selecting the largest shear stress from the shear stresses generated by the cutting forces applied by the cutting flute of the simulated tool to the simulated workpiece as the target shear stress, the target shear stress can truly reflect a largest force endured by the simulated
25 workpiece in a direction parallel to the shear plane due to the action of the simulated tool. Since force has a reaction force, the target shear stress can accurately characterize the largest force endured by the simulated tool in the direction along the shear plane. By selecting the largest contact pressure from the contact pressures between the cutting flute of the simulated tool and the simulated workpiece as the target contact pressure, the target contact pressure can truly reflect the most extreme force

endured by the simulated workpiece in a direction perpendicular to the shear plane due to the action of the simulated tool. Since force has a reaction force, the target contact pressure can accurately characterize a most extreme force endured by the simulated tool in the direction perpendicular to the shear plane. By selecting the highest temperature from the temperatures of the cutting flute of the simulated tool as the first target temperature and the lowest temperature as the second target temperature, the first target temperature and the second target temperature can accurately characterize the highest and lowest temperatures endured by the simulated tool. Determining the target shear stress, the target contact pressure, the first target temperature, and the second target temperature as the thermo-mechanical coupling parameters enables these parameters to truly and accurately characterize the extreme working condition where force and temperature jointly act on the simulated tool during the cutting process.

[0071] S13, a predicted service life of the simulated tool is determined according to the thermo-mechanical coupling parameters, a life coefficient corresponding to the simulated tool, and preset material property parameters.

[0072] In some embodiments of the present application, the preset algorithm of the electronic device determining the predicted service life of the simulated tool according to the thermo-mechanical coupling parameters, the life coefficient corresponding to the simulated tool, and the preset material property parameters, in other words, the preset algorithm performs the following steps: S131: determining a resultant stress of the simulated tool on the simulated workpiece according to the target shear stress and the target contact pressure; S132: determining a temperature amplitude of the simulated tool according to the first target temperature and the second target temperature; S133: determining a cutting cycle number of the simulated tool according to the resultant stress, the temperature amplitude, the life coefficient, and the preset material property parameters; S134: determining the predicted service life according to the cutting cycle number. Exemplarily, the electronic device can determine the resultant stress of the simulated tool on the simulated workpiece based on the target shear stress and the target contact pressure using a preset formula. For example, the calculation method for the resultant stress can refer to the following formula (1):

[0073]
$$S = \sqrt{P^2 + \tau^2}; (1)$$

[0074] where, S represents the resultant stress, P represents the target contact pressure, τ represents the target shear stress.

[0075] In some embodiments, the above formula (1) is only an example and is not limited in practical applications. For example, the electronic device can also perform a weighting operation on a calculation result of the above formula (1) to obtain the resultant stress.

[0076] In this embodiment, since the target shear stress can accurately characterize the largest force endured by the simulated tool in the direction along the shear plane, and the target contact pressure can accurately characterize the most extreme force endured by the simulated tool in the direction perpendicular to the shear plane, calculating the resultant stress based on the target contact pressure and the target shear stress enables the resultant stress to accurately characterize the comprehensive stress intensity of the simulated tool. For example, the resultant stress can refer to the arrow pointing to S in FIG. 8.

[0077] Exemplarily, the electronic device can determine the temperature amplitude of the simulated tool based on a difference or a weighted difference between the first target temperature and the second target temperature. For example, the calculation method for the temperature amplitude can refer to the following formula (2):

$$[0078] \quad T = T_p - T_v; (2)$$

[0079] where, T represents the temperature amplitude, T_p represents the first target temperature, T_v represents the second target temperature.

[0080] In some embodiments, the above formula (2) is only an example and is not limited in practical applications. For example, the electronic device can also perform a weighting operation on a calculation result of the above formula (2) to obtain the temperature amplitude.

[0081] In this embodiment, since the first target temperature and the second target temperature can accurately characterize the highest and lowest temperatures endured by the simulated tool, determining the temperature amplitude based on the difference between the first target temperature and the second target temperature enables the temperature amplitude to accurately characterize the maximum temperature fluctuation amplitude of the simulated tool.

[0082] In some embodiments of the present application, the life coefficient corresponding to the simulated tool can characterize a basic life of the simulated tool when cutting the simulated workpiece

at the rotational speed in the machining parameters. It can be used to characterize an influence of the rotational speed of the simulated tool on the predicted service life.

[0083] In some embodiments of the present application, the preset material property parameters corresponding to the simulated tool can be used to characterize the influence of the material thermodynamic properties of the simulated tool on the predicted service life. The preset material property parameters corresponding to the simulated tool can be diverse parameter combinations.

[0084] In some embodiments, the preset material property parameters corresponding to the simulated tool may include a stress coefficient, a thermal shock strength coefficient, a first constant, and a second constant.

[0085] Among them, the stress coefficient can be regarded as a threshold or a critical value for the resultant stress, representing a maximum stress level that the simulated tool can withstand without affecting its service life. It can reflect the ability of the simulated tool to resist deformation, crack propagation, etc.

[0086] The thermal shock strength coefficient can be regarded as a threshold or a critical value for the temperature amplitude, representing a maximum temperature fluctuation amplitude corresponding to the simulated tool without affecting its service life. It can reflect an ability of the simulated tool to resist thermal shock, etc.

[0087] The first constant and the second constant can be greater than zero. The first constant can be used to control a change of the predicted service life of the simulated tool with the resultant stress.

The larger the first constant, the more sensitive the predicted service life is to changes in the resultant stress; the smaller the first constant, the less sensitive the predicted service life is to changes in the resultant stress. The second constant can be used to control a change of the predicted service life of the simulated tool with the temperature amplitude. The larger the second constant, the more sensitive the predicted service life is to changes in the temperature amplitude; the smaller the second constant, the less sensitive the predicted service life is to changes in the temperature amplitude.

[0088] In other embodiments, the preset material property parameters corresponding to the simulated tool may only include the aforementioned first constant and the aforementioned second constant. In some embodiments of the present application, in another embodiment, step S13, determining the predicted service life of the simulated tool according to the thermo-mechanical

coupling parameters, the life coefficient corresponding to the simulated tool, and the preset material property parameters, further includes: determining the life coefficient, the stress coefficient, the first constant, the thermal shock strength coefficient, and the second constant according to the material grade corresponding to the simulated tool and a preset matching table of material grades of simulated tools and performance constants. Specifically, a material grade of a simulated tool can be defined by tool material property parameters. That is, material grades of different simulated tools can be distinguished by different tool material property parameters, composition, and the like. Different tool material property parameters cause simulated tools to have different thermodynamic properties. Therefore, the values of the preset material property parameters corresponding to different material grades of simulated tools may differ.

[0089] For example, as shown in FIG. 11, it is a preset matching table of material grades of simulated tools and performance constants according to an embodiment of the present application. a rotational velocity coefficient represents the life coefficient. If the material grades of the simulated tools obtained by the electronic device include L108, K44UF, CTS24Z, F6, FIG. 11 shows the rotational velocity coefficient A, a stress coefficient B, a tool material first constant C, a thermal shock strength coefficient D, and a second constant E corresponding to each material grade corresponding to the simulated tool. Among them, the rotational velocity coefficient A corresponding to each material grade corresponding to the simulated tool is 506000; the stress coefficient B corresponding to the simulated tools having the material grades L108 and F6 is 1750, the stress coefficient B corresponding to the simulated tools having the material grades K44UF and CTS24Z is 1700; the tool material first constant C corresponding to the simulated tool having the material grade L108 is 0.09, the tool material first constant C corresponding to the simulated tools having the material grades K44UF, CTS24Z, and F6 is 0.06; the thermal shock strength coefficient D corresponding to the simulated tools having the material grades L108 and F6 is 130, the thermal shock strength coefficient D corresponding to the simulated tool having the material grade CTS24Z is 135, the thermal shock strength coefficient D corresponding to the simulated tool having the material grade K44UF is 140; the second constant E corresponding to the simulated tool having the material grade L108 is 0.16, the second constant E corresponding to the simulated tools having the material grades

CTS24Z and F6 is 0.13, and the second constant E corresponding to the simulated tool having the material grade K44UF is 0.14.

[0090] In some embodiments of the present application, the method for generating the life coefficient and preset material property parameters corresponding to the simulated tool can refer to the description of steps S41 to S46 below.

[0091] In some embodiments of the present application, the electronic device can directly determine the cutting cycle number as the predicted service life.

[0092] In other embodiments of the present application, the electronic device can convert the cutting cycle number into a cutting length according to a feed amount of the simulated tool, and use the cutting length as the predicted service life. The feed amount of the simulated tool can be obtained from the machining parameters in the simulation parameters. For example, the unit of cutting length can be meters or centimeters. The embodiments of the present application do not limit this.

[0093] In this embodiment, since the resultant stress can accurately characterize the comprehensive stress intensity of the simulated tool, the temperature amplitude can accurately characterize the maximum temperature fluctuation amplitude of the simulated tool, the life coefficient can be used to characterize the influence of the rotational speed of the simulated tool on the predicted service life, and the preset material property parameters can be used to characterize the influence of the thermodynamic properties of the simulated tool material on the predicted service life, determining the cutting cycle number of the simulated tool according to the resultant stress, temperature amplitude, life coefficient, and preset material property parameters can comprehensively consider the influences of multiple factors such as temperature, stress, rotational speed, and material thermodynamic properties, thereby enabling rapid and accurate determination of the predicted service life of the simulated tool. In this way, the prediction efficiency of tool service life can be improved.

[0094] The method for predicting tool service life provided by the embodiments of the present application can be effectively applied to a design and development stage of tools. In an early design stage, data of the resultant stress (S) and the tool temperature amplitude (T) of a designed tool is obtained through the simulation software, and the predicted service life is calculated based on the method for predicting tool service life provided by the embodiments of the present application. This not only improves a design efficiency but also quantifies an effect of design improvements without

conducting experiments. For example, as shown in FIG. 12, it is a comparison chart of predicted service lives corresponding to multiple tool design schemes according to an embodiment of the present application. According to FIG. 12, among four tool design schemes S11, A12, A13, and A14, the scheme A12 corresponds to a highest average cutting life, reaching 85 meters. Therefore, the scheme A12 is an optimal design among the four tool design schemes.

[0095] In the tool service life prediction solution provided by the embodiments of the present application, the simulated machining is performed on the simulated workpiece using the simulated tool, enabling the simulation data to prospectively reflect potential issues such as tool wear that may occur during actual cutting processes. Through the simulated machining, reliance on physical resources in tool development can be reduced, thereby lowering the development cycle and trial-and-error costs of tools. Feature analysis is performed on the simulation data to obtain thermo-mechanical coupling parameters, enabling these parameters to truly and accurately characterize the working condition where force and temperature jointly act on the simulated tool during the cutting process. According to the thermo-mechanical coupling parameters, the life coefficient corresponding to the simulated tool, and the preset material property parameters, the influences of multiple factors such as temperature, stress, rotational speed, and the thermodynamic properties of the simulated tool material can be comprehensively considered, thereby enabling rapid and accurate determination of the predicted service life. In this way, workpiece consumption can be avoided, resource waste can be reduced, and the prediction efficiency of tool life can be improved.

[0096] In some embodiments of the present application, if the preset material property parameters corresponding to the simulated tool include the stress coefficient, the thermal shock strength coefficient, the first constant, and the second constant, the electronic device can determine the cutting cycle number of the simulated tool as the predicted service life according to the resultant stress, the temperature amplitude, the life coefficient, and the aforementioned preset material property parameters. For example, as shown in FIG. 13, it is a flowchart of a method for determining the cutting cycle number according to an embodiment of the present application, including the following steps:

[0097] S21, a stress sensitivity parameter of the simulated tool is determined according to the first constant, the resultant stress, and the stress coefficient.

[0098] In some embodiments, the first constant can be set customarily, which is not limited in the present application. The first constant can be a value greater than zero, used to control the sensitivity of the predicted service life of the simulated tool to changes in the resultant stress. For example, the larger the first constant, the more sensitive the predicted service life is to changes in the resultant stress; the smaller the first constant, the less sensitive the predicted service life is to changes in the resultant stress.

[0099] In some embodiments, the stress coefficient can be regarded as a threshold or critical value for the resultant stress, representing the maximum stress level that the simulated tool can withstand without affecting its service life.

[00100] In some embodiments, the electronic device determining the stress sensitivity parameter of the simulated tool according to the first constant, the resultant stress, and the stress coefficient includes: S211: calculating a difference between the resultant stress and the stress coefficient; S212: performing an operation on the difference using the first constant to obtain the stress sensitivity parameter of the simulated tool. For example, the calculation method for the stress sensitivity parameter can refer to the following formula (3):

$$[00101] \quad M = (S - B)^{-C}; (3)$$

[00102] where, M represents a stress sensitivity coefficient (i.e., the stress sensitivity parameter), S represents the resultant stress, B represents the stress coefficient, C represents the first constant.

[00103] In this embodiment, since the stress coefficient represents the maximum stress level that the simulated tool can withstand without affecting its service life, the difference between the resultant stress and the stress coefficient can characterize the effective stress that actually affects the predicted service life of the simulated tool. Since the first constant is used to control the sensitivity of the predicted service life of the simulated tool to changes in the resultant stress, performing an operation on the difference between the resultant stress and the stress coefficient using the first constant to obtain the stress sensitivity coefficient of the simulated tool enables the stress sensitivity coefficient to accurately characterize the degree of influence of the effective resultant stress on the predicted service life of the simulated tool.

[00104] S22, a temperature sensitivity parameter of the simulated tool is determined according to the second constant, the temperature amplitude, and the thermal shock strength coefficient.

[00105] In some embodiments, the second constant can be set customarily, which is not limited in the present application. The second constant can be a value greater than zero, used to control the sensitivity of the predicted service life of the simulated tool to changes in the temperature amplitude. For example, the larger the second constant, the more sensitive the predicted service life is to changes in the temperature amplitude; the smaller the second constant, the less sensitive the predicted service life is to changes in the temperature amplitude.

[00106] In some embodiments, the thermal shock strength coefficient can be regarded as a threshold or a critical value for the temperature amplitude, representing a maximum temperature fluctuation amplitude corresponding to the simulated tool without affecting its service life.

[00107] In some embodiments, the electronic device determining the temperature sensitivity parameter of the simulated tool according to the second constant, the temperature amplitude, and the thermal shock strength coefficient includes: S221: calculating a difference between the temperature amplitude and the thermal shock strength coefficient; S222: performing an operation on the difference using the second constant to obtain the temperature sensitivity coefficient of the simulated tool. For example, the calculation method for the temperature sensitivity parameter can refer to the following formula (4):

$$[00108] \quad N = (T - D)^{-E}; (4)$$

[00109] where, N represents the temperature sensitivity coefficient (i.e., the temperature sensitivity parameter), T represents the temperature amplitude, D represents the thermal shock strength coefficient, E represents the second constant.

[00110] In this embodiment, since the thermal shock strength coefficient represents the maximum temperature fluctuation amplitude corresponding to the simulated tool without affecting its service life, the difference between the temperature amplitude and the thermal shock strength coefficient can characterize the effective temperature fluctuation amplitude that actually affects the predicted service life of the simulated tool. Since the second constant is used to control the sensitivity of the predicted service life of the simulated tool to changes in the temperature amplitude, performing an operation on the difference between the temperature amplitude and the thermal shock strength coefficient using the second constant to obtain the temperature sensitivity coefficient of the simulated tool enables the

temperature sensitivity coefficient to accurately characterize the degree of influence of the effective temperature fluctuation amplitude on the predicted service life of the simulated tool.

[00111] S23, the cutting cycle number is determined according to the life coefficient, the stress sensitivity parameter, and the temperature sensitivity parameter.

5 [00112] In some embodiments, the electronic device determines the cutting cycle number based on a product of the life coefficient, the stress sensitivity parameter, and the temperature sensitivity parameter.

[00113] For example, a calculation method for the cutting cycle number can refer to the following formula (5):

10 [00114] $N_f = A(S - B)^{-C}(T - D)^{-E}; (5)$

[00115] where, N_f represents the cutting cycle number, $(S - B)^{-C}$ represents the stress sensitivity coefficient, A represents the life coefficient, S represents the resultant stress, B represents the stress coefficient, C represents the first constant, $(T - D)^{-E}$ represents the temperature sensitivity coefficient, T represents the temperature amplitude, D represents the thermal shock strength coefficient, E represents the second constant.

[00116] In this embodiment, since the stress sensitivity coefficient can accurately characterize the degree of influence of the effective resultant stress on the predicted service life of the simulated tool, and the temperature sensitivity coefficient can characterize the degree of influence of the effective temperature fluctuation amplitude on the predicted service life of the simulated tool, determining the cutting cycle number according to the life coefficient, stress sensitivity parameter, and temperature sensitivity parameter can comprehensively consider the influences of multiple factors such as temperature fluctuation amplitude, resultant stress, and rotational speed, thereby enabling rapid and accurate determination of the cutting cycle number.

20 [00117] In other embodiments of the present application, if the preset material property parameters include the first constant and the second constant, the electronic device can determine the cutting cycle number of the simulated tool as the predicted service life according to the resultant stress, the temperature amplitude, the life coefficient, and the preset material property parameters. For example,

as shown in FIG. 14, it is another flowchart of a method for determining the cutting cycle number according to an embodiment of the present application, including the following steps:

[00118] S31, a stress sensitivity parameter of the simulated tool is determined according to the first constant and the resultant stress.

5 **[00119]** In some embodiments, the first constant can be set customarily, which is not limited in the present application. The first constant can be a value greater than zero, used to control the sensitivity of the predicted service life of the simulated tool to changes in the resultant stress. For example, the larger the first constant, the more sensitive the predicted service life is to changes in the resultant stress; the smaller the first constant, the less sensitive the predicted service life is to changes in the
10 resultant stress.

[00120] In some embodiments, the electronic device can perform an operation on the resultant stress using the first constant to obtain the stress sensitivity parameter of the simulated tool. For example, the calculation method for the stress sensitivity parameter can refer to the following formula (6):

[00121] $M = S^{-C}$; (6)

15 **[00122]** where, M represents the stress sensitivity coefficient, S represents the resultant stress, C represents the first constant.

[00123] In this embodiment, since the first constant is used to control the sensitivity of the predicted service life of the simulated tool to changes in the resultant stress, performing an operation on the difference between the resultant stress and the stress coefficient using the first constant to obtain the
20 stress sensitivity coefficient of the simulated tool enables the stress sensitivity coefficient to accurately characterize the degree of influence of the resultant stress on the predicted service life of the simulated tool.

[00124] S32, a temperature sensitivity parameter of the simulated tool is determined according to the second constant and the temperature amplitude.

25 **[00125]** In some embodiments, the second constant can be set customarily, which is not limited in the present application. The second constant can be a value greater than zero, used to control the sensitivity of the predicted service life of the simulated tool to changes in the temperature amplitude. For example, the larger the second constant, the more sensitive the predicted service life is to changes

in the temperature amplitude; the smaller the second constant, the less sensitive the predicted service life is to changes in the temperature amplitude.

[00126] In some embodiments, the electronic device can perform an operation on the temperature amplitude using the second constant to obtain the temperature sensitivity coefficient of the simulated tool. For example, the calculation method for the temperature sensitivity parameter can refer to the following formula (7):

$$[00127] \quad N = T^{-E}; (7)$$

[00128] where, N represents the temperature sensitivity coefficient, T represents the temperature amplitude, E represents the second constant.

[00129] In this embodiment, since the second constant is used to control the sensitivity of the predicted service life of the simulated tool to changes in the temperature amplitude, performing an operation on the difference between the temperature amplitude and the thermal shock strength coefficient using the second constant to obtain the temperature sensitivity coefficient of the simulated tool enables the temperature sensitivity coefficient to accurately characterize the degree of influence of the temperature fluctuation amplitude on the predicted service life of the simulated tool.

[00130] S33, the cutting cycle number is determined according to the life coefficient, the stress sensitivity parameter, and the temperature sensitivity parameter.

[00131] In some embodiments, the electronic device determines the cutting cycle number based on the product of the life coefficient, the stress sensitivity parameter, and the temperature sensitivity parameter.

[00132] For example, a calculation method for the cutting cycle number can refer to the following formula (8):

$$[00133] \quad N_f = AS^{-C}T^{-E}; (8)$$

[00134] where, N_f represents the cutting cycle number, A represents the life coefficient, S^{-C} represents the stress sensitivity coefficient, S represents the resultant stress, C represents the first constant, T^{-E} represents the temperature sensitivity coefficient, T represents the temperature amplitude, E represents the second constant.

[00135] In this embodiment, since the stress sensitivity coefficient can accurately characterize the degree of influence of the resultant stress on the predicted service life of the simulated tool, and the temperature sensitivity coefficient can characterize the degree of influence of the temperature fluctuation amplitude on the predicted service life of the simulated tool, determining the cutting cycle number according to the life coefficient, stress sensitivity parameter, and temperature sensitivity parameter can comprehensively consider the influences of multiple factors such as temperature fluctuation amplitude, resultant stress, and rotational speed, thereby enabling rapid determination of the cutting cycle number.

[00136] In some embodiments of the present application, the preset algorithm of the electronic device can determine the predicted service life of the simulated tool according to the thermo-mechanical coupling parameters, the life coefficient corresponding to the simulated tool, and the preset material property parameters. As shown in FIG. 15, it is a flowchart of a method for generating the life coefficient and the preset material property parameters corresponding to the simulated tool according to an embodiment of the present application, the preset algorithm performs the following steps:

[00137] S41, a preset initial life coefficient and initial material property parameters are obtained, and an actual service life of a real tool corresponding to the simulated tool is obtained.

[00138] In some embodiments, the initial life coefficient and the initial material property parameters can be set customarily, which is not limited in the present application. Among them, types of the initial material property parameters are the same as those of the preset material property parameters corresponding to the simulated tool. For example, if the preset material property parameters corresponding to the simulated tool include a total of four parameters: stress coefficient, thermal shock strength coefficient, first constant, and second constant, the initial material property parameters may also include a total of four parameters: stress coefficient, thermal shock strength coefficient, first constant, and second constant. Or, if the preset material property parameters corresponding to the simulated tool include a total of two parameters: first constant and second constant, the initial material property parameters may also include a total of two parameters: first constant and second constant.

[00139] In some embodiments, continuing from the aforementioned different material grades of simulated tools, correspondingly, different real tools can also be distinguished using different material grades. For example, L108, K44UF, CTS24Z, F6 can be four different material grades of real tools.

[00140] Among them, there can be multiple real tools of each material grade, and the multiple real tools of each material grade may have different tool design parameters. The actual service life of the real tool can be represented by the cutting cycle number. The aforementioned simulated tool and its related parameters are used to characterize the real tool and its related parameters.

[00141] In some embodiments, to ensure that the finally obtained life coefficient and preset material property parameters are suitable for different tool designs of the same material grade corresponding to the real tool, the electronic device can obtain actual service lives of multiple real tools of the same material grade but with different tool design parameters, in order to obtain the life coefficient and preset material property parameters corresponding to the simulated tool of this material grade at the rotational speed in the machining parameters.

[00142] S42, a predicted service life of the real tool is determined according to the initial life coefficient, the initial material property parameters, and thermo-mechanical coupling parameters corresponding to the real tool.

[00143] In some embodiments, the predicted service life of the real tool can also be represented by the cutting cycle number.

[00144] In some embodiments, for multiple real tools of the same material grade, the predicted service life of each real tool can be obtained according to the initial life coefficient, the initial material property parameters, and the thermo-mechanical coupling parameters corresponding to each real tool.

[00145] For example, as shown in FIG. 16, it is a schematic diagram of actual service life and predicted service life of real tools according to an embodiment of the present application. If the material grades of the simulated tools obtained by the electronic device include L108, K44UF, CTS24Z, F6, based on material grades L108, K44UF, CTS24Z, F6, the actual service life and predicted service life of two real tools for each material grade can be obtained as shown from FIG. 16. Among them, the two real tools of each material grade have different tool design parameters (i.e., the axial rake angle and the axial relief angle). The actual service life of each real tool of each

material grade is represented by the actual cutting cycle number, and its predicted service life is represented by the predicted cutting cycle number.

[00146] In some embodiments, the method for the electronic device to determine the predicted service life of the real tool according to the initial life coefficient, the initial material property parameters, and the thermo-mechanical coupling parameters corresponding to the real tool can refer to the description of step S13. The method for determining the thermo-mechanical coupling parameters corresponding to the real tool can refer to the descriptions of steps S11 to S12, which will not be repeated in the embodiments of the present application.

[00147] S43, a life error is determined based on the actual service life and the predicted service life of the real tool.

[00148] In some embodiments, the electronic device can determine the life error as a difference between the actual service life and the predicted service life of the real tool, or a weighted difference between the actual service life and the predicted service life of the real tool, or a product of a difference between the actual service life and the predicted service life of the real tool and a preset coefficient.

[00149] Exemplarily, a calculation method for the life error can refer to the following formula (9):

$$[00150] \quad SSE = \sum_{i=1}^n (N_{observerd} - N_{predicted})^2; \quad (9)$$

[00151] where, SSE represents the life error, n represents the number of real tools of each material grade, $N_{observerd}$ and $N_{predicted}$ represent the actual service life and predicted service life of each real tool of each material grade, respectively. For example, taking FIG. 16 as an example, for the real tools of material grades L108, K44UF, CTS24Z, F6 in FIG. 16, there are two real tools for each material grade, corresponding to different tool design parameters (e.g., the axial rake angle and the axial relief angle), so n can be 2. The above example is for illustration only and is not limited in practical applications.

[00152] In this embodiment, the life error can characterize a gap and a difference between the actual service life of the real tool and its predicted service life.

[00153] S44, whether the life error satisfies a preset condition is determined.

[00154] In some embodiments, the preset condition can be set customarily, which is not limited in the present application. For example, the preset condition can be that the life error no longer decreases, or the preset condition can be that the life error is within a preset numerical range.

[00155] In this embodiment, if the life error does not satisfy the preset condition, step S45 is executed; if the life error satisfies the preset condition, step S46 is executed.

[00156] S45, the life error is updated by adjusting the initial life coefficient and the initial material property parameters.

[00157] In some embodiments, after adjusting the initial life coefficient and the initial material property parameters, the electronic device can determine an updated predicted service life according to the adjusted initial life coefficient and the adjusted initial material property parameters, and determine the updated life error according to the updated predicted service life and the corresponding actual service life.

[00158] When adjusting the initial material property parameters, all parameters in the initial material property parameters can be adjusted, or only some parameters can be adjusted. For example, only the stress coefficient B and the tool material first constant C in the initial material property parameters can be adjusted, while keeping other parameters in the initial material property parameters unchanged; or only the stress coefficient B and the thermal shock strength coefficient D can be adjusted, while keeping other parameters in the initial material property parameters unchanged.

[00159] In some embodiments, the electronic device can use a fitting algorithm to adjust the life coefficient and the preset material property parameters, so that the life error can quickly converge and satisfy the preset condition. For example, the fitting algorithm can be a least squares method, a regression algorithm, etc. The embodiments of the present application do not limit the type of fitting algorithm.

[00160] In some embodiments, after updating the life error, the electronic device continues to execute step S44 to continue determining whether the updated life error satisfies the preset condition. The above calculation process for the updated life error may be executed multiple times until the updated life error satisfies the preset condition.

[00161] In this embodiment, by using the preset condition as a constraint on the life error, adjusting the life coefficient and the preset material property parameters, and determining the updated predicted

service life according to the adjusted life coefficient and preset material property parameters, the updated predicted service life can gradually approach the corresponding actual service life.

[00162] S46, the life coefficient corresponding to the life error satisfying the preset condition is determined as the life coefficient corresponding to the simulated tool, and the preset material property parameters corresponding to the life error satisfying the preset condition are determined as the preset material property parameters corresponding to the simulated tool.

[00163] In this embodiment, determining the life coefficient corresponding to the life error satisfying the preset condition as the life coefficient corresponding to the simulated tool, and determining the preset material property parameters corresponding to the life error satisfying the preset condition as the preset material property parameters corresponding to the simulated tool, can ensure that the life coefficient and preset material property parameters corresponding to the simulated tool match the characteristics of the corresponding real tool, thereby ensuring the accuracy of the predicted service life calculated using the life coefficient and preset material property parameters corresponding to the simulated tool. Since the life coefficient and preset material property parameters corresponding to the simulated tool are fitted from the actual service lives and predicted service lives of different tool designs of the same material grade corresponding to the real tool, the life coefficient and preset material property parameters corresponding to the simulated tool possess generalization capability for this type of tool and can be used to predict the service lives of different tool designs of the same material grade corresponding to the real tool.

[00164] For example, as shown in FIG. 17, it is a structural schematic diagram of an electronic device according to an embodiment of the present application. The electronic device 10 can be an electronic device such as a computer, a tablet computer, a laptop, a mobile phone, or a server. The embodiments of the present application do not impose any restrictions on the specific type of the electronic device.

[00165] In FIG. 17, the electronic device 10 may include a communication module 101, a storage device 102, a processor 103, an input/output (I/O) interface 104, and a bus 105. The processor 103 is coupled to the communication module 101, the storage device 102, and the input/output interface 104 respectively via the bus 105.

[00166] The communication module 101 may include a wired communication module and/or a wireless communication module. The wired communication module can provide one or more solutions for wired communication such as universal serial bus (USB), controller area network (CAN), etc. The wireless communication module can provide one or more solutions for wireless communication such as wireless fidelity (Wi-Fi), BLUETOOTH (BT), mobile communication network, frequency modulation (FM), near field communication (NFC), infrared (IR) technology, etc.

[00167] The storage device 102 may include one or more random access memories (RAM) and one or more non-volatile memories (NVM). The random access memory can be directly read from and written to by the processor 103, and can be used to store executable programs (e.g., machine instructions) or other running programs, and can also be used to store user and application data, etc. The random access memory may include static random access memory (SRAM), dynamic random access memory (DRAM), synchronous dynamic random access memory (SDRAM), double data rate synchronous dynamic random access memory (DDR SDRAM), etc.

[00168] The non-volatile memory can also store executable programs and store user and application data, etc., which can be loaded into the random access memory in advance for the processor 103 to directly read from and write to. The non-volatile memory may include disk storage devices, flash memory. For example, the flash memory can be Nand Flash.

[00169] The storage device 102 is used to store one or more computer programs. The one or more computer programs are configured to be executed by the processor 103. The one or more computer programs include a plurality of instructions. When the plurality of instructions are executed by the processor 103, the method for predicting tool service life executed on the electronic device 10 can be implemented.

[00170] In other embodiments, the electronic device 10 shown in FIG. 17 also includes an external memory interface for connecting an external memory to expand the storage capacity of the electronic device 10.

[00171] The processor 103 may include one or more processing units. For example, the processor 103 may include an application processor (AP), a modem processor, a graphics processing unit (GPU), an image signal processor (ISP), a controller, a video codec, a digital signal processor (DSP), and/or

a neural-network processing unit (NPU), etc. Different processing units can be independent devices or integrated in one or more processors.

[00172] The processor 103 provides computing and control capabilities. For example, the processor 103 is used to execute the computer program stored in the storage device 102 to implement the
5 aforementioned tool service life prediction method.

[00173] The input/output interface 104 is used to provide channels for user input or output. For example, the input/output interface 104 can be used to connect various input/output devices such as a mouse, keyboard, touch device, display screen, etc., allowing users to input information or visualize information.

10 **[00174]** The bus 105 is at least used to provide communication channels among the communication module 101, the storage device 102, the processor 103, and the input/output interface 104 in the electronic device 10.

[00175] It can be understood that the structure illustrated in the embodiments of the present application does not constitute a specific limitation on the electronic device 10. In other embodiments
15 of the present application, the electronic device 10 may include more or fewer components than shown, or combine some components, or split some components, or have different component arrangements. The components shown may be implemented in hardware, software, or a combination of software and hardware.

[00176] The embodiments of the present application also provide a computer-readable storage
20 medium. Computer programs are stored on the computer-readable storage medium, and the computer programs include program instructions. The method implemented when the program instructions are executed can refer to the methods in the various embodiments of the present application described above.

[00177] The computer-readable storage medium may be the internal memory of the electronic device
25 described in the above embodiments, such as the hard disk or memory of the electronic device. The computer-readable storage medium may also be an external storage device of the electronic device, such as a plug-in hard disk equipped on the electronic device, a Smart Media Card (SMC), a Secure Digital (SD) card, a Flash Card, etc.

[00178] In some embodiments, the computer-readable storage medium may include a storage program area and a storage data area. The storage program area may store an operating system, at least one application program required for functions, etc. The storage data area may store data created according to the use of the electronic device, etc.

5 **[00179]** In the several embodiments provided in the present application, it should be understood that the disclosed system, device, and method may be implemented in other ways. For example, the device embodiments described above are merely illustrative. For example, the division of modules is only a division of logical functions. In actual implementation, there may be other division methods.

[00180] The modules described as separate components may or may not be physically separated.

10 The components displayed as modules may or may not be physical units, that is, they may be located in one place or distributed across multiple network units. Some or all of the modules may be selected according to actual needs to achieve the objectives of the embodiments.

[00181] In addition, the functional modules in the various embodiments of the present application may be integrated into one processing unit, or each module may exist physically alone, or two or more modules may be integrated into one unit. The above integrated units can be implemented in the form of hardware or in the form of hardware plus software functional modules.

15 **[00182]** Therefore, from any point of view, the embodiments should be regarded as exemplary and not restrictive. The scope of the present application is defined by the appended claims rather than the above description. Therefore, it is intended that all changes falling within the meaning and scope of equivalent elements of the claims be included in the present application. Any reference signs in the claims should not be construed as limiting the involved claims.

20 **[00183]** Furthermore, the term "including" does not exclude other units or steps, and the singular does not exclude the plural. The multiple units or devices described in the present application can also be implemented by one unit or device through software or hardware. Terms such as "first" and "second" are used to denote names and do not indicate any specific order.

25 **[00184]** Finally, it should be noted that the above embodiments are only used to illustrate the technical solutions of the present application and not to limit them. Although the present application has been described in detail with reference to preferred embodiments, those skilled in the art should understand that they can modify or equivalently replace the technical solutions of the present

application without departing from the spirit and scope of the technical solutions of the present application.

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CLAIMS

What is claimed is:

- 5 1. A method for predicting tool service life, comprising:

obtaining simulation data by performing simulated machining on a simulated workpiece using simulation parameters of a simulated tool;

obtaining thermo-mechanical coupling parameters corresponding to the simulated tool by performing feature analysis on the simulation data; and

10 determining a predicted service life of the simulated tool according to the thermo-mechanical coupling parameters, a life coefficient corresponding to the simulated tool, and preset material property parameters.
2. The method for predicting tool service life according to claim 1, wherein the thermo-mechanical coupling parameters comprise a target shear stress and target temperatures, and the obtaining thermo-
15 mechanical coupling parameters corresponding to the simulated tool by performing feature analysis on the simulation data comprises:

determining, based on the simulation data, shear stresses generated by cutting forces applied by a cutting flute of the simulated tool to the simulated workpiece;

determining the target shear stress corresponding to the simulated tool based on the shear stresses
20 corresponding to the cutting flute; and

determining the target temperatures corresponding to the simulated tool based on temperatures of the cutting flute.
3. The method for predicting tool service life according to claim 2, wherein the thermo-mechanical coupling parameters further comprise a target contact pressure, and the obtaining thermo-mechanical
25 coupling parameters corresponding to the simulated tool by performing feature analysis on the

simulation data further comprises:

determining, based on the simulation data, contact pressures between the cutting flute and the simulated workpiece; and

determining the target contact pressure corresponding to the simulated tool based on the contact pressures corresponding to the cutting flute.

4. The method for predicting tool service life according to claim 3, wherein the target temperatures comprise a first target temperature and a second target temperature, and the determining the predicted service life of the simulated tool according to the thermo-mechanical coupling parameters, the life coefficient corresponding to the simulated tool, and preset material property parameters comprises:

determining a resultant stress of the simulated tool on the simulated workpiece according to the target shear stress and the target contact pressures;

determining a temperature amplitude of the simulated tool according to the first target temperature and the second target temperature;

determining a cutting cycle number of the simulated tool according to the resultant stress, the temperature amplitude, the life coefficient, and the preset material property parameters; and

determining the predicted service life according to the cutting cycle number.

5. The method for predicting tool service life according to claim 4, wherein the preset material property parameters comprise a first constant and a second constant, and the determining the cutting cycle number of the simulated tool according to the resultant stress, the temperature amplitude, the life coefficient, and the preset material property parameters comprises:

determining a stress sensitivity parameter of the simulated tool according to the first constant and the resultant stress;

determining a temperature sensitivity parameter of the simulated tool according to the second constant and the temperature amplitude; and

determining the cutting cycle number according to the life coefficient, the stress sensitivity parameter,

and the temperature sensitivity parameter.

6. The method for predicting tool service life according to claim 4, wherein the preset material property parameters comprise a stress coefficient, a thermal shock strength coefficient, a first constant, and a second constant, and the determining the cutting cycle number of the simulated tool according to the resultant stress, the temperature amplitude, the life coefficient, and the preset material property parameters comprises:

determining a stress sensitivity parameter of the simulated tool according to the first constant, the resultant stress, and the stress coefficient;

determining a temperature sensitivity parameter of the simulated tool according to the second constant, the temperature amplitude, and the thermal shock strength coefficient; and

determining the cutting cycle number according to the life coefficient, the stress sensitivity parameter, and the temperature sensitivity parameter.

7. The method for predicting tool service life according to claim 1, wherein the obtaining simulation data by performing simulated machining on the simulated workpiece using simulation parameters of the simulated tool comprises:

obtaining the simulated tool and the simulation parameters of the simulated tool;

determining the simulated workpiece according to the simulated tool;

obtaining simulation result data by performing a simulation operation on the simulated workpiece based on the simulation parameters and the simulated tool;

obtaining analysis result data by performing simulation analysis on the simulation result data; and
obtain the simulation data by performing noise filtering processing on the analysis result data.

8. The method for predicting tool service life according to claim 1, further comprising:

obtaining a preset initial life coefficient and initial material property parameters, and obtaining an actual service life of a real tool corresponding to the simulated tool;

determining a predicted service life of the real tool according to the initial life coefficient, the initial material property parameters, and thermo-mechanical coupling parameters corresponding to the real tool; and

determining a life error based on the actual service life and the predicted service life of the real tool.

5 9. The method for predicting tool service life according to claim 8, further comprising:

updating the life error by adjusting the initial life coefficient and the initial material property parameters, until the life error satisfies a preset condition;

determining a life coefficient corresponding to the life error satisfying the preset condition as the life coefficient corresponding to the simulated tool; and

10 determining initial material property parameters corresponding to the life error satisfying the preset condition as the preset material property parameters corresponding to the simulated tool.

10. An electronic device, comprising:

a storage device storing at least one instruction; and

a processor executing the at least one instruction to implement the method for predicting tool service

15 life according to any one of claims 1 to 9.

11. A computer-readable storage medium, wherein computer-readable instructions are stored in the computer-readable storage medium, and the computer-readable instructions are executed by a processor of an electronic device to implement the method for predicting tool service life according to any one of claims 1 to 9.

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