Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).
TECHNICAL FIELD

[0001] This disclosure generally relates to automatically controlled machine tools, and deals more particularly with a system and method for automatically controlling the feed rate of an ultrasonic knife used to cut material, especially multiple plies of composite material.

BACKGROUND

[0002] Ultrasonic cutters are currently used to cut sheet and other materials using a knife powered by an ultrasonic transducer. One application of ultrasonic cutters may be found in the field of composite materials where multiple layers or plies of uncured composite material forming a layup may be simultaneously cut to a desired shape using an ultrasonically powered knife. In some cases, the ultrasonic cutter may be mounted on a CNC (computer numerical control) controlled machine tool that includes an automatic tape laying head capable of laying down and cutting multiple, overlapping layers of composite tape.

[0003] A sheet cutting machine in which a guidance system moves a blade across a work surface is described in EP-A-0,351,223. The blade height is adjusted in accordance with stored data of irregularities of the guidance system and work surface relative to each other. The machine is also operable in a mapping mode in which the blade is replaced by a sensor which is scanned over the work surface, and the sensor output data is stored in the memory.

[0004] The process of cutting the composite material is relatively slow in comparison to the rate at which the tape may be applied. The speed of the cutting process may be determined, in part, by the maximum feed rate of the knife through the material and depth of cut. Thicker parts require multiple passes in order to fully cut through all plies of material, with each pass of the cutter being deeper than the last. Currently, an open-loop ply cutting process is used that requires constant operator monitoring and manual adjustment of the feed rate override dial, which may result in suboptimal cutting operations, including suboptimal cutting speed. Knife feed rates are manually adjusted by an operator during cutting based on observed fluctuations in the ultrasonic power meter. Perceived “safe” power levels are maintained by overriding the programmed feed rate, which may result in cutting times that are less than optimal. Moreover, operators may not be able to detect transient or peak load conditions and react quickly enough to decrease feed rates before possible knife malfunction occurs. In some cases, excessive feed rates may also result in suboptimal cutter operation.

[0005] The prior art includes an adaptive control apparatus having a load detector that detects a load which acts on a cutting tool during a machining operation of a workpiece. Such adaptive control techniques have not, however, been applied to CNC ultrasonic cutters used to cut multiple plies of composite material.

SUMMARY

[0006] Accordingly, there is a need for a method and system for cutting plies of composite material using a CNC controlled ultrasonic cutter that employs adaptive control in order to optimize feed rate and/or reduce knife damage and cutting errors.

[0007] A method and system are provided for cutting composite plies using an automatically controlled ultrasonic cutter and adaptive control to optimize the feed rate. Feed rates are adjusted to optimal levels based on knife condition in order to maximize productivity. A parameter related to cutting, such as knife load is measured and is used to produce a feedback signal that is used to adjust the feed rate without human intervention. The feed rate is quickly adjusted when knife and/or ply material conditions change, such as knife sharpness, number of plies, depth of cut, angle of cut in relation to ply fiber direction, thickness of the plies, tackiness of material, compaction force used during layup, and ply toughness, or unpredicted events occur such as knife breakage. Automatic adjustment of feed rates result in a high average feed rate to maximize productivity, while relieving the operator of the need to constantly monitoring knife load and manually overriding the feed rate. Finally, the amount of programming required to control the cutter may be reduced, because a relatively high constant feed rate can be programmed and then adaptively adjusted to actual cutting conditions.

[0008] According to a first aspect of the invention a method is provided for cutting composite plies, comprising: feeding an ultrasonic knife through the plies; measuring at least one parameter selected from a power load on an ultrasonic transducer used to drive the knife, a deflection of the knife and a temperature of the knife as the knife cuts the plies; and, generating a feed rate signal to optimize the feed rate of the knife based on the measured parameter. The measured parameter may comprise one of the power load delivered to an ultrasonic transducer used to drive the knife, a deflection of the knife and/or the temperature of the knife. The method may further comprise feeding back the measured parameter to a controller and using the controller to generate the feed rate signal. The method may also include comparing the value of the measured parameter with a pre-selected value, and generating the feed rate signal based on the results of the comparison.

[0009] According to a second aspect of the invention a system is provided for cutting material, comprising: an ultrasonic powered knife for cutting the material; control means for controlling the rate at which the knife is fed through the material; sensing means for sensing at least one parameter selected from a power load on an ultrasonic transducer used to drive the knife, a deflection of
the knife and a temperature of the knife; and, a set of programmed instructions used by the control means for optimizing the feed rate of the knife based on the sensed parameter. The sensing means may include a transducer for converting side loads on the knife into an electrical signal representing the measured parameter. The sensing means may also include a sensor for sensing ultrasonic power delivered to the knife. The control means may include a controller for generating a commanded feed rate control signal based on the sensed side loads on the knife and ultrasonic power load delivered to the knife. The control means may include a first controller for controlling the movement of the knife, and, a second controller for generating a control signal used by the first controller to optimize the feed rate of the knife.

[0010] The disclosed embodiments satisfy the need for a method and system for cutting composite plies using adaptive control to optimize feed rate, reduce machine downtime and minimize operator intervention and oversight.

[0011] Other features, benefits and advantages of the disclosed embodiments will become apparent from the following description of embodiments, when viewed in accordance with the attached drawings and appended claims.

BRIEF DESCRIPTION OF THE ILLUSTRATIONS

[0012] FIG. 1 is a combined block and diagrammatic illustration of a system for cutting composite plies.
FIG. 2 is a side view of an ultrasonic cutter;
FIG. 3 is a block diagram broadly illustrating the steps of a method for cutting composite plies.
FIG. 4 is a more detailed flow diagram illustrating the method for cutting composite plies using adaptive control.
FIG. 5 is a flow diagram of aircraft production and service methodology.
FIG. 6 is a block diagram of an aircraft.

DETAILED DESCRIPTION

[0013] Reference is first made to FIG. 1 which illustrates a system 10 for cutting multiple plies 14 of a composite material using an automatically controlled, ultrasonic cutter generally indicated by the numeral 12. Although multiple plies 14 of composite material are illustrated in connection with the disclosed embodiments, it is to be understood that a single ply of composite material may be cut, as well as materials other than composite materials. The plies may be green (uncured) where the cutter 12 is used to cut shapes of plies that are used to form a layup during the initial fabrication of a structure. However, embodiments of the disclosure may also be used to cut partially or fully cured plies after a structure has been fabricated, as during repairs on a composite aircraft assembly or subassembly, where a section of the assembly/subassembly must be cut out.

[0014] The ultrasonic cutter 12 is mounted on a toolhead 16 that may be moved along multiple machine axes 17 in order to follow a preprogrammed cutting path through the plies 14. Referring now also to FIG. 2, the ultrasonic cutter 12 includes a cutting knife 22 driven by an ultrasonic transducer 18 which is attached to the toolhead 16. The knife 22 reciprocates in the direction of the arrow 23 at ultrasonic frequencies. A forward cutting edge 25 on the knife 22 is fed into the plies 14 in the direction of feed 27 at a feed rate Fcurrent indicated by the numeral 31, such that the plane of the knife 22 is maintained generally perpendicular to the planes of the plies 14. The knife 22 may be attached by a releasable connection 21 from an ultrasonic power generator 24. The transducer 18 then converts the energy into vibrations of very low amplitude. The amplitude of the vibrations can be amplified by a booster 19 before delivery to the horn 20 and knife 22. A closed-loop control maintains the amplitude by delivering more power to the transducer 18. Excessively high power levels may automatically shut down the cutting unit 12.

[0015] The movement (feed) and operation of the ultrasonic cutter 12 are controlled by an automatic controller 26 which may comprise for example, without limitation, a CNC (computer numerical control) controller that employs an NC (numerical control) program 28. The automatic controller 26 is programmed to control the movement of the ultrasonic cutter 12 in a path through the multiple plies 14 at a predetermined feed rate 31 represented by a commanded feed rate signal 30 issued by the automatic controller 26 to the ultrasonic cutter 12.

[0016] The value of the commanded feed rate signal 30 and thus, the actual feed rate 31 of the cutter 12, is the product of the programmed feed rate established by the NC program 28, and a "feed rate override" value. For example, if the programmed feed rate is 10 inch per minute (25.4cm/minute), and the feed rate override value is 80%, the actual feed rate 31 of the cutter 12 will be 10 x 80% = 8 inch per minute (20.32cm/minute). As will be discussed in more detail below, embodiments of the disclosure optimize the actual feed rate 31 of the cutter 12 using feedback signals to adjust the feed rate override value. As used herein, the terms "optimize" and "optimizing" the feed rate may include increasing or decreasing the feed rate, or stopping knife feed, as when the knife breaks or may be about to break.

[0017] The amount of ultrasonic power, i.e. power load delivered to the transducer 18 by the ultrasonic power generator 24 is monitored by the automatic controller 26. Generally, the ultrasonic power load required to drive the transducer 18 in order to obtain satisfactory ply cutting is proportional to the load imposed on the knife 22 by cutting of the plies 14; a greater number of plies 14 cre-
ates a higher load on the knife 22 that requires higher levels of power to drive the transducer 18. As stated previously, knife 22 and/or material conditions can also significantly affect power load levels.

[0018] In accordance with the disclosed embodiments, the rate at which the ultrasonic cutter 12 is fed through the plies 14 may be adjusted and optimized using feedback signals 42 that are used by the automatic controller 26 to adjust the commanded feed rate 30. The feedback signals 42 are generated using one or more measured parameters related to the operation of the knife 22. As will be described below, the ultrasonic power load delivered to the transducer 18 by the power generator 24 as well as a side load on the knife 22 may be used as measured parameters to generate the feedback signals 42. However, the use of other parameters as feedback signals may also be possible, such as without limitation, the temperature of the knife 22 and/or deflection of the knife 22.

[0019] The side load imposed on the knife 22 by the multiple plies 14 as they are cut is measured by a sensor 32 which may comprise, for example, and without limitation, a strain gauge or similar strain or force measuring device which converts the measured side load into a sensor signal 34 that is delivered to a signal conditioner 40. An ultrasonic power signal 38, proportional to the electrical power load delivered to the transducer 18, is also sent to the signal conditioner 40. The signal conditioner 40 may comprise any of various well known circuits, including for example and without limitation, amplifiers (not shown) and optical isolators (not shown) which function to condition signals 34, 38, so as to render them compatible for processing by an adaptive control computer 44.

[0020] The feedback signals 42 are combined and processed by the computer 44. The computer 44 also communicates with the automatic controller 26 to obtain the current feed rate override setting 41 through an I/O (input/output) interface 43. Stored setup parameters 46 for the computer 44 may be established through a user interface 48 in order to control the particular manner in which the computer 44 adjusts the current feed rate 31 override setting 41 based on the values of the feedback signals 42. Based on the setup parameters 46, instructions 47 from the executed NC program 28, the values of the current feed rate override setting 41 acquired from the automatic controller 26 and the feedback signals 42, computer 44 issues an optimized feed rate override signal 45 to the automatic controller 26 which results in an adjustment of the commanded feed rate 30 in order to optimize the feed rate 31 of the ultrasonic cutter 12.

[0021] In some applications, it may not be uncommon for the knife 22 to "stray" during the cutting process, particularly where the knife 22 has relatively low stiffness to resist side loading. Knife straying may increase side loads on the knife 22 and/or result in higher power consumption by the cutter 12. Similarly, when the knife 22 becomes dull and/or the material plies 14 become thicker or more numerous, the power consumed by the transducer 18 increases accordingly. In accordance with the disclosed embodiments, as this power consumption increases, the adaptive control computer 44 reduces the feed rate override value in order to maintain a predefined level of power consumption.

[0022] As discussed above, the disclosed embodiments adjust the feed rate 31 of the ultrasonic cutter 12 based on the condition of the knife 22 in order to maximize productivity. The side loads imposed on the knife are measured and the feed rate 31 is adjusted accordingly without the need for human intervention. In the event that an unpredicted event, such as a sudden increase of the cutting load at the knife 22, the adaptive control method of the embodiments may quickly terminate the cutting process in order to reduce the possibility of breakage of the knife 22 and/or damage to the part.

[0023] Attention is now directed to FIG. 3 which broadly depicts the overall steps of one method embodiment. Beginning at step 50, an initial feed rate Fcurrent 31 is selected, which may form part of the NC control program 28 (FIG. 1). Next, at step 52, the knife 22 is automatically fed through the multiple plies 14 at the initial feed rate Fcurrent 31. As the plies 14 are cut, one or more parameters are measured at step 54 which are related to operation of the knife 22. As previously mentioned, in the illustrated embodiment, the measured parameters comprise the power Pi used to drive the knife 22, and the side load Bi on the knife 22 resulting from the resistance presented by the plies 14. Finally, at 56, the initial feed rate 31 is changed to a new feed rate Fnew based on the measured parameters.

[0024] Details of another method embodiment are illustrated in FIG. 4. At 60, power and side load setup parameters are retrieved from a setup parameter file 58 and read into a memory (not shown). At 64, the requirements for controlling the knife 22 during the current cutting sequence are derived from the NC program 28. Using the setup parameters stored in memory at 60 and the requirements of the current cutting sequence derived at 64, a power limit (Pmi) and a radial load limit (Bmi) are each calculated for the current cutting sequence as shown at step 66. The side load sensor signal and the ultrasonic power signal 34, 38 respectively are received at 68. At step 70, a determination is made as to whether either Pi is greater than Pmi or Bi is greater than Bmi. If either of the calculated limits Pi, Bi exceeds the corresponding measured values Pmi, Bmi, then at step 80, a maximum load ratio Rmi is determined by the highest value between the two ratios Pi/Pmi and Bi/Bmi. Thus, Rmi can be described as follows:

\[ Rmi = \text{Max} \{\frac{Pi}{Pmi}, \frac{Bi}{Bmi}\} \]

[0025] If neither Pi nor Bi are determined to exceed the calculated limits at step 70, then the process moves to step 72 where a decision is made of whether to allow...
a new feed rate override value FROV Fi greater than the current feed rate Fi. If the decision is negative at 72, then the new feed rate override value FROV Fj is set equal to the current feed rate override Fi at step 74 and the resulting value is delivered to a summing point 84. However, if it is determined that the new feed rate override Fj may exceed the current feed rate Fi at 72, then the process proceeds to step 80 where the maximum load ratio Rmi is calculated as previously described. At step 82, a new feed rate override value Fj is calculated as follows:

\[ F_j = \frac{F_i}{R_{mi}} \]

[0026] The values of Fi used at 74 and 82 are received from a feed rate override switch 76 located forming part of the automatic controller 26, which loads the current value of feed rate override Fi at 78. The new feed rate override Fj obtained at either step 74 or step 82 is delivered to the summing point 84. The new feed rate override Fj having been established, its value is sent to the automatic controller 26 as shown at the step 88, and the next set of sensor inputs are read at 86.

[0027] Embodiments of the disclosure may find use in a variety of potential applications, particularly in the transportation industry, including for example, aerospace, marine and automotive applications. Thus, referring now to FIGS. 5 and 6, embodiments of the disclosure may be used in the context of an aircraft manufacturing and service method 90 as shown in Figure 5 and an aircraft 92 as shown in Figure 6. Aircraft applications of the disclosed embodiments may include, for example, without limitation, composite stiffened members such as fuselage skins, wing skins, control surfaces, hatches, floor panels, door panels, access panels and empennages, to name a few. During pre-production, exemplary method 90 may include specification and design 94 of the aircraft 92 and material procurement 96. During production, component and subassembly manufacturing 98 and system integration 100 of the aircraft 92 takes place. Thereafter, the aircraft 92 may go through certification and delivery 102 in order to be placed in service 104. While in service by a customer, the aircraft 92 is scheduled for routine maintenance and service 106 (which may also include modification, reconfiguration, refurbishment, and so on).

[0028] Each of the processes of method 90 may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

[0029] As shown in FIG. 6, the aircraft 92 produced by exemplary method 90 may include an airframe 108 with a plurality of systems 110 and an interior 112. Examples of high-level systems 110 include one or more of a propulsion system 114, an electrical system 116, a hydraulic system 118, and an environmental system 120. Any number of other systems may be included. Although an aerospace example is shown, the principles of the disclosure may be applied to other industries, such as the marine and automotive industries.

[0030] Systems and methods embodied herein may be employed during any one or more of the stages of the production and service method 90. For example, components or subassemblies corresponding to production process 90 may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft 92 is in service. Also, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during the production stages 98 and 100, for example, by substantially expediting assembly of or reducing the cost of an aircraft 92. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof may be utilized while the aircraft 92 is in service, for example and without limitation, to maintenance and service 106.

[0031] Although the embodiments of this disclosure have been described with respect to certain exemplary embodiments, it is to be understood that the specific embodiments are for purposes of illustration and not limitation, as other variations, within the scope of the claims, will occur to those of skill in the art.

Claims

1. A method of cutting composite plies, comprising:

   feeding an ultrasonic knife (22) through the plies (14);
   measuring at least one parameter selected from a power load on an ultrasonic transducer used to drive the knife, a deflection of the knife and a temperature of the knife as the knife (22) cuts the plies (14); and,
   generating a feed rate signal to optimize the feed rate of the knife (22) based on the measured parameter.

2. The method of claim 1, wherein:

   feeding the knife (22) includes controlling the movement of the knife (22) using an automatic controller (26), and,
   generating the feed rate signal is performed using the automatic controller (26).

3. The method of claim 1, further comprising:

   feeding back the measured parameter to a controller (44), and
4. The method of claim 1, further comprising:

comparing the value of the measured parameter with a preselected value, and

wherein generating the feed rate signal is based on the results of the comparison.

5. A system for cutting material, comprising:

an ultrasonic powered knife (22) for cutting the material;

control means (26,44) for controlling the rate at which the knife (22) is fed through the material;

sensing means (32) for sensing at least one parameter selected from a power load on an ultrasonic transducer used to drive the knife, a deflection of the knife and a temperature of the knife (22); and,

a set of programmed instructions used by the control means (26,44) for optimizing the feed rate of the knife (22) based on the sensed parameter.

6. The system of claim 5, wherein the sensing means (32) includes:

a first sensor for sensing the ultrasonic power load delivered to the knife (22), and

a second sensor (32) for sensing side loads on the knife (22).

7. The system of claim 6, wherein the control means (26,44) includes a controller for generating a commanded feedrate control signal based on the sensed side loads on the knife (22) and ultrasonic power delivered to the knife (22).

8. The system of claim 5, wherein the control means (26,44) includes:

a first controller (26) for controlling the movement of the knife (22), and,

a second controller (44) for generating a control signal used by the first controller (26) to optimize the feed rate of the knife (22).

Patentansprüche

1. Verfahren zum Schneiden von Verbundlagen, umfassend:

führen eines Ultraschallmessers (22) durch die Lagen (14);

Messen von zumindest einem Parameter, der

unter einer Leistungsaufnahme eines zum Betrieb des Messers verwendeten Ultraschallwandlers, einer Auslenkung des Messers und einer Temperatur des Messers bei einem Schneiden des Messers (22) durch die Lagen (14) ausgewählt ist;

Erzeugen eines Vorschubsignals zum Optimieren des Vorschubs des Messers (22) auf Basis des gemessenen Parameters.

2. Verfahren nach Anspruch 1, worin:

das Führen des Messers (22) ein Steuern der Bewegung des Messers (22) unter Verwendung einer automatischen Steuerung (26) umfasst, und

das Erzeugen des Vorschubsignals unter Verwendung der automatischen Steuerung (26) erfolgt.

3. Verfahren nach Anspruch 1, das ferner umfasst:

Rückführen des gemessenen Parameters an eine Steuerung (44) und

worin das Erzeugen des Vorschubsignals durch die Steuerung (44) erfolgt.

4. Verfahren nach Anspruch 1, das ferner umfasst:

Vergleichen des Werts des gemessenen Parameters mit einem vorgewählten Wert, und

worin das Erzeugen des Vorschubsignals auf den Ergebnissen des Vergleichs basiert.

5. System zum Schneiden von Material, das Folgendes umfasst:

ein ultraschallbetriebenes Messer (22) zum Schneiden des Materials;

eine Steuereinrichtung (26, 44) zum Steuern der Geschwindigkeit, mit der das Messer (22) durch das Material geführt wird;

eine Sensoreinrichtung (32) zum Erfassen von zumindest einem Parameter, der unter einer Leistungsaufnahme eines zum Betrieb des Messers verwendeten Ultraschallwandlers, einer Auslenkung des Messers und einer Temperatur des Messers (22) ausgewählt ist; und

einen Satz programmiert Anweisungen zur Verwendung durch die Steuereinrichtung (26, 44) für eine Optimierung des Vorschubs des Messers (22) auf Basis der erfassten Parameter.

6. System nach Anspruch 5, wobei die Sensoreinrichtung (32) Folgendes umfasst:

einen ersten Sensor zum Erfassen der dem
Messer (22) zugeführten Ultraschallleistung, und
einen zweiten Sensor (32) zum Erfassen von
seitlichen Belastungen des Messers (22).

7. System nach Anspruch 6, wobei die Steuereinrich-
tung (26, 44) eine Steuerung zum Erzeugen eines
angewiesenen Vorschubsteuersignals auf Basis der
erfassten seitlichen Belastungen des Messers (22)
und einer dem Messer (22) zugeführten Ultraschall-
leistung umfasst.

8. System nach Anspruch 6, wobei die Steuereinrich-
tung (26, 44) Folgendes umfasst:
eine erste Steuerung (26) zum Steuern der Be-
wegung des Messers (22), und
eine zweite Steuerung (44) zum Erzeugung ei-
nes Steuersignals, das von der ersten Steue-
 rung (26) zum Optimieren des Vorschubs des
Messers (22) verwendet wird.

Revendications

1. Procédé de coupe de plis composites, comprenant:
amener un couteau ultrasonique (22) à travers
les plis (14) ;
mesurer au moins un paramètre sélectionné
parmi une charge de puissance sur un transduc-
teur ultrasonique utilisé pour entraîner le cou-
teau, une déviation du couteau et une tempéra-
ture du couteau lorsque le couteau (22) coupe
les plis (14) ; et
produire un signal de vitesse d’avancement
pour optimiser la vitesse d’avancement du cou-
teau (22) sur la base du paramètre mesuré.

2. Procédé selon la revendication 1, dans lequel:
l’aménée du couteau (22) comprend la com-
mande du mouvement du couteau (22) en utili-
sant un dispositif de commande automatique
(26) et
la génération du signal de la vitesse d’avance-
ment est exécutée en utilisant le dispositif de 
commande automatique (26).

3. Procédé selon la revendication 1, comprenant en
outre:
ramener le paramètre mesuré à un dispositif de
commande (44) et
où la production du signal de la vitesse d’avan-
cement est exécutée par le dispositif de com-
 mande (44).

4. Procédé selon la revendication 1, comprenant en
outre:
comparer la valeur du paramètre mesuré avec
une valeur présélectionnée, et
où la production du signal de la vitesse d’avan-
cement est basée sur les résultats de la com-
 paraison.

5. Système pour couper du matériau, comprenant:
un couteau actionné de manière ultrasonique
(22) pour couper le matériau;
um moyen de commande (26, 44) pour comman-
der la vitesse à laquelle le couteau (22) passe
t à travers le matériau;
um moyen de détection (32) pour détecter au
moins un paramètre sélectionné parmi une
charge de puissance sur un transducteur ultra-
sonique utilisé pour entraîner le couteau, une
déviation du couteau et une température du cou-
teau (22); et
un ensemble d’instructions programmées utili-
sées par le moyen de commande (26, 44) pour
optimiser la vitesse d’avancement du couteau
(22) sur la base du paramètre détecté.

6. Système selon la revendication 5, dans lequel le
moyen de détection (32) comprend:
un premier capteur pour détecter la charge de
puissance ultrasonique délivrée au couteau
(22), et
un deuxième capteur (32) pour détecter des
charges latérales sur le couteau (22).

7. Système selon la revendication 6, dans lequel le
moyen de commande (26, 44) comprend un dispo-
sitif de commande pour produire un signal de com-
mande de vitesse d’avancement commandée sur la
base des charges latérales détectées sur le couteau
(22) et la puissance ultrasonique délivrée au couteau
(22).

8. Système selon la revendication 5, dans lequel le
moyen de commande (26, 44) comprend:
un premier dispositif de commande (26) pour
commander le mouvement du couteau (22), et
un deuxième dispositif de commande (44) pour
produire un signal de commande utilisé par le
premier dispositif de commande (26) pour opti-
miser la vitesse d’avancement du couteau (22).
FIG. 2

SELECT INITIAL FEED RATE (Fcurrent) 50

FEED KNIFE THROUGH PILES AT INITIAL FEED RATE (Fcurrent) 52

MEASURE PARAMETER(S) (P1, B1) 54

CHANGE FEED RATE TO NEW RATE (Fnew) BASED ON MEASURED PARAMETER(S) 56

FIG. 3
REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description