United States Patent [19]

Hahn et al.

[11] **3,913,277**

[45] **Oct. 21, 1975**

[54] **GRINDING MACHINE**

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[73] Assignee: **Cincinnati Milacron-Heald Corporation**, Worcester, Mass.

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Related U.S. Application Data

[63] Continuation of Ser. No. 285,628, Sept. 1, 1972, which is a continuation of Ser. No. 94,389, Dec. 2, 1970, abandoned.

[52] **U.S. Cl.** **51/165.77**; 51/134.5; 51/165.87; 51/165.92

[51] **Int. Cl.²** **B24B 49/10**

[58] **Field of Search** ..... 51/165 R, 165.71, 165.77, 51/165.8, 165.82–165.86, 165.9–165.92, 139, 134.5

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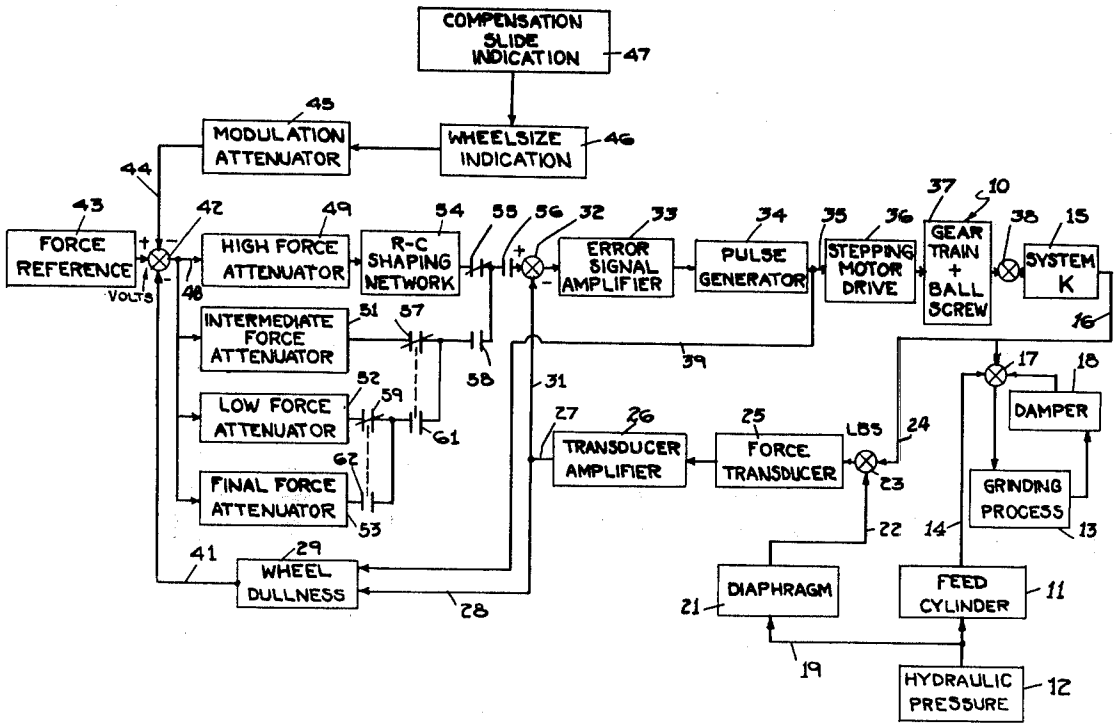
[57] **ABSTRACT**

This invention relates to a grinding machine making use of a closed-loop control of grinding force. In the control system, data on wheel size and wheel dullness are used to continuously determine grinding rate.

1 Claim, 2 Drawing Figures



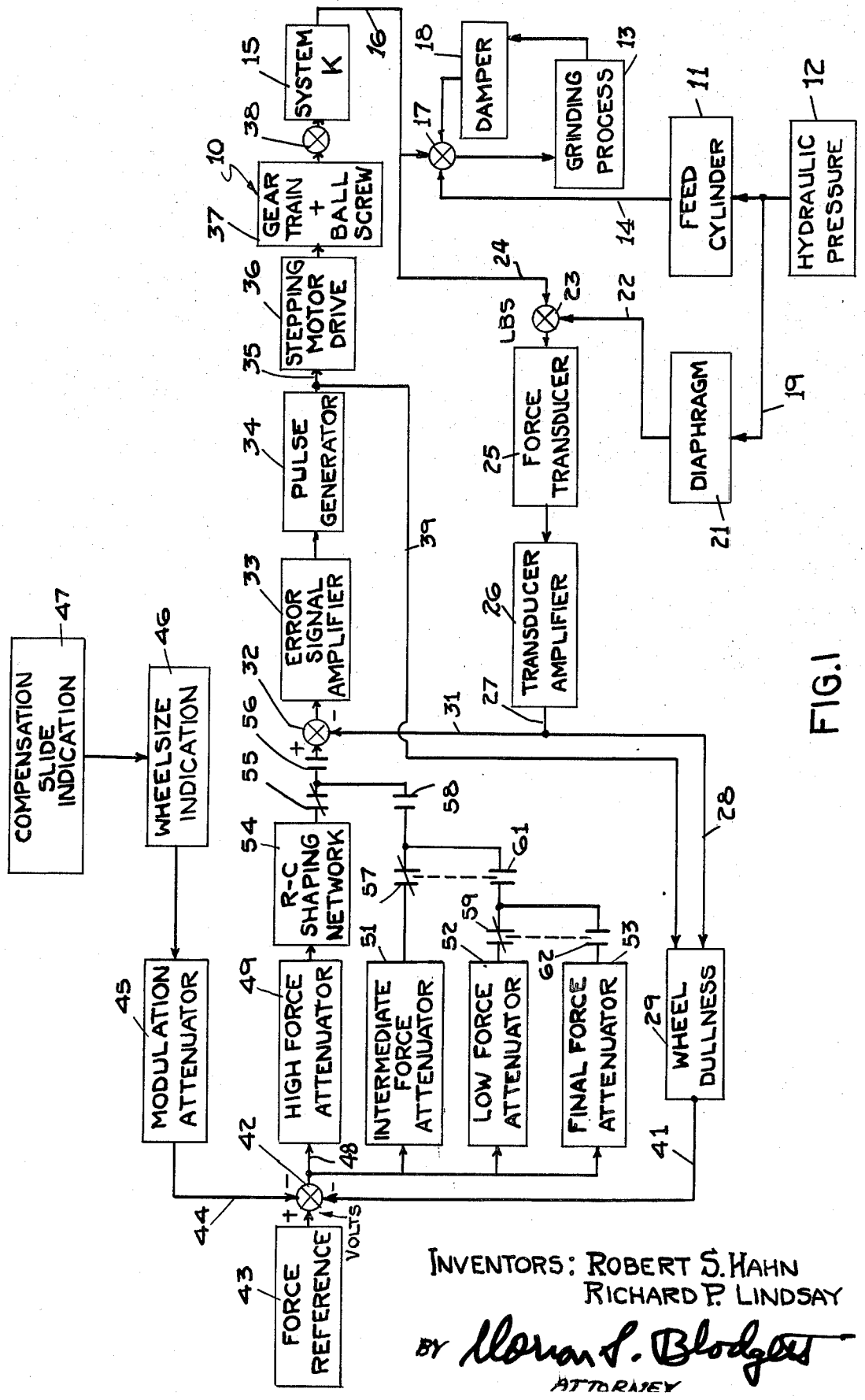


FIG. 1

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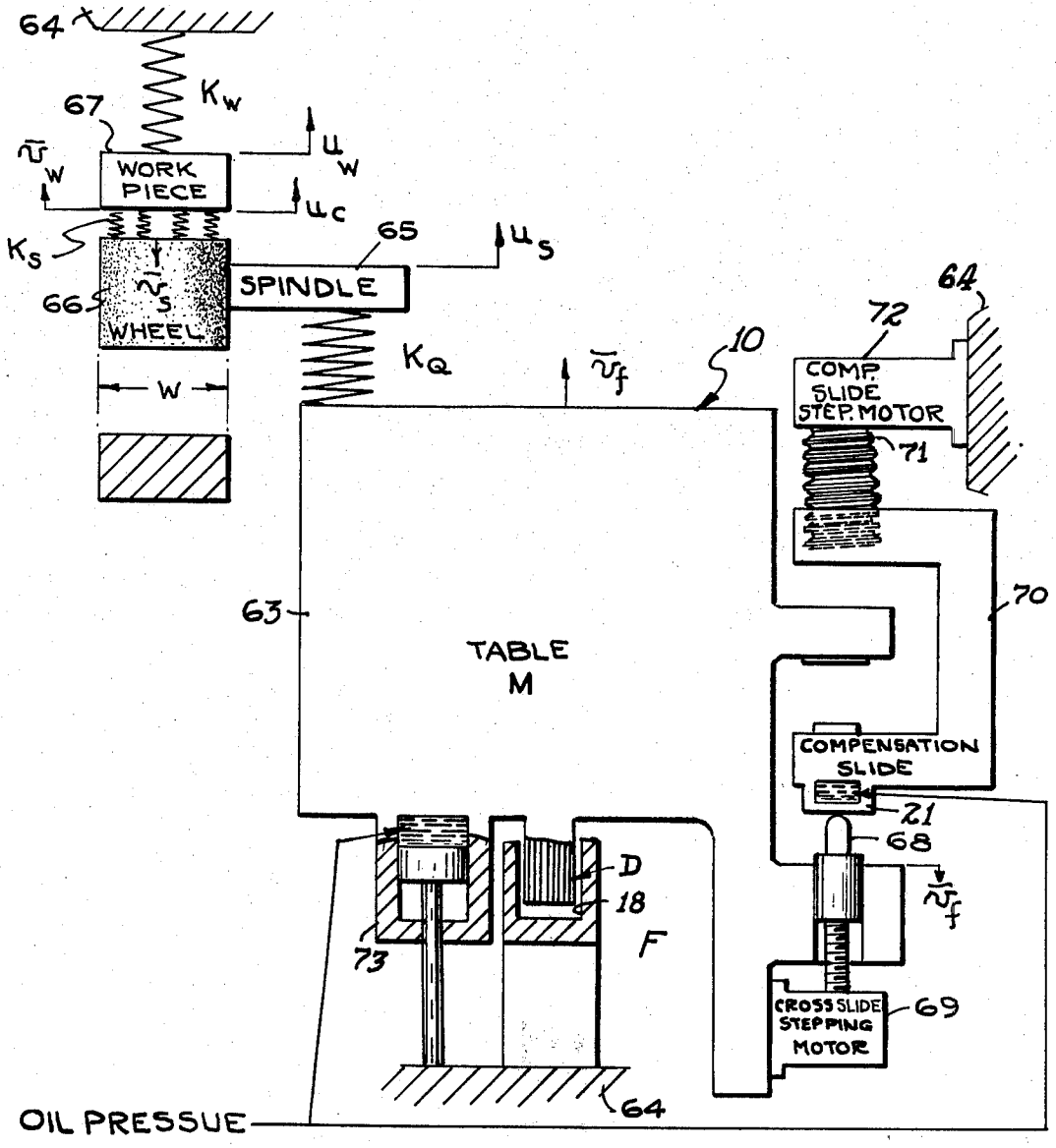
64
67
K_w
$\bar{v}_w$
WORK PIECE
u_w
u_c
K_s
65
u_s
66
$\bar{v}_s$
WHEEL
SPINDLE
w
K_Q
$\bar{v}_f$
10
64
72
COMP. SLIDE STEP. MOTOR
71
63
TABLE M
70
COMPENSATION SLIDE
21
68
D
18
F
73
$\bar{v}_f$
CROSS SLIDE STEPPING MOTOR
69
64
OIL PRESSUE

FIG.2

GRINDING MACHINE

This is a continuation of application Ser. No. **285,628** filed Sept. **1,** 1972, which is a continuation of application Ser. No. **94,389** filed Dec. **2, 1970.**

BACKGROUND OF THE INVENTION

In the operation of a grinding machine, there are several advantages to operating in such a manner that the force is controlled at a predetermined value and the rate of feed is allowed to vary uncontrollably. However, there are also attendant disadvantages, particularly where the machine used is an internal grinding machine; in that case, the abrasive wheel is mounted on a cantilevered spindle and is subject to considerable bending. There are so many variables that enter into the determination of the actual grinding force between the wheel and the workpiece that all kinds of problems are presented. The simplest method of controlling the force is to use a hydraulic cylinder for cross-feed and to control the oil pressure in the cylinder. In a rough way (assuming that there is no friction in the cross-slide), the force between the abrasive wheel and the workpiece is proportional to the pressure of the oil in the cylinder. However, as a practical matter, a number of variables enter into the picture that destroy this simple relationship. The sharpness or cutting ability of a wheel can vary from time to time and from wheel to wheel. The nature of the material being ground also varies. The force changes when the size of the wheel changes as it is dressed down from one grinding cycle to the next. Variation in force between the abrasive wheel and the workpiece can cause variation in taper in the finished ground surface and so on. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a grinding machine having a control for maintaining the force between the abrasive wheel and the workpiece at a constant perdetermined value.

Another object of this invention is the provision of an internal grinding machine in which taper and surface finish can be maintained at a predetermined value.

A further object of the present invention is the provision of a grinding machine having a closed-loop force control which is relatively simple in construction and operation.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

SUMMARY OF THE INVENTION

In general, the invention has to do with a grinding machine having a base, having a table carrying a wheelhead with a spindle and abrasive wheel mounted on the base, and having a table carrying a workhead with a workpiece mounted on the base. Feed means is provided to bring about relative movement between the tables transversely of the spindle to cause a grinding action between the wheel and the workpiece. A gage is provided for measuring the instantaneous force between the wheel and the workpiece and a feed-back control receives a signal from the gage and is operative, when the signal varies from a predetermined value; to adjust the feed means.

BRIEF DESCRIPTION OF THE DRAWINGS

The character of the invention, however, may be best understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

FIG. **1** is a schematic view of a grinding machine and its controls built in accordance with the principles of the present invention, and

FIG. **2** is a schematic view of the operative portions of the grinding machine.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. **1** it can be seen that the grinding machine, indicated generally by the reference numeral in **10** includes a feed cylinder **11** which receives a constant hydraulic pressure from a source **12.** The feed cylinder **11** is operative on the grinding process **13,** as indicated by a line **14.** The grinding process is also affected by the system spring constant K indicated by the box **15.** The spring constant K is shown in FIG. **2** as the combined spring constant of the machine and constitutes the sum of Kw, Ks, and Kg. For the purpose of demonstrating control logic, a line **16** leads from the box **15** to a signal junction **17** to show that the grinding process **13** is affected both by the system spring constant and by the force from the feed cylinder **11.** A damper box **18** is connected to the grinding process **13** and to the junction **17** to show the manner in which the damper effects the grinding process.

A line **19** extends from the source **12** to a diaphragm-type force measuring device **21** of the type shown in the U.S. Pat. No. **3,618,269,** dated Nov. **9, 1971.** This device contains a diaphragm which receives the same oil pressure as the feed cylinder **11,** the other side of the diaphragm receiving the full grinding force of the machine. A strain gage mounted on the diaphragm gives a signal indicative of the grinding force and this appears on the line **22** and is applied to one inlet of the junction **23.** The other inlet receives a signal from the system K box **15** through a line **24.** The combined effects of the grinding process force and the signal from the diaphragm **21** is felt by the force transducer **25** which is amplified in the amplifier **26** resulting in a signal on a line **27.** This signal passes along a line **28** to a wheel dullness indicator **29** and along a line **31** to a junction **32.**

The signal from the junction **32** is introduced into an error signal amplifier **33** whose output signal is introduced to a pulse generator **34.** The ouput of the pulse generator **34** appears on a line **35** leading to a stepping motor drive **36** which operates through a gear train and ball screw apparatus **37** which, in turn, operates through a junction **38** whose signal is felt in the system K box **15.**

The output line **35** of the pulse generator **34** is connected by a line **39** which is connected to the input of the wheel dullness indicator **29.** The output of this indicator appears on a line **41** which is connected to a junction **42.** Also connected to the junction **42** is a force reference box **43** and a line **44** leading from a modulation attenuator **45.** This attenuator receives a signal from a wheel size indicator **46** which, in turn, receives a signal from a compensation slide indicator **47.** The wheel size indicator **46** is of the type shown and described in the patent application of Robillard Ser. No. **877,092, filed Nov. 17, 1969,** now U.S. Pat. No.

3,601,930 dated Aug. 31, 1971. The wheel dullness indicator 29 is of the type shown and described in the U.S. Pat. No. 3,745,710, dated July 17, 1973.

The output of the junction 42 appears on a line 48 which is introduced into a high force attenuator 49, an intermediate force attenuator 51, a low force attenuator 52, and a final force attenuator 53. The high force attenuator 49 feeds into an R-C shaping network 54 and from there through a normally closed contactor 55 and a normally open contactor 56 (which is always closed during grinding) into the junction 32. The intermediate force attenuator 51 is connected through a normally closed contactor 57 and a normally open contactor 58 to a point between the contactors 55 and 56. The low force attenuator 52 is connected through a normally closed contactor 59 and a normally open contactor 61 to a point between the contactors 57 and 58. The final force attenuator 53 is connected through a normally open contactor 62 to a point between the contactors 59 and 61. The contactors 55 and 58 form part of the same relay and, therefore, change condition at the same time. Similarly, the contactors 57 and 61 form part of the same relay as do the contactors 59 and 62.

FIG. 2 shows somewhat schematically a grinding machine with which the control of FIG. 1 is used. It can be seen that the wheelhead table 63 has a mass m and is pressed rearwardly by the feed cylinder 73 as it travels over 18. base 64. The travel is damped by damper 18 The table carries a spindle 65 with an abrasive wheel 66 mounted thereon. The wheel operates on the surface of a workpiece 67 which, in turn, is mounted on the base 64. The table 63 has a retractable stop 68 operated by a stepping motor 69. This stop engages on occasion the diaphragm 21 mounted on the compensation slide 70. The compensation slide is moved relative to the base 64 by means of a screw 71 operated by a stepping motor 72. The same pressure oil that appears behind the diaphragm 21 also operates the feed cylinder 73.

It is obvious that the minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact from herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

1. A grinding machine for producing a surface of revolution on a workpiece, comprising:

a. a base,

b. a table carrying a wheelhead with a spindle and abrasive wheel mounted on the base,

c. means for mounting the workpiece on the base,

d. feed means to bring about relative movement between the tables and the base transversely of the spindle to bring about an instantaneous force between the wheel and the workpiece to cause a grinding action between the wheel and the workpiece,

e. a gage for measuring the instantaneous force between the wheel and the workpiece,

f. a sensing system adapted to determine the wheel size and the wheel dullness and to generate signals indicative of these physical characteristics, and

g. a feed-back control receiving a combined signal from the gage and the sensing system, and operative, when the combined signal varies from a predetermined value, to adjust the feed means.

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