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(54) **Improved grinding process and apparatus**

Verbessertes Schleifverfahren und Vorrichtung

Procédée et appreil de meulage amélioré

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WO-A-98/09772
DE-A- 4 133 754
US-A- 4 561 218

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Description

Field of the invention

[0001] This invention concerns a grinding machine and grinding method as per the preamble of claims 3 and 1. An example of such a method and machine is disclosed by DE-A-4 133 754.

Background to the invention

[0002] The use of CBN wheels in grinding processes has resulted in the requirement for large volumes of coolant to be delivered at ever higher pressures and velocity. CBN wheels tend to have a higher density and lower porosity than conventional Aluminium Oxide wheels. Grinding forces are higher and it is possible that the coolant contributes to the generation of high dynamic forces between the grinding wheel and the workpiece.

[0003] In order to grind at ever higher production rates and optimise maximum wheel life, it has been necessary to continue to increase coolant flows and pressures. In parallel with this it has been observed that profile quality and consistency in ground parts has deteriorated.

[0004] Document DE-A-4133754 discloses a control system for a grinding machine in which the changes in feed rate between rough grinding, finish grinding and spark-out are automatically determined as a result of signals from a grinding position sensor and a grinding load sensor.

Summary of the invention

[0005] According to one aspect of the invention there is provided a method of grinding an external surface of a workpiece, comprising the steps of directing liquid coolant onto the external surface being ground, and monitoring the grinding process by means of a probe for detecting the dimension of the surface, characterised in that during a predetermined final stage of a grinding cycle, before final size is reached, the rate and/or direction of flow of liquid coolant onto said surface is altered for at least part of the duration of said final stage, so that a reduced flow of the coolant reaches said external surface, whereby the accuracy of final grinding of the workpiece is improved.

[0006] The method is particularly applicable when grinding with a CBN grinding wheel.

[0007] Using the method of the invention, it has been found that a cam lobe profile can be improved and grinding errors in the final size reduced from 10's of microns to 2 or 3 microns during finish grinding, if the coolant flow is reduced or at least in part directed away from the region of engagement during the grinding of the final 20 microns down to final size.

[0008] In a similar manner, using the grinding method of the invention, the out-of-roundness of a crankpin has been reduced from a 10 micron envelope to an envelope of less than 1 micron, by reducing or deflecting or even removing the high pressure coolant flow when the component was 25 microns above final size, and maintaining the reduced or deflected flow (or turning off the flow) for the duration of the final 25 micron grind.

[0009] Even more surprisingly the width between side cheeks of a crankpin bearing even during a rough grind operation has been maintained more constant, therefore maintaining them parallel, by reducing or deflecting or removing the coolant flow during the last stage of grinding the two parallel faces.

[0010] According to another aspect of the invention there is provided a grinding machine comprising a grinding wheel, drive means for rotating the wheel to effect grinding of an external surface of a workpiece, means for rotating the workpiece during grinding, means for effecting relative movement between the grinding wheel and the workpiece to bring the wheel and the external surface of workpiece into engagement for grinding and to maintain such engagement for the duration of a grinding cycle, means for directing a jet of liquid coolant onto the wheel or the workpiece or both, at least in the region of the engagement of the wheel and the workpiece, sensing means for sensing when the grind cycle is nearing completion and the workpiece has a predetermined oversize condition remaining to be ground, said sensing means comprising a workpiece engaging probe for detecting the dimension of the external surface being ground, and means for generating a control signal responsive to signals from the sensing means, characterised by coolant control means for altering the rate of flow of coolant from the jet and/or the direction of the jet, sensing means for means for supplying the control signal to the coolant control means to alter the jet of liquid coolant so as to deflect, redirect, or reduce the jet when said predetermined oversize condition is sensed and for at least part of the duration of the remainder of the grinding cycle.

[0011] Alternatively or in addition, the sensing means may comprise means responsive to the advance of the grinding wheel during the grinding cycle, which is programmed to deliver a signal when the grinding wheel has advanced through a given distance thereby indicating that said predetermined oversize condition has been reached during which coolant flow is to be altered.

[0012] Where the grinding process is computer controlled and the position of the wheel relative to the workpiece and the distance to final size are both available to the computer, the coolant flow control means may be controlled by signals from the computer.

Brief Description of the Drawings

[0013] The invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

Figure 1 is a side view of part of a grinding machine;

Figure 2 is a schematic diagram of a control circuit for the coolant flow for the machine of Figure 1;

Figure 3 is a graph showing a typical cycle of grinding feed movement against time; and

Figure 4 is a graph showing an example of coolant flow rate, against a time base corresponding to that of Figure 3.

Detailed Description

[0014] Referring first to Figure 1, there is shown part of a grinding machine including a CBN grinding wheel 10 rotating clockwise, as indicated by the arrow. The wheel is shown in grinding contact with a contra-rotating cylindrical workpiece 12, in this case a crankpin rotating about the main axis of a crankshaft (not shown).

[0015] In order for the wheel to follow the orbiting movement of the crankpin 12, the wheel is moved horizontally backwards and forwards under computer control by means known per se.

[0016] A coolant nozzle 14 feeds a jet of coolant liquid down into the zone of contact between the wheel and the crankpin. The nozzle is mounted on a wheelhead (not shown) on which the wheel 12 itself is rotatably mounted.

[0017] In view of the high metal removal rates achievable with CBN wheels, it is necessary to have a large coolant flow from the nozzle 14 during the main grinding feed. It has been found that the jet of coolant flow increases the force exerted on the crankpin being ground, and hence tends to reduce the grinding accuracy which this invention seeks to mitigate.

[0018] Figure 2 shows the control circuit for the coolant, in which a pump (not shown) feeds coolant under pressure along a supply line 16 to a solenoid operated selector valve 18 which, in this example, is under the control of the computer. The selector valve has two positions, a first normal position (as shown) in which a full flow of coolant passes through it, and is fed via line 19 to the nozzle 14, and a second position in which the flow is throttled so that a reduced flow is fed to the nozzle. The reduced flow can be adjusted by a flow control valve 20 which connects the pump to the selector valve 18 along a line 21 parallel to the line 16.

[0019] A typical cycle of grinding feed against time is shown in Figure 3. The feed rate progressively reduces from an initial fast feed 22 and a medium feed 24 down to a slow feed 26, after which there is a dwell period 28 in which the feed ceases and sizing of the workpiece occurs, in this case the crankpin 12.

[0020] In accordance with the invention, and as illustrated in Figure 4, the coolant flow is maintained at a full rate 30 during the fast feed and up to the end of the slow feed 26, whereupon the computer issues a command signal to the selector valve 18 to cut the flow down to a reduced rate 32 for the duration of the dwell period 28. At the end of the dwell period, the coolant flow is completely stopped while the grinding wheel executes a rapid retract, as shown at 34 in Figure 3. Adjustment of the control valve 20 enables the ratio of the full flow to reduced flow to be varied to cater for differing conditions.

[0021] Since the crankshaft is not uniformly stiff when subjected to side forces, there is a tendency for different amounts of material to be ground away in different planes, causing the crankpin to be ground to a non-round shape. Reducing the flow rate 32 during the final stage of grinding reduces the coolant pressure at the nozzle 14, and hence the force on the crankpin (when grinding forces are low already), and it has been found that the out-of-roundness of the crankpin can be reduced from approximately 10 microns to less than 1 micron, in terms of its true diameter. Thus, the invention enables a higher accuracy and truer grinding profile to be achieved than previously.

[0022] As an alternative to reducing the flow rate, as aforesaid, the coolant could be directed away from the wheel during the final grinding stage. However, it is believed that this alternative would be more complicated and less practical than reducing the flow rate.

Claims

1. A method of grinding an external surface of a workpiece (12), comprising the steps of directing liquid coolant onto the external surface being ground, and monitoring the grinding process by means of a probe for detecting the dimension of the surface, **characterised in that** during a predetermined final stage (28) of a grinding cycle, before final size is reached, the rate and/or direction of flow of liquid coolant onto said surface is altered for at least part of the duration of said final stage, so that a reduced flow of the coolant reaches said external surface, whereby the accuracy of final grinding of the workpiece is improved.

2. A method according to claim 1, in which altering the flow of coolant comprises reducing the flow to a fraction of the full flow, during said predetermined final stage.

3. A grinding machine comprising a grinding wheel (10), drive means for rotating the wheel to effect grinding of an external surface of a workpiece (12), means for rotating the workpiece during grinding, means for effecting relative movement between the grinding wheel and the workpiece to bring the wheel and the external surface of workpiece into engagement for grinding and to maintain such engagement for the duration of a grinding cycle, means (14) for directing a jet of liquid coolant onto the wheel or the workpiece or both, at least in the region of the engagement of the wheel and the workpiece, sensing

means for sensing when the grind cycle is nearing completion and the workpiece has a predetermined oversize condition remaining to be ground, said sensing means comprising a workpiece engaging probe for detecting the dimension of the external surface being ground, and means for generating a control signal responsive to signals from the sensing means, **characterised by** coolant control means (18) for altering the rate of flow of coolant from the jet and/or the direction of the jet, means for supplying the control signal to the coolant control means (18) to alter the jet of coolant liquid so as to deflect, redirect, or reduce the jet when said predetermined oversize condition is sensed and for at least part of the duration of the remainder (28) of the grinding cycle.

4. A machine according to claim 3 and further comprising machine control means responsive to the control signal to resume a grinding cycle after the alteration of the coolant jet has been effected, to complete the grinding process.

5. A machine according to any one of claim 3 or claim 4, in which the sensing means comprises means responsive to the advance of the grinding wheel (10) during the grinding cycle, which is programmed to deliver a signal when the wheel has advanced through a given distance thereby indicating that said predetermined oversize condition has been reached during which coolant flow is to be altered.

6. A machine according to any one of claims 3 to 5 comprising a computer for controlling the grinding process, both the position of the grinding wheel relative to the workpiece and the distance to final size being available to the computer, wherein the coolant control means (18) is controlled by signals from the computer.

7. A machine according to any one of claims 3 to 6, in which the coolant control means is a selector valve (18) connected between a coolant pump and a nozzle (14) for forming the jet, and operable to produce a full flow or a reduced flow of coolant.

8. A machine according to claim 7 further comprising a flow control valve (20) upstream of the selector valve (18) and operable to vary said reduced flow of coolant.

9. A machine according to any one of claims 3 to 8, in which the grinding wheel (10) is a CBN wheel.

Patentansprüche

1. Verfahren zum Schleifen einer äußeren Oberfläche eines Werkstücks (12), das die Schritte umfasst: Leiten von flüssigem Kühlmittel auf die zu schleifende äußere Oberfläche und Überwachen des Schleifverfahrens durch einen Sensor zur Erfassung der Abmessung der Oberfläche, **dadurch gekennzeichnet, dass** während einer vorher bestimmten Endphase (28) eines Schleifzyklus vor Erreichen der Endgröße die Durchflussmenge und/oder die Richtung des Stroms von flüssigem Kühlmittel auf die Oberfläche wenigstens während eines Teils der Dauer der Endphase geändert wird, so dass ein verringerter Strom des Kühlmittels die äußere Oberfläche erreicht, wodurch die Genauigkeit des abschließenden Schleifens des Werkstücks verbessert wird.

2. Verfahren nach Anspruch 1, bei dem die Änderung des Stroms des Kühlmittels eine Reduzierung des Stroms auf einen Bruchteil des vollen Stroms während der vorher bestimmten Endphase umfasst.

3. Schleifmaschine, die Folgendes aufweist: eine Schleifscheibe (10), Antriebsmittel zum Drehen der Scheibe, um ein Schleifen einer äußeren Oberfläche eines Werkstücks (12) zu bewirken, Mittel zum Drehen des Werkstücks während des Schleifens, Mittel zum Erzeugen einer relativen Bewegung zwischen der Schleifscheibe und dem Werkstück, um die Scheibe und die äußere Oberfläche des Werkstücks in Eingriff für das Schleifen zu bringen und diesen Eingriff während der Dauer eines Schleifzyklus aufrechtzuerhalten, Mittel (14) zum Leiten eines Strahls von flüssigem Kühlmittel auf die Scheibe oder das Werkstück oder beide wenigstens in dem Bereich des Eingriffs der Scheibe und des Werkstücks, Erfassungsmittel zum Erfassen, wann der Schleifzyklus sich der Vollendung nähert und das Werkstück einen Zustand einer vorher bestimmten Übergröße hat, die noch zu schleifen bleibt, wobei das Erfassungsmittel einen Werkstück-Eingriffssensor zur Erfassung der Abmessung der zu schleifenden äußeren Oberfläche aufweist, und Mittel zum Erzeugen eines Steuerungssignals in Abhängigkeit von Signalen von dem Erfassungsmittel, **gekennzeichnet durch** ein Kühlmittel-Steuerungsmittel (18) zum Ändern des Durchsatzes des Kühlmittels aus dem Strahl und/oder zum Ändern der Richtung des Strahls, Mittel zum Leiten des Steuerungssignals an das Kühlmittel-Steuerungsmittel (18) zum Ändern des Strahls der Kühlflüssigkeit, so dass der Strahl abgelenkt, umgeleitet oder reduziert wird, wenn der vorher bestimmte Übergrößen-Zustand erfasst wird, während wenigstens eines Teils der Restdauer (28) des Schleifzyklus.

4. Maschine nach Anspruch 3, die weiterhin aufweist: ein Maschinensteuerungsmittel, das auf das Steue-

rungssignal zur Wiederaufnahme eines Schleifzyklus reagiert, nachdem die Änderung des Kühlmittelstrahls bewirkt wurde, um das Schleifverfahren zu vollenden.

5. Maschine nach Anspruch 3 oder 4, bei der das Erfassungsmittel ein Mittel umfasst, das auf das Vorrücken der Schleifscheibe (10) während des Schleifzyklus reagiert und das so programmiert ist, dass es ein Signal erzeugt, wenn die Scheibe über eine gegebene Strecke vorgerückt ist, und dadurch anzeigt, dass der vorher bestimmte Übergrößen-Zustand erreicht ist, während dessen der Kühlmittelstrom geändert wird.

6. Maschine nach einem der Ansprüche 3 bis 5, die einen Computer zur Steuerung des Schleifverfahrens umfasst, wobei sowohl die Position der Schleifscheibe bezüglich des Werkstücks sowie der Abstand zur Endgröße für den Computer verfügbar sind, wobei das Kühlmittel-Steuerungsmittel (18) durch Signale von dem Computer gesteuert wird.

7. Maschine nach einem der Ansprüche 3 bis 6, bei dem das Kühlmittel-Steuerungsmittel ein Wahlventil (18) ist, das eine Kühlmittelpumpe und eine Düse (14) zum Bilden des Strahls verbindet und so betätigbar ist, dass es einen vollen Strom oder einen reduzierten Strom des Kühlmittels erzeugt.

8. Maschine nach Anspruch 7, die weiterhin ein Stromregelventil (20) stromaufwärts des Wahlventils (18) aufweist, das so betätigbar ist, dass es den reduzierten Strom des Kühlmittels variiert.

9. Maschine nach einem der Ansprüche 3 bis 8, bei der die Schleifscheibe (10) eine CBN-Scheibe ist.

Revendications

1. Procédé de meulage d'une surface extérieure d'une pièce (12), comprenant les étapes consistant à diriger un fluide de refroidissement sur la surface extérieure à meuler, et à surveiller le processus de meulage à l'aide d'une sonde pour détecter la dimension de la surface, **caractérisé en ce que**, pendant un stade final prédéterminé (28) d'un cycle de rectification, avant l'obtention des cotes finales, le débit et/ou l'orientation du jet de fluide de refroidissement vers ladite surface sont modifiés pendant au moins une partie de la durée dudit stade final, de façon qu'un jet réduit du fluide de refroidissement atteigne ladite surface extérieure, ce qui permet d'améliorer la précision de la rectification finale de la pièce.

2. Procédé selon la revendication 1, dans lequel la modification du débit du fluide de refroidissement consiste à réduire le jet à une fraction du jet complet, pendant ledit stade final prédéterminé.

3. Dispositif de meulage comprenant une meule de rectification (10), des moyens d'entraînement pour faire tourner la meule afin de réaliser un meulage d'une surface extérieure d'une pièce (12), un moyen pour faire tourner la pièce pendant le meulage, des moyens pour réaliser un mouvement relatif entre la meule et la pièce de façon à placer au contact l'une de l'autre la meule et la surface extérieure de la pièce pour le meulage et à maintenir ledit contact pendant la durée d'un cycle de meulage, des moyens (14) pour diriger un jet de fluide de refroidissement vers la meule ou la pièce ou vers les deux, au moins dans la zone de contact de la meule et de la pièce, des moyens de détection pour détecter le moment où le cycle de meulage approche de son terme et où il reste encore un excédent prédéterminé de matière de la pièce à meuler, lesdits moyens de détection comprenant une sonde au contact de la pièce pour détecter la dimension de la surface extérieure à meuler, et des moyens pour produire un signal de commande en réponse à des signaux fournis par les moyens de détection, **caractérisée par** un moyen de commande (18) de fluide de refroidissement servant à modifier le débit du fluide de refroidissement à partir du jet et/ou de l'orientation du jet, des moyens pour fournir le signal de commande au moyen de commande (18) de fluide de refroidissement afin de modifier le jet du fluide de refroidissement de manière à dévier, réorienter ou réduire le jet lorsque ledit état d'excédent de matière prédéterminée est détecté et pendant au moins une partie de la durée du reste (28) du cycle de meulage.

4. Dispositif de meulage selon la revendication 3, comprenant en outre des moyens de commande du dispositif réagissant au signal de commande pour reprendre un cycle de meulage après la modification du jet de fluide de refroidissement, pour terminer l'opération de meulage.

5. Dispositif selon l'une quelconque des revendications 3 et 4, dans laquelle les moyens de détection comportent des moyens réagissant à l'avance de la meule (10) pendant le cycle de meulage, qui est programmé pour fournir un signal lorsque la meule a avancé sur une distance donnée indiquant que ledit état d'excédent prédéterminé de matière a été atteint, état pendant lequel ledit débit du fluide de refroidissement doit être modifié.

6. Dispositif selon l'une quelconque des revendications 3 à 5, comprenant un ordinateur pour commander le processus de meulage, la position de la

meule par rapport à la pièce et la distance jusqu'à la cote finale étant toutes deux communiquées à l'ordinateur, le moyen de commande (18) de fluide de refroidissement étant commandé par des signaux fournis par l'ordinateur.

7. Dispositif selon l'une quelconque des revendications 3 à 6, dans laquelle le moyen de commande du fluide de refroidissement est une vanne de distribution (18) montée entre une pompe de fluide de refroidissement et une buse (14) servant à former le jet, et permettant de produire un jet complet ou un jet réduit de fluide de refroidissement.

8. Dispositif selon la revendication 7, comprenant en outre en amont de la vanne de distribution (18) un régulateur (20) de débit servant à modifier ledit débit réduit du fluide de refroidissement.

9. Dispositif selon l'une quelconque des revendications 3 à 8, dans laquelle la meule (10) est une meule au nitrure de bore cristallin.

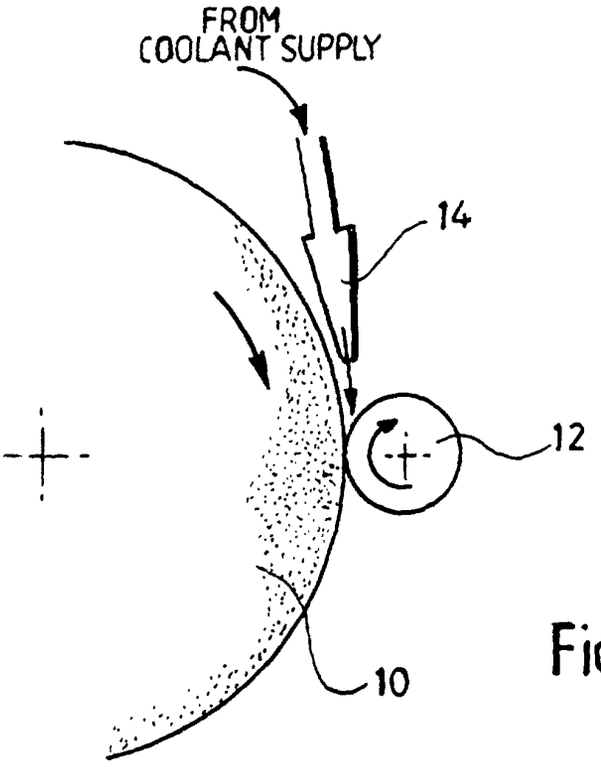
FROM
COOLANT SUPPLY
14
12
10

Fig. 1

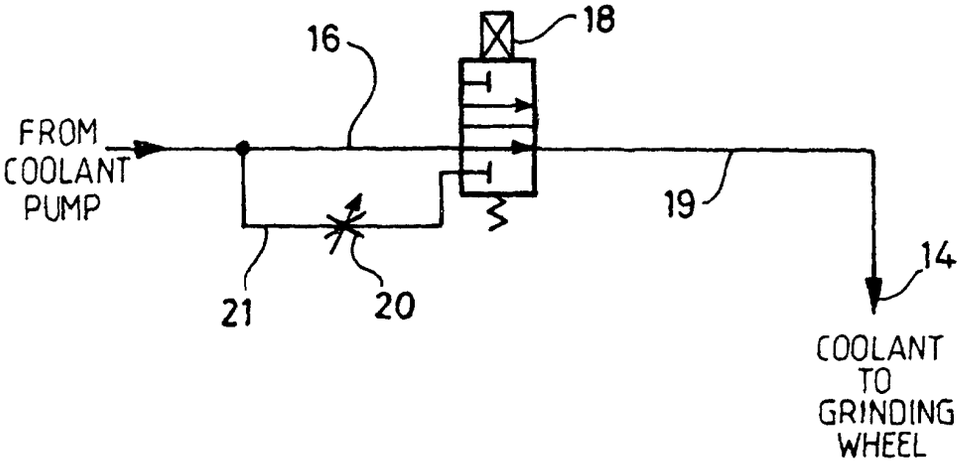
16
18
FROM
COOLANT
PUMP
19
14
21
20
COOLANT
TO
GRINDING
WHEEL

Fig. 2

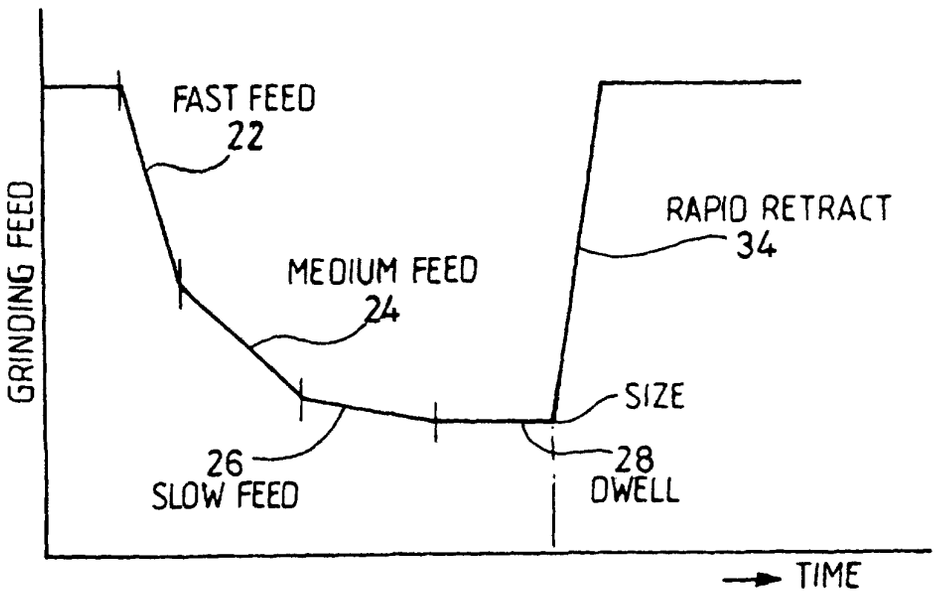
GRINDING FEED
FAST FEED
22
MEDIUM FEED
24
RAPID RETRACT
34
SIZE
26
SLOW FEED
28
DWELL
TIME

Fig. 3

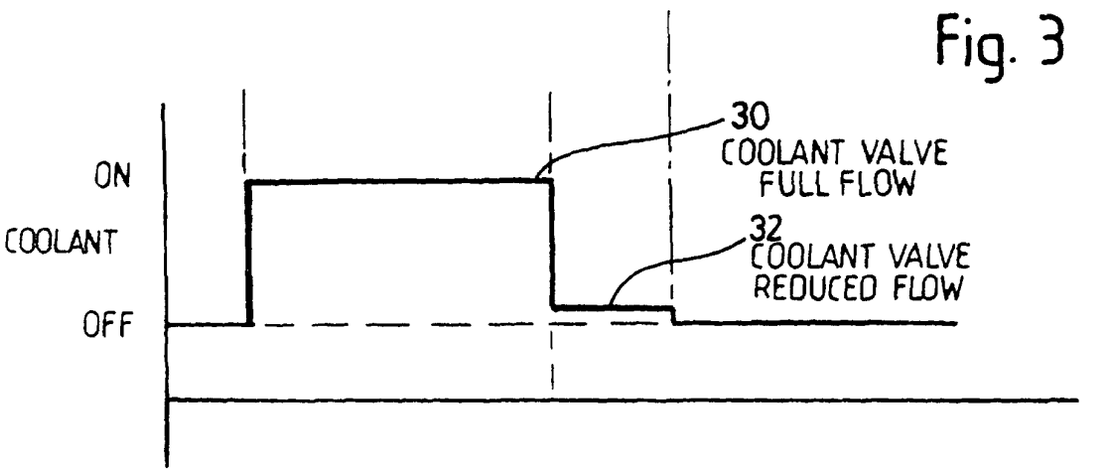
ON
COOLANT
OFF
30
COOLANT VALVE
FULL FLOW
32
COOLANT VALVE
REDUCED FLOW

Fig. 4