

DESCRIPTION

Laser Liquid Crystal Marker and Method for Judging
Deterioration of Liquid Crystal

TECHNICAL FIELD

The present invention relates to a laser liquid crystal marker and a method for judging deterioration of liquid crystal and, in particular, to a laser liquid crystal marker and a method for judging deterioration of liquid crystal which are suitable for a workpiece printing that requires a high level of accuracy.

BACKGROUND ART

There exist a variety of conventional laser liquid crystal markers, also called "transmission-type liquid crystal mask markers". Generally speaking, a laser liquid crystal marker comprises a laser oscillator, a lens system for expanding, condensing or collimating a laser beam, a liquid crystal serving as a transmission-type liquid crystal mask for arbitrary pattern display, one or two sets of X-Y deflectors for deflecting the optical path of the laser beam, a controller for performing a synchronized control of a separately provided work feeder, etc. In such a construction, the controller causes the laser oscillator to

oscillate a laser beam, which is applied to the liquid crystal. The laser beam transmitted through the liquid crystal is applied to the surface of a workpiece, whereby the pattern of the liquid crystal is printed on the surface of the workpiece.

In such a laser liquid crystal marker, the clearness in printing deteriorates with use. In the conventional laser liquid crystal markers, this deterioration has only been coped with empirically, that is, by methods that are not rational enough. The judgment as to whether the liquid crystal has deteriorated or not has been made by visually examining the printing conditions (the degree of clearness in printing, etc.) on the workpiece surface. With the current state of the art, any deterioration in the printing conditions has been coped with, for example, by appropriately increasing the laser output, cleaning the lense system, replacing the liquid crystal, adjusting the driving system of the X-Y deflectors or the work feeder, or replacing the controller. Such measures cannot be regarded as appropriate in coping with the above deterioration.

According to a known printing method, a liquid crystal operation display section is provided in a part of the liquid crystal, and a detector is connected to this display section, which is irradiated with a beam of light different from that for printing to thereby detect changes in the

response time of the liquid crystal due to changes in the ambient temperature; on the basis of this detection, the switching operation time for the laser is corrected by the controller, thereby realizing a clear printing on the surface of a workpiece (See, for example, Japanese Patent Laid-Open No. 64-11088). However, with the above-described method, in which the operation time is corrected in correspondence with changes in the response time of the liquid crystal, the degree of deterioration of the liquid crystal cannot be checked, nor can the liquid crystal itself be controlled for clear printing.

In another conventional technique, already proposed by the present applicant, there is provided a laser liquid crystal marker called a "YAG laser mask marker" (See Japanese Patent Laid-Open No. 5-42379), which is equipped with first and second X-Y deflectors arranged on either side of the liquid crystal. Separate still images are sequentially displayed through the liquid crystal. The first X-Y deflector causes a laser beam to scan each separate still image, and the second X-Y deflector causes the laser beam transmitted through the separate still images to be sequentially applied in deflective irradiation to the surface of a workpiece until the entire printing is completed, thereby realizing a high-accuracy, high-speed continuous printing. However, the above method has a

problem in that the deterioration in the clearness in printing on the workpiece surface cannot be checked by a rational method, so that it is rather difficult to properly cope with the deterioration in clearness.

DISCLOSURE OF THE INVENTION

In coping with this problem of deterioration in clearness of printing, the present applicant directed his attention to the following fact: the light transmittance of a liquid crystal can be varied by varying the voltage applied thereto. In other words, the clearness in printing can be controlled through applied voltage. This control ought to be realized by adding a specific program to the controller used in an existing laser liquid crystal marker (or a simple additional controller that is separately provided). However, varying the applied voltage at random will only result in variations in printing accuracy. Further, there is a range of applied voltage in which it is difficult to maintain an optimum printing condition even by varying the applied voltage (which range corresponds to the time at which the liquid crystal is to be replaced). Thus, the present applicant came to a conclusion that, by constantly keeping track of the degree of deterioration of the liquid crystal, it ought to be possible to apply an optimum voltage corresponding to the degree of

deterioration, thereby making it possible at least to prevent the deterioration in printing accuracy due to the deterioration of the liquid crystal.

The present invention has been made with a view toward solving the above problems in the prior-art technique, focusing attention on the above point. It is accordingly an object of the present invention to provide a liquid crystal marker and a method of judging deterioration of liquid crystal in which, to maintain a high level of accuracy in printing, it is possible to control the applied voltage in correspondence with the degree of deterioration of the liquid crystal, decide on the time at which the liquid crystal is to be-replaced and, further, maintain a high level of accuracy in printing even in continuous high-speed printing.

In a first aspect of the present invention, there is provided a laser liquid crystal marker comprising: a controller; a temperature sensor connected to the controller and adapted to detect a liquid crystal temperature T_i ; light emitting means for irradiating the liquid crystal with light; and light receiving means for receiving the light transmitted through the liquid crystal, wherein the controller stores in advance correlation characteristics P of an applied voltage V of the liquid crystal and a light transmittance Q using a liquid crystal temperature T in a

normal liquid crystal as a parameter, wherein an irradiation quantity of light R1 emitted by the light emitting means and transmission quantity of light R2 received by the light receiving means are input to the controller to calculate a light transmittance Q_i from the irradiation quantity of light R1 and the transmitted quantity of light R2, and wherein an optimum light transmittance Q_o corresponding to the applied voltage V_i of the liquid crystal at the time of this calculation and the liquid crystal temperature T_i supplied from the temperature sensor is extracted from the correlation characteristics P, the controller adjusting the applied voltage V_i of the liquid crystal so that the light transmittance Q_i becomes equal to the light transmittance Q_o . The controller stores in advance correlation characteristics P of the applied voltage V of the liquid crystal and the light transmittance Q using a liquid crystal temperature T in a normal liquid crystal as a parameter, and, when judging the degree of deterioration of this liquid crystal, the irradiation quantity of light R1 emitted from the light emitting means and the transmitted quantity of light R2 received by light receiving means are input to the controller to calculate the light transmittance Q_i from the irradiation quantity of light R1 and the transmitted quantity of light R2, wherein the optimum light transmittance Q_o corresponding to the applied voltage V_i of

the liquid crystal at the time of this calculation and the light crystal temperature T_i supplied from the temperature sensor is extracted from the correlation characteristic P , and wherein, by adjusting this liquid crystal applied temperature V_i , the light transmittance Q_i and the optimum light transmittance Q_o are equalized; further, when the light transmittance Q_i and the optimum light transmittance Q_o do not become equal to each other even by adjusting the applied voltage V_i of the liquid crystal, the controller outputs a message to the effect that the liquid crystal has been deteriorated.

With this construction, two light transmittances Q , one at the light crystal temperature T_i and the other at the applied voltage V_i of the liquid crystal, can be obtained. One is a light transmittance Q_i calculated from the irradiation quantity of light R_1 and the transmitted quantity of light R_2 ; and the other is the optimum light transmittance Q_o extracted from correlation characteristics P in a normal liquid crystal. The liquid crystal application voltage V_i is adjusted by the controller so that the light transmittance Q_i and the optimum light transmittance become equal to each other, and printing is performed while maintaining this optimum light transmittance Q_o , so that a satisfactory degree of clearness can be obtained, and an optimum printing condition can be

maintained. When the optimum light transmittance Q_0 cannot be obtained even by adjusting the applied voltage V_i of the liquid crystal, a message is output to the effect that the liquid crystal has been deteriorated, whereby the time of replacement for the liquid crystal due to the expiration of service life can be properly decided upon.

In a second aspect of the present invention, there is provided a laser liquid crystal marker, wherein connected to a controller are light emitting means for irradiating a liquid crystal with light and light receiving means for receiving the light transmitted through the liquid crystal, wherein the controller stores in advance a reference value S_0 , and an irradiation quantity of light R_1 emitted by the light emitting means and a transmitted quantity of light R_2 received by the light receiving means are input to the controller to calculate a detection value S_i thereof, the controller adjusting the applied voltage V_i of the liquid crystal so that the detection value S_i becomes equal to the reference value S_0 . The controller stores in advance the reference value S_0 and an application voltage threshold value V_m , and the irradiation quantity of light R_1 emitted by the light emitting means and the transmitted quantity of light R_2 received by the light receiving means are input to the controller to calculate the detection value S_i thereof, the controller adjusting the applied voltage V_i of the

liquid crystal so that the detection value S_i becomes equal to the reference value S_o ; when this applied voltage V_i of the liquid crystal is in excess of the application voltage threshold value V_m , the controller outputs a warning.

Unlike the construction according to the first aspect of the invention, the above-described construction is intended for the case in which the liquid crystal temperature T_i is not considered as a parameter. This proves useful, in particular, when the laser liquid crystal marker to be operated is installed in an air-conditioned room, with the working liquid crystal temperature at the time of driving being known. That is, a reference value S_o corresponding to the working liquid crystal temperature T_i is set in advance in the controller, and the applied voltage V_i of the liquid crystal is adjusted so that the detection value S_i becomes equal to this reference value S_o . Further, by providing an application voltage threshold value V_m that serves as a voltage corresponding to the liquid crystal deterioration limit, etc. in the controller, the applied voltage V_i of the liquid crystal is adjusted so that the detection value S_i becomes equal to the reference value S_o . When this applied voltage V_i of the liquid crystal is in excess of the application voltage threshold value V_m , a warning is issued, whereby an optimum printing condition can be maintained, and the degree of deterioration corresponding

to the limit of the service life of the liquid crystal can be correctly determined.

In a third aspect of the present invention, there is provided a laser liquid crystal marker, in which, connected to a controller are light emitting means and light receiving means, and in which a voltage is applied to a liquid crystal from the controller for a successive rewrite display of various still images for marking, with a still image for testing being appropriately displayed, wherein the light emitting means projects light onto the displayed still image for testing, and the light receiving means receives the light transmitted through the still image for testing, wherein the controller stores in advance an optimum light transmittance Q_0 , and effects interrupt display of the still image for testing during at least one of the rewrite processes for the still images for marking, wherein a transmitted quantity of light R_2 is input during this interrupt display from the light receiving means, and the light transmittance Q_i of the liquid crystal is calculated from the transmitted quantity of light R_2 and the irradiation quantity of light R_1 , the controller adjusting the applied voltage V_i of the liquid crystal so that the light transmittance Q_i becomes equal to the optimum light transmittance Q_0 . The controller stores in advance the optimum light transmittance Q_0 , and, during at least one of

the rewriting processes for the still images for marking, causes a still image for testing to be displayed, and after this, effects interrupt of the repetition of the equalization in electric potential of all the common terminals and segment terminals, and during this interrupt, inputs the transmitted quantity of light R_2 from the light receiving means to calculate the light transmittance Q_i of the liquid crystal from the transmitted quantity of light R_2 and the irradiation quantity of light R_1 of the light emitting means, the controller adjusting the applied voltage V_i of the liquid crystal so that this light transmittance Q_i becomes equal to the optimum light transmittance Q_0 .

In this construction, an interrupt display of a still image for testing (an image for measuring light transmittance) is effected during the rewriting of a successive rewrite display of still images for marking (images for printing) on the liquid crystal, and, during this interrupt display, the transmittance Q_i is measured, and compared with the optimum light transmittance Q_0 to thereby adjust the applied voltage V_i of the liquid crystal for the still images. Due to this arrangement, it is possible to maintain an optimum printing condition even in a laser liquid crystal marker capable of continuous high-speed printing. Further, due to the equalization in potential of the terminals of the liquid crystal, it is possible to

maintain an optimum printing condition capable of high-speed continuous printing. That is, an interrupt in a laser liquid crystal marker for high-accuracy, high-speed printing, which is best performed during workpiece standby periods so as not to cause a reduction in throughput, can in some cases be insufficient, that is, a satisfactory result cannot be obtained by simply effecting an interrupt display of a still image for testing for the measurement of the transmittance Q_i . That is, when even this workpiece standby period is very short, it is necessary, even when a command to erase the still image for testing is issued, to display a next still image for testing before the after-image thereof has vanished, resulting a deterioration in printing performance. However, in such cases, as in the present invention, immediately after the display of the testing still image on the liquid crystal (which is normally effected for a very short period of time), all the common and segment terminals of this liquid crystal are equalized in electric potential, whereby the testing still image vanishes leaving practically no after-image, so that it is possible to maintain an optimum printing condition.

In a fourth aspect of the present invention, there is provided a method for judging deterioration of liquid crystal, the method comprising the steps of: irradiating a liquid crystal with light in an irradiation quantity of

light R_1 ; detecting a transmitted quantity of light R_2 transmitted through this liquid crystal; calculating a light transmittance Q_i on the basis of the irradiation light quantity R_1 and the transmitted quantity of light R_2 ; and judging the degree of deterioration of the liquid crystal from changes with time of this light transmittance Q_i .

Due to this arrangement, it is possible to correctly judge the degree of deterioration of a liquid crystal. Thus, unlike the conventional empirical measures, this method makes it possible to check the degree of deterioration of a liquid crystal on a rational basis and properly replace the liquid crystal.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view showing the construction of a laser liquid crystal marker according to the first aspect of the present invention; Figs. 2A through 2C are views illustrating how the laser liquid crystal marker of Fig. 1 is controlled, of which Fig. 2A is a flowchart illustrating the section of the operation of the controller for judging the degree of deterioration of a liquid crystal, Fig. 2B is a graph showing correlation characteristics of liquid crystal application voltage and light transmittance when liquid crystal temperature is used as a parameter, and Fig. 2C is a graph showing correlation characteristics of liquid

crystal application voltage and light transmittance when deterioration of liquid crystal is used as a parameter; Fig. 3 is a flowchart illustrating control procedures for a controller in another embodiment according to the first aspect of the present invention; Fig. 4 is a schematic view showing the construction of a laser liquid crystal marker according to the second and third aspects of the present invention; Fig. 5 is a flowchart illustrating control procedures for a controller according to the second aspect of the present invention; Fig. 6 is a flowchart illustrating control procedures for a controller in another embodiment according to the second aspect of the present invention; Fig. 7 is a diagram showing an example of a printing cycle according to the third aspect of the present invention; Fig. 8 is a flowchart illustrating control procedures for a controller according to the third aspect of the present invention; and Fig. 9 is a schematic diagram illustrating a system for measuring the degree of deterioration of a liquid crystal according to the fourth aspect of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

A preferred embodiment of a laser liquid crystal marker according to the first aspect of the invention will now be described in detail with reference to the accompanying drawings.

Fig. 1 shows the hardware construction of a laser liquid crystal marker, in which laser scanning is performed on a pattern of a liquid crystal 2 by a polygon mirror 9X and a galvanoscanner 9Y, which serve as XY deflectors. A laser beam L1 emitted from a laser oscillator 1 travels through a beam shaping device 81, and is first deflected in the Y-direction by the galvanoscanner 9Y. Then, it is deflected in the X-direction by the polygon mirror 9X. The laser beam thus deflected is further deflected by a lens 82 such that it is condensed on a reflecting mirror 83. In this process, scanning irradiation is effected on a pattern of the liquid crystal 2, and exclusively a transmission laser beam L2 which is in conformity with the pattern is applied to the reflecting mirror 83. The transmission laser beam L2, reflected by the reflecting mirror 83, is transmitted through an objective lens 84 before it is applied to the surface of a workpiece 3 on a work feeder 10 to thereby print the pattern on the surface of the workpiece 3. In this construction, the driving system for the laser oscillator 1, the XY deflectors 9X and 9Y, the liquid crystal 2 and the work feeder 10, is electrically connected to a controller 7 and synchronously controlled by the controller 7. Further, electrically connected to the controller 7 are a temperature sensor 4 for detecting the temperature T_i of the liquid crystal 2, light emitting means

5 for irradiating the liquid crystal 2 with light in an irradiation quantity of light R1, and light receiving means 6 for receiving the light transmitted through the light crystal 2, in a transmitted light quantity R2. Apart from the synchronous control mentioned above, this controller performs control procedures described below.

The software construction of the controller 7, in the construction described above, will be described with reference to Figs. 1 and 2A through 2C. The controller 7 stores in advance correlation characteristics P of the liquid crystal application voltage V applied to the liquid crystal 2 for pattern display and the light transmittance Q of the liquid crystal 2 at the time of light transmission, using liquid crystal temperatures T of this liquid crystal 2 as parameters (step 101). As shown in Fig. 2B, when, for example, the liquid crystal temperature T is a specific temperature T1, the light transmittance Q (the vertical axis) of the liquid crystal 2 has a correlation characteristic P1, in which it changes with the liquid crystal application voltage V (the horizontal axis). When the liquid crystal temperature gradually increases ($T = T1 \rightarrow T2 \rightarrow Tn$), or the liquid crystal 2 deteriorates, this correlation characteristic P indicates a shift upward toward the left-hand side, as can be seen from the diagram ($P = P1 \rightarrow P2 \rightarrow Pn$). In short, a rise in the liquid crystal

temperature T , a deterioration in the liquid crystal 2, or an increase in the liquid crystal application voltage V causes the light transmittance Q of the liquid crystal 2 to increase. It should be noted that an increase in the liquid crystal temperature T and an increase or decrease in the liquid crystal application voltage V are factors which can be set independently of a deterioration in the liquid crystal. Thus, to measure the degree of deterioration of the liquid crystal 2, the controller 7 stores the following correlation characteristic P in advance: using liquid crystal temperatures T of the liquid crystal 2 as parameters, light is applied from the light emitting means 5, consisting of a semiconductor laser or the like, to the liquid crystal 2 while varying the application voltage V applied to the liquid crystal 2 for pattern display, and the light transmitted through the liquid crystal 2 is received by the light receiving means 6, which consists of a PIN diode or the like. From the irradiation quantity of light $R1$ and the transmitted quantity of light $R2$, the light transmittance Q of the liquid crystal 2 is calculated to obtain the correlation characteristics P shown in Fig. 2B, which are, as stated above, stored.

Next, the controller 7 judges the degree of deterioration of an actually used liquid crystal 2, and performs control so as to maintain an optimum light

transmittance Q_0 . That is, the applied voltage V_i of the liquid crystal and the liquid crystal temperature T_i are input to the controller 7 (step 102). In this embodiment, a system is adopted in which the controller 7 also outputs the liquid crystal application voltage V applied to the liquid crystal 2, so that this liquid crystal application voltage V is used as the applied voltage V_i of the liquid crystal. In a case in which the controller 7 is separately arranged with respect to the controller of the main body, the liquid crystal application voltage V is input from the controller of the main body. In that case, the liquid crystal temperature T_i is input from the temperature sensor 4.

Next, the controller 7 extracts a characteristic corresponding to the liquid crystal temperature T_i from the correlation characteristics P stored. This will be regarded as the correlation characteristic $P_i(T_i)$ shown in Fig. 2C. This allows the correlation characteristic $P_i(T_i)$ serving as a reference to be determined, whereby an optimum light transmittance Q_0 for the normal liquid crystal 2 at the liquid crystal application voltage V_i is obtained. Almost simultaneously with this, the controller 7 calculates the light transmittance Q_i of the liquid crystal 2 in use from the irradiation quantity of light R_1 and the transmitted quantity of light R_2 (step 103). Since the irradiation quantity of light R_1 from the light emitting

means 5 is determined by the quantity of electricity the controller 7 has supplied to the light emitting means 5, this quantity of electricity is obtained through internal processing.

Next, the controller 7 makes a judgment as to whether the light transmittance Q_i is equal to the optimum light transmittance Q_o or not (step 104). When it is determined that it is not, the applied voltage V_i of the liquid crystal is adjusted so that the light transmittance Q_i becomes equal to the optimum light transmittance Q_o (step 105). This procedure is based on the fact that, if there is no deterioration in the liquid crystal 2, the light transmittance Q_i is equal to the optimum light transmittance Q_o and is constant, whereas, if the liquid crystal 2 has deteriorated, the light transmittance Q_i becomes, as stated above, larger than the optimum light transmittance Q_i even when the liquid crystal temperature T_i or the applied voltage V_i of the liquid crystal is the same (The characteristics shown in Fig. 2C: $P_i(T_i) \rightarrow P_{u1}(T_i) \rightarrow P_{u2}(T_i)$). By adjusting this applied voltage V_i of the liquid crystal, it is possible to obtain the optimum light transmittance ($Q_i = Q_o$) even when the liquid crystal 2 has deteriorated. However, when the deterioration of the liquid crystal 2 further progresses, a condition is brought about in which, as indicated by the characteristic $P_{u2}(T_i)$, the

optimum light transmittance Q_0 cannot be obtained even by adjusting the applied voltage V_i of the liquid crystal ($V_i \rightarrow V_{ie}$, $Q_i \neq Q_0$) (step 106). In this case, it is determined that the liquid crystal 2 is at the end of its service life (step 107), and a display to that effect is output as required (step 108). As stated above, printing is performed while checking the condition of the characteristics of the liquid crystal on the basis of a rational judgment, so that a satisfactory level of clearness is obtained, and an optimum printing condition is maintained. Further, it is possible to properly check the service life of the liquid crystal.

Further, as shown in Fig. 3, steps 106 through 108 in the software construction of the controller of the above-described embodiment (See Fig. 2A) may be omitted. This makes it possible to maintain an optimum printing condition. The time for replacement of the liquid crystal may be decided upon by setting it in advance in terms of printing time, etc., checking the printing condition of the workpiece surface, etc. Further, in an applied case, in step 105 of the above-described embodiment, the progress in the deterioration of the liquid crystal may be visually output based on the amount of adjustment of the liquid crystal application voltage.

A preferred embodiment of a laser liquid crystal marker

according to the second aspect of the invention will be described in detail with reference to the accompanying drawings.

Fig. 4 shows the hardware construction of this embodiment. The construction of this embodiment only differs from that of Fig. 1 in that the temperature sensor 4 is removed, so a description of the hardware construction will be omitted, and the software construction will be described with reference to Fig. 4 and Fig. 5, the latter of which shows an example of the software. In the controller 7, a reference value S_0 of the light transmittance of a normal liquid crystal 2 is set beforehand through external operation (step 121). Input to the controller 7 are the irradiation quantity of light R_1 of the light emitting means 5 and the transmitted quantity of light R_2 from the light receiving means 6, on the basis of which a detection value S_i of the transmittance is calculated (step 122). Next, the controller 7 compares the detection value S_i with the above-mentioned reference value S_0 (step 123). When they are not equal to each other, it adjusts the applied voltage V_i of the liquid crystal so that they become equal to each other (step 124). This makes it possible to constantly maintain a high level of printing accuracy. This embodiment is particularly suitable for cases in which there is no need to consider the liquid crystal temperature T_i as a parameter,

for example, a case in which the apparatus is installed in an environment of a constant temperature.

Next, Fig. 6 shows an embodiment of the software construction which is different from that of Fig. 5. Previously set in the controller 7 through external operation are the reference value S_0 of the light transmittance of a normal liquid crystal 2 and the liquid crystal application voltage threshold value V_m , of which the maximum and minimum application voltage threshold values V_{max} and V_{min} are determined beforehand (step 131). The controller 7 calculates the detection value S_i of the light transmittance from the irradiation quantity of light R_1 of the light emitting means 5 and the transmitted quantity of light R_2 of the light receiving means (step 132). Next, it compares this detection value S_i with the reference value S_0 (step 133). When the values are different from each other, it adjusts the applied voltage V_i of the liquid crystal by increasing or decreasing it so that the detection value S_i becomes equal to the reference value S_0 (step 134). In this adjustment, the adjusted applied voltage V_i of the liquid crystal is compared with the maximum application voltage threshold value V_{max} and the minimum application voltage threshold value V_{min} (step 135). When $V_i \geq V_{max}$ (step 135-1), or when $V_i \leq V_{min}$ (step 135-2), a warning is output (step 136). The warning can be given by a separately

provided alarm, display lamp or the like. Due to this arrangement, it is possible to maintain the printing accuracy at a constant level and properly judge the degree of deterioration of the liquid crystal, which must be dealt with by replacement or the like.

The term "light transmittance" also covers the following cases, etc: for example, in the calculation of the light transmittances Q , Q_0 and Q_i , when all the values of the irradiation light quantity R_1 of the light emitting means 5, on which they are based, are the same, the object of the present invention can be achieved solely through comparison of the transmission light quantities R_2 , without having to calculate the light transmittances Q , Q_0 and Q_i one by one. In another case, the irradiation quantity of light R_1 when calculating the optimum light transmittance Q_0 of the normal liquid crystal 2 and the irradiation quantity of light R_1 when calculating the light transmittance Q_i of the liquid crystal 2 in use are set in a predetermined proportion (for example, $1/1.5$), whereby it is possible to achieve the object of the present invention through comparison of the transmittance light quantities R_2 . Thus, in these cases also, the operation is substantially the same as the calculation of the light quantity.

A preferred embodiment of a laser liquid crystal marker according to the third aspect of the invention will now be

described in detail with reference to the accompanying drawings.

This embodiment will be separately described with respect to the hardware and software constructions thereof. In the hardware construction, as shown in Fig. 4, the laser beam L1 emitted from the laser oscillator 1 first travels through a beam shaping device 81, and is first deflected in the Y-direction by the galvanoscanner 9Y. Then, it is deflected in the X-direction by the polygon mirror 9X to scan a still image for marking on the liquid crystal 2. The laser beam thus deflected is further deflected by a lens 82 and condensed on a reflecting mirror 83. In this process, scanning irradiation is effected on the still image for marking of the liquid crystal 2. A transmission laser beam L2, which is in conformity with this still image for marking, is applied to the reflecting mirror 83. The transmitted laser beam L2, reflected by the reflecting mirror 83, is transmitted through an objective lens 84 before it is applied to the surface of a workpiece 3 on a work feeder 10 to thereby print the still image for marking on the surface of the workpiece 3. In this construction, the driving system for the laser oscillator 1, the XY deflectors 9X and 9Y, the liquid crystal 2 and the work feeder 10, is electrically connected to a controller 7 and synchronously controlled by the controller 7.

Further, apart from the above still image for marking, the liquid crystal 2 also displays, as needed, a still image for testing through application of voltage from the controller 7. Further, light emitting means 5 consisting of a light emitting device or the like and light receiving means 6 consisting of a light receiving device or the like are provided. Light from this light emitting means 5 is transmitted through the still image for testing displayed on the liquid crystal 2, and the transmitted light is received by the light receiving means 6. Further, the transmitted quantity of light R_2 of this received light is output to the controller 7 from the light receiving means 6. The light emitting means 5 and the light receiving means 6 are electrically connected to the controller 7 and synchronously controlled by this controller 7. Further, the controller 7 stores in advance an optimum light transmittance Q_0 and the irradiation quantity of light R_1 of the light emitting means 5. The optimum light transmittance Q_0 is a value set in the controller 7 in advance based on the characteristics of the liquid crystal 2 when the laser liquid crystal marker is in continuous service.

Next, the software construction will be described. As shown in Fig. 7, this embodiment consists of a high-accuracy, high-speed continuous printing laser liquid crystal marker having a printing cycle t of approximately

0.8 seconds. One cycle is composed of a marking still image display time (printing time) t_1 , which is approximately 0.3 seconds, and a workpiece standby time (workpiece moving and printing position fixing time) t_2 , which is approximately 0.5 seconds. The workpiece standby time t_2 is composed of interrupt display periods t_{21} for the testing still image, each of which is approximately 0.1 seconds, and potential equalization periods t_{22} for adjusting the voltages at all the common and segment terminals of the liquid crystal 2 to 0V (that is, grounding all the terminals), each of which is approximately 0.04 seconds. These display and potential equalization periods are each repeated three times. A control flowchart for this repetitive control is shown in Fig. 8.

In this construction, of the three occurrences of the interrupt display of the still image for testing, in the first interrupt display period t_{21} for the testing still image, the controller 7 inputs the transmitted quantity of light R_2 from the light receiving means 6, and, from this transmitted quantity of light R_2 and the irradiation light quantity R_1 , calculates the actual light transmittance Q_i , adjusting the applied voltage V_i of the liquid crystal for still images so that the light transmittance Q_i becomes equal to the optimum light transmittance Q_0 . This makes it possible to maintain a high-accuracy printing even in the

case of a laser liquid crystal marker of a high-speed continuous printing type. It is naturally possible to repeat the input, calculation, comparison and adjustment in all of the three interrupt display periods, or this repetition may be only effected at odd or even numbers of times of occurrence of interrupt display as needed. Further, the number of times of interrupt display in the workpiece standby period t_2 is not limited to three; it may also be two or less or four or more.

Although the above embodiment has been described with reference to a laser liquid crystal marker of a high-speed continuous printing type, it should be noted that the display of a still image for marking subsequent to a still image for testing must inevitably mean that the still image for testing is erased. Thus, in a laser liquid crystal marker in which there is sufficient time for the after-image of the still image for testing to disappear, it is only necessary to effect interrupt display of the still image for testing during a rewriting period for still image for marking if the printing to be performed is such that it allows sufficient time for the after-image to disappear.

A preferred embodiment of a method of judging deterioration of liquid crystal according to the fourth aspect of the invention will be described with reference to the accompanying drawings.

In this embodiment, only that section related to the judgment of deterioration of liquid crystal in the first aspect of the invention is extracted as an application example. Fig. 9 schematically illustrates the construction of a laser liquid crystal marker according to this embodiment. First, to check the condition of deterioration of the liquid crystal 2, the liquid crystal 2 is irradiated with light in an irradiation quantity R_1 from the light emitting means 5, and the light transmitted through this liquid crystal 2, in a transmitted quantity of light R_2 , is received by the light receiving means 6, and, on the basis of the irradiation light quantity R_1 and the transmitted quantity of light R_2 , a light transmittance Q_1 is calculated by the controller 7. With respect to this light transmittance Q_1 , items of data obtained through changes with time are compared with a light transmittance serving as a reference corresponding to the limit of deterioration; when the data obtained through changes with time is in excess of this reference value, it is determined that the liquid crystal 2 has deteriorated. Due to this arrangement, it is possible to judge the deterioration of the liquid crystal rationally and correctly. Regarding the environment in which the laser liquid crystal marker is to be installed, if it is difficult to maintain the liquid crystal 2 at a fixed temperature, it is desirable to equip the liquid

crystal 2 with a temperature sensor 4 and take the temperature into account when judging the degree of deterioration. Further, this method of judging deterioration is, as is apparent from the hardware construction schematically shown in Fig. 9, applicable to the laser liquid crystal markers of the present invention described above. Further, it is also applicable to ordinary laser liquid crystal markers as long as they use a transmission-type liquid crystal 2.

The laser liquid crystal markers to which the present invention are applicable are not limited to the types of laser liquid crystal markers as shown in the above embodiments but are applicable to other types of laser liquid crystal markers. There is naturally no limitation regarding the type of lens, the mounting position thereof, etc. Further, instead of the XY deflectors in the above-described constructions (See Fig. 1) (That is, scanning can be done away with), it is possible to adopt, for example, a system in which a laser beam L1 is collectively applied from the laser oscillator 1 to the entire pattern of the liquid crystal 2 through a magnifying lens, or a system in which, instead of the reflecting mirror 83, a second XY deflector is additionally provided at this position so as to realize a wide printing range without having to move the workpiece.

INDUSTRIAL APPLICABILITY

In accordance with the present invention, there are provided a useful laser liquid crystal marker and method of judging deterioration of liquid crystal in which the application voltage is controlled for adjustment in correspondence with the degree of deterioration of the liquid crystal, whereby a high level of printing accuracy can be maintained, and the time for replacement of the liquid crystal can be determined; further, even in the case of a continuous high-speed printing, a high-level of printing accuracy can be maintained.

WHAT IS CLAIMED IS:

1. A laser liquid crystal marker at least comprising: a laser oscillator, a liquid crystal for arbitrarily displaying a pattern, and a controller connected to said liquid crystal and adapted to control an applied voltage V_i of the liquid crystal for displaying said pattern, a laser beam emitted from said laser oscillator and transmitted through said liquid crystal being applied to the surface of a workpiece to thereby print said pattern on the surface of said workpiece, wherein connected to said controller are a temperature sensor for detecting a liquid crystal temperature T_i , light emitting means for applying light to said liquid crystal, and light receiving means for receiving the light transmitted through said liquid crystal, and wherein said controller stores in advance correlation characteristics P of liquid crystal application voltages V and light transmittances Q using liquid crystal temperatures T in a normal liquid crystal as parameters, and, input to the controller are an irradiation quantity of light R_1 emitted from said light emitting means and a transmitted quantity of light R_2 received by said light receiving means, the controller calculating a light transmittance Q_i from the quantity of light R_1 and the quantity of light R_2 , and, further, extracting from said correlation characteristics P an optimum light transmittance Q_0 corresponding to the



applied voltage V_i of the liquid crystal at the time of the above calculation and the liquid crystal temperature T_i supplied from said temperature sensor, adjusting said applied voltage V_i of the liquid crystal so that said light transmittance Q_i becomes equal to said optimum light transmittance Q_o .

2. A laser liquid crystal marker according to Claim 1, wherein said controller stores in advance correlation characteristics P of liquid crystal application voltage V and light transmittance Q using liquid crystal temperatures T in a normal liquid crystal as parameters, and, input to the controller are an irradiation quantity of light R_1 emitted from said light emitting means and a transmitted quantity of light R_2 received by said light receiving means, the controller calculating a light transmittance Q_i from the quantity of light R_1 and the quantity of light R_2 , and, further, extracting from said correlation characteristics P an optimum light transmittance Q_o corresponding to the applied voltage V_i of the liquid crystal at the time of the above calculation and the liquid crystal temperature T_i supplied from said temperature sensor, adjusting said applied voltage V_i of the liquid crystal so that said light transmittance Q_i becomes equal to said optimum light transmittance Q_o , and wherein, when the light transmittance



Q_i does not become equal to the optimum light transmittance Q_0 even by adjusting the applied voltage V_i of the liquid crystal, said controller outputs a message to the effect that said liquid crystal has deteriorated.

3. A laser liquid crystal marker at least comprising: a laser oscillator, a liquid crystal for arbitrarily displaying a pattern, and a controller connected to said liquid crystal and adapted to control an applied voltage V_i of the liquid crystal for displaying said pattern, a laser beam emitted from said laser oscillator and transmitted through said liquid crystal being applied to the surface of a workpiece to thereby print said pattern on the surface of said workpiece, wherein, connected to said controller are light emitting means for applying light to said liquid crystal and light receiving means for receiving the light transmitted through said liquid crystal, and wherein said controller stores in advance a reference value S_0 and, input to the controller are an irradiation quantity of light R_1 emitted from said light emitting means and a transmitted quantity of light R_2 received by said light receiving means, the controller calculating a detection value S_i thereof, adjusting the voltage V_i applied to said liquid crystal so that said detection value S_i becomes equal to said reference value S_0 .



4. A laser liquid crystal marker according to Claim 3, wherein said controller stores in advance a reference value S_0 and an application voltage threshold value V_m and inputs an irradiation quantity of light R_1 emitted from said light emitting means and a transmitted quantity of light R_2 received by said light receiving means to calculate a detection value S_i thereof, adjusting the voltage V_i applied to said liquid crystal so that said detection value S_i becomes equal to said reference value S_0 , and wherein, when said voltage V_i applied to the liquid crystal is in excess of the application voltage threshold value V_m , said controller outputs a warning.

5. A laser liquid crystal marker at least comprising: a laser oscillator, a liquid crystal for arbitrarily displaying a pattern, and a controller connected to said liquid crystal and adapted to control an applied voltage V_i of the liquid crystal for displaying said pattern, a laser beam emitted from said laser oscillator and transmitted through said liquid crystal being applied to the surface of a workpiece to thereby print said pattern on the surface of said workpiece, wherein, connected to said controller are light emitting means and light receiving means, wherein a voltage is applied to said liquid crystal from said



controller to successively effect rewrite display of various still images for marking and display, as needed, a still image for testing, said light emitting means projecting light onto said still image for testing, said light receiving means receiving the light transmitted through said still image for testing, and wherein said controller stores in advance an optimum light transmittance Q_0 , effects interrupt display of said still image for testing during at least one of the rewrite procedures for said still images for marking, inputs, during said interrupt display, a transmitted quantity of light R_2 from said light receiving means, and calculates the light transmittance Q_i of said liquid crystal from said transmitted quantity of light R_2 and the irradiation quantity of light R_1 of said light emitting means, adjusting the voltage V_i applied to said liquid crystal so that said light transmittance Q_i becomes equal to said optimum light transmittance Q_0 .

6. A laser liquid crystal marker according to Claim 5, wherein said controller stores in advance an optimum light transmittance Q_0 , first effects display of said still image for testing during at least one of the rewrite procedures for said still images for marking, then effects interrupt of repetition of equalization in electric potential of all the common and segment terminals of said liquid crystal, inputs,



during said interrupt, a transmitted quantity of light R2 from said light receiving means, and calculates the light transmittance Q_i of said liquid crystal from said transmitted quantity of light R2 and the irradiation quantity of light R1 of said light emitting means, adjusting the voltage V_i applied to said liquid crystal so that said light transmittance Q_i becomes equal to said optimum light transmittance Q_o .

7. A method for judging deterioration of liquid crystal for use in a laser liquid crystal marker which is equipped with a liquid crystal for arbitrarily displaying a pattern and which applies a laser beam emitted from a laser oscillator and transmitted through said liquid crystal to the surface of a workpiece to thereby print said pattern on the surface of said workpiece, wherein said liquid crystal is irradiated with light in an irradiation quantity of light R1, and wherein a transmitted quantity of light R2 from said liquid crystal is detected to calculate a light transmittance Q_i based on said irradiation quantity of light R1 and said transmitted quantity of light R2, the degree of deterioration of said liquid crystal being judged from changes with time of said light transmittance Q_i .

