Title	Condition Setting Method Utilizing Data Base System in CO₂ Laser Surface Hardening (Report I) : Fundamental Concept(Welding Physics, Processes & Instruments)
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Condition Setting Method Utilizing Data Base System in CO_2 Laser Surface Hardening (Report I) [†]
— Fundamental Concept —

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Abstract

One of the welding condition setting method is investigated. Decision of the welding condition is performed by the heuristic method utilizing data base system. In this study, the authors avoid to fix the relations among parameters by using the data on welding in the form of data base where any parameters or any relations among them can be easily managed.

The study is restricted within the condition setting of "CO_2 Laser Surface Hardening", as the primary approach for welding condition setting.

KEY WORDS: (Computation) (Data) (Process Conditions) (Optimisation) (CO_2) (Lasers) (Hardening)

1. Introduction

The welding condition setting method has been studied by many researchers in the numerical method, on the basis of experimental data, using computer.[1,2,3]

However, it is well known that the actual welding is affected by the very various factors and it has many problems in practical ·use to set the welding condition under the fixed relations among parameters as usually done in the method which is widely used at present, because it is comparatively easy to construct the algorithm.

In this study, the authors avoid to fix the relations among parameters by using the data on welding in the form of data base where any parameters or any relations among them can be easily managed. Therefore, the flexible method can be used and we determine the optimum welding conditions or get the very powerful tool for the welding condition setting by using such data base.

It is important to utilize the data effectively in the laser welding that has only little data, partly because of the shortness of its history. Then, as the first experiment of "Condition Setting Method Utilizing Data Base", this study is restricted within the condition setting of "CO_2 Laser Surface Hardening".

The following is discussed on the condition setting method of CO_2 laser surface hardening utilizing data base, especially on the partial surface hardening method of the material of complicated shape that has high necessity for CO_2 laser.[4,5,6]

2. Organization of Software System

As this study is utilizing the data base, it is important not only to use it easily, but also to put it independent of the application system. That is, we use the data base free from care of its all maintenance.

The software system developed in this study is composed of two parts, the data base management part and the processing part that decides the surface hardening conditions on the basis of data. The block diagram of the system is shown in **Fig. 1**. The core of this system is condition calculation program, and the main subject in this study is how to construct it. The condition setting of surface hardening is made in this program. Therefore, it can be said that other program modules are prepared for servicing the necessary data to this program.

In a series of modules, a part of data base manager and semantic formatter is the resident part of the system, and other modules are activated at need. The comunication between data base management part and processing part is unified in the form of supervisor call that is called data base comunication line

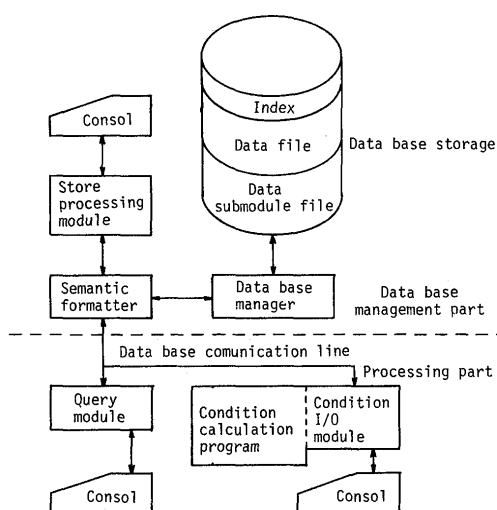The following is described the outline of each module.

Fig. 1 Block diagram of software system

2.1. Semantic formatter

This module generates the structure of data base on the basis of the schema or subschema, and organizes and modifies all data submodels through data base manager.[7, 8]

That is to say, it interfaces between two logical data structures, the first is defined and used at the processing part, the second is managed by data base manager. The integrated data base can be utilized and maintained and its independence can be assured with this method. Using this module, the data submodel of the only data that is necessary in any studies is organized in free format, and it can realize the short access pass and free operation.

2.2. Data base manager

This module converts between the structures of physical memory and logical memory, that is, it inputs and outputs logical data on request from the semantic formatter.

The physical memory structure is based on the concept of modified B-tree and the data structure of LISP.[9, 10]

By this structure, the physical access time is shortened, and the organization of the data submodel based on a subschema is simplified. Usually all the necessary data can be included in the submodel. Therefore, it is possible to speed up the data submodel organization and to shorten the access path to the model.

2.3. Store processing module

This module is activated at the time the data are fed to the data base. By using this module in the query-answer form data are modified and saved to the data base in the format of the schema that was determined at the start of the data construction. This module requires the necessary data on the results of experiments with their conditions. Because few experimental data generally have all parameters known, the module fits the input data for the data base structure by editing their defecs and redundancies. This edition is important for the data base to have flexibility.

2.4. Query module

The data base is directly accessible through the consol by this module, and the data can be retrieved by the set of key words and, or the appointment of the data structure. In addition to the conventional commands[11, 12] this module has some commands to examine the subschema and to construct the data submodel which are important functions for this study. As this module can run not only interpreter mode, but also direct mode, the definition of subschema and the data submodel construction based on the subschema are usually carried out with this module when each of condition calculation modules is required.

3. Condition calculation program

Surface hardening conditions are decided utilizing the data base prepared as mentioned above. Because the object of this study is the data processing rather by the form of expression or graph than by the numerical method. LISP is used as the program language in this program. It has the specific interface module for comunication to the data base.[10]

The block diagram of this program is shown in **Fig. 2**, which consists of LISP interpreter, interface module, and each routine for condition calculation written by LISP. The condition calculation routines consist of resident main routines and each utility routine that is rolled in and rolled out by the main routines.

The condition setting method is constructed of two phases.

————In the first phase, the program for condition setting is made from some experimental results. The data base has already been constructed on the basis of the data obtained from the surface hardening experiment of plane plates performed as pre-experiment and the data on the special shaped base metal obtained through the learning which will be discussed after. The processing of the first phase is made by condition evaluation main routine. The program of condition setting is constructed by this routine using any utility routines based on the heuristic method.[13] (Differentiation and integration of the primary functions, and evaluation of equations and dynamic examination of equations.)

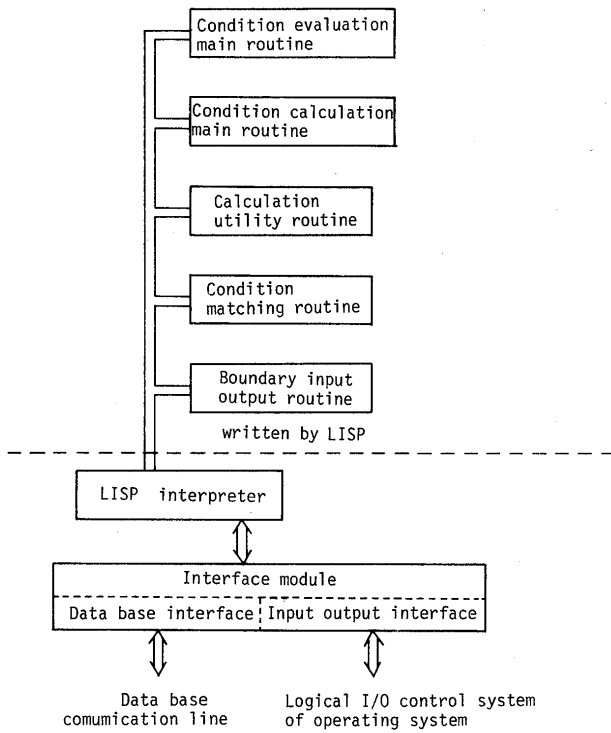As parameters for saving the experimental data to data base,

Fig. 2 Block diagram of condition calculation program

each condition parameter of
　—Dimension and physical constants of base metal
　(heat conductivity, specific heat, CCT curve, density,
　hardness, absorptivity of laser beam, width, length,
　thickness, shape)
　—Characteristics of laser beam
　(output power, spot size, distribution, scan speed)
and each result parameter of
　—Surface hardness and three-dimensional distribu-
　tion
　—Metal structure
are all or partly used.
and as the base of processing, the basic equation of
point heat source equiation (1) is used.

$$T = \frac{q}{c\rho} \frac{e^{-\frac{r^2}{4kt}}}{(2\sqrt{\pi kt})^3} \qquad (1)$$

where r^2 : $x^2 + y^2 + z^2$
　　q : impulse heat input by laser beam at origin
　　　　(0,0,0) and time 0
　　c : specific heat of base metal
　　ρ : density of base metal
　　k : thermal diffusivity of base metal
　　t : time
　　T : temperature at position (x, y, z)
and the equation that integrates
the laser beam distribution and time are:

$$T = \frac{Ak}{4c\rho(\sqrt{\pi k})^3} \int_0^\infty \frac{dt}{\sqrt{t^3}} \int_{-\infty}^\infty dx' \int_{-\infty}^\infty w(x',y')$$

$$exp \left[-\frac{(x - x'+vt)^2 + (y - y')^2 + z^2}{4kt} \right] dy \qquad (2)$$

where $w(x, y)$:　heat input density at position (x, y)
　　　A　　　: absorptivity of beam
　　　v　　　: velocity for x direction
　　　T　　　: temperature at (x, y, z) when the
　　　　　　　　heat source moves on a semi-infinite
　　　　　　　　plane from infinite distance on the
　　　　　　　　x axis by the velocity v
　　These equations are evaluated by symbolic
manipulation in the condition evaluation routine.
　　Equation (3) is used if the cooling rate is required.

$$\frac{\partial T}{\partial t} = k \nabla^2 T \qquad (3)$$

The program examines the symmetry and equivalence
of each axis, and automatically analizes by the symbolic
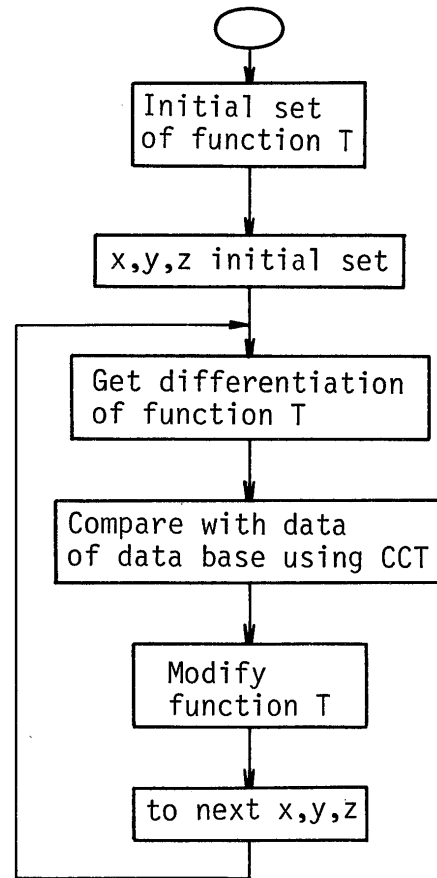manipulation using differentiation and so on.

Fig. 3 Concept of function T investigation

And, as the data base has CCT curve data, the program examines three-dimensional distribution of temperature, and its cooling rate, refers them to CCT curves, automatically analizes the approximate expression of T or $\partial T/\partial t$ etc., and evaluates it as correct expression by fixing the parameters. The approximate expression can not be always proved theoretically. The concept of this algorithm is shown in **Fig. 3**.

———In the second phase, the practical conditions of surface hardening are decided. This processing is carried out at the condition calculation main routine. To satisfy the surface hardening requirements that were fed by boundary I/O routine, this routine tries to find out the conditions by the heuristic method using all expressions that are obtained in phase 1. The expressions in this place are not only the equations, but also the procedures in general means. The routine outputs the most reliable conditions, or outputs that the requirements are impossible. Then we actually examine by the conditions of output, and feed the result to this routine. If the result is suited to the requirements, the process is finished, and if not, as the program tries to find out the conditions using the result with the priority, this process continues until the suitable result is got. It is regarded that the system learnes in the broader means on feeding the result to the store processing module.

As already stated, each processing of two phases is done by the condition evaluation main routine and the condition calculation main routine. These two routines utilize calculation utility routine for the analysis of expressions, condition matching routine for the comparision with data in data base, and boundary input output routine for the input, output through the consol. Each of these routines is cut off from the main routine and treated as the garbages, when it becomes unnecessery.

The results of the evaluation are stored as the utility routine with the restricted conditions by manual, thus the program can learn. Once the utility routine was stored, until it is deleted by any reason, it is activated as one utility routine by the main routine.

4. Conclusion

The above mentioned method is to analize and decide the conditions by the heuristic method based on the thought that the data base is a concurrence of information and knowledge against the condition setting algorithms that is ordinarily made by simply using several equations or loops.

Although this method is not always better than the manual analysis by cut and try method at present, the authours are confident that such research method will take a good position of laboratory automation when it is taken into consideration that the computer science will be developed at increasingly rapid speed.

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