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FUTURE DIRECTION OF WELDING STRUCTURE PRODUCTION

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Abstract

"On basis of a general survey on the history of industrialization of developed countries in the world, the authors point out the welding technology, particularly the arc welding, still Wl be one of the most important technology used for making heavy industry structures in the future, even for quite a long historical period. But differs FM the past 30 years, it Wl be greatly reformed with the development of high tech, namely electronics n computer science. The remarkabe characteristics of this reform Wl be automation of welding structure production. In order to promote this trend three directions, namely, intelligent control of the welding process, welding expert system n FMS CIMS of welding structure production are emphasised. Finally several projects which are considered of importance at the moment are mentioned."

1. INTRODUCTION

(1) Trends of Welding Structure Production in China in View Point Industry Development History.

In order to predict the trends of welding structure production in China, it is necessary to make a short review on the history of the main industrialized countries in the world. Table 1 shows the changes of most prosperous industry with the age for the main industrialized countries in the world. It can be found that there is a common rule, the industries were developed according to the order, light and textile industry; shipbuilding, petroleum and chemical industry; automobile industry, electronics industry, aeronautic and aerospace industry. It displays the general law of development of science and technology of the mankind. All of the industrialized countries has gone through a period of prosperously developed heavy industry with shipbuilding, petroleum, chemical and automobile industries as it representatives. To study on the situation of this period, it is not difficult to find that it has two special features.

A. Rapid development of iron and steel industry i.e. rapid increase of steel production.

As the products of heavy industry are heavy, thick and big, it requires large steel consumption. Quantity of steel production of a country reflects its level of heavy industry development.

B. Welding technology plays a significant role in industrilization of the nation.

According to statistics more than 40% of the produced steel can be turned into products only when they are processed by welding technology. All the equipments for shipbuilding, petroleum, chemical and power engineering industries are made of heavy welded structures, they can not be made without welding technology, particularly arc welding technology. Therefore it requires and inevitably makes the progress of welding technology. Table 2 lists the steel production of Japan, it can be seen that it increased rapidly

Table 1 The most prosperous industries of developed countries in different age.

Country	Ages				
	Before War II	1950s	1960s	1970s	1980s
U.S.A.	Ship Building Petrochemical Industry	Automobile Industry		Electronic Industry	Aerospace Industry
W. Europe	Textile & Light Industry	Ship Building, Petrochemical Industry	Automobile Industry		
Japan		Textil & Light Industry	Ship Building, Petrochemical Industry	Automobile Industry	Electronic Industry
S. Korea Taiwan				Ship Building, Petrochemical Industry	Automobile Industry

Table 2 Production of steel in Japan.

Year	1920	1940	1945	1950	1960	1970	1975	1980	1985
Annual output (million ton)	1	6	0.6	5	21	86.5	110	100	105

after 1960 with its development of shipbuilding, petroleum and chemical industries, in 1975 it broke hundred million tons per year. The steel production keeps more or less stable when heavy industry is developed to a certain high level. According to statistics the heavy industry may be regarded as being matured when the steel production reach the norm of about 600 kg per person. Japanese experts considered that Japan's heavy industry with steel, shipbuilding, huge structure and automobile production as its core became matured in 1980. The manufacturing industry of heavy structures in USA shrinked already in 1970's. Although its steel production did reach 150 million tons per year, but it returned back and fluctuates around 80 million tons per year in last years.

The situation faced by our country is quite different, the level of heavy industry in China is very low. If taking the steel production per person as criterion, then it lags behind not only after USA, Japan and European countries but also some of the developing countries (see Table 3). As published in official report of Chinese goverment the increasing rate of steel production in China in the near future will be 2.5 million tons per year, accordingly it will reach totally 90 million tons per year or 75 kg per person-year in 2000 (see Table 4). That means China still has to go a long way to develop its heavy industry. It can be expected that welding structure production will have a great development in the near future.

(2) Direction of Welding Structure Production in China

It differs from USA Japan and other industrialized countries, China will develope its heavy inductry in the age of high tech. Therefore, it provides the possibility to absorb the most advanced technology, such as electronics, computer, robot and intelligent technology for the development of welding structure production. To automate the welding structure production with the aim of improving quality, increasing productivity, and replacing the manual operation particularly under extreme conditions (preheating, underwater conditions etc.) will be the main direction of the technology of welding structure production in China. In this way China can make it much faster to develope its heavy industry than USA, Japan and other industrialized countries.

To Promote the automation of welding structure production in China several points are of great importance which can be described below.

Table 3 Steel production and population in 1985

Country or district	Annual Output (million ton)	Population (million)	Annual Output per person (kg/person)
U.S.S.R.	154	260	592
Japan	105	110	1,050
U.S.A.	80.3	220	365
W. Germany	40.3	61	664
Italy	23.7	56	423
France	18.8	53	355
UK	15.7	55	285
India	11.4	620	18
Brazil	20.5	112	183
Spain	14.2	36.6	388
Canada	14.5	23	630
Australia	6.4	14	457
Sweden	4.8	8	600
Mexico	7.4	64.6	115
The Netherlands	5.5	13.9	397
S. Korea	13.5	36	375
Taiwan	5	15	333
Turkey	4.9	42	116
China	46.7	1000	47
Total	717	4000	173

Table 4 Steel production in China

Year	1982	1983	1984	1985	1986	1987	2000 (plan)
Output per year (million ton)	37.2	40	43.4	46.7	50	56	90

2. INTELLIGENT CONTROL OF WELDING PROCESS

Welding is one of the most complicated means of metal processing. There is a lot of parameters and operations which should be controlled in order to achieve good quality of weld. For several decades many efforts have been made to mechanize the process, but up to the moment, mechanization can be achieved only for individual operation or parameters. In order to guarantee the welding quality, the welding process as whole is still conducted under supervision of human-being. The available developments in this field which can be mentioned are automatic arc length control, bead width or penetration control, wire extension control, automatic seam tracking etc. All these developments may be classified according to its nature as single input-single output closed loop control system, the block diagram of which is shown in Fig. 1. This type of control is simple in construction and easy to realize. It is worthy to mention a recent development regarding welding power source, the adaptive control of pulse MIG welding process. According to the signal of arc length the power source can determine itself 4 welding parameters, so that to keep the arc stable with spray metal transfer over wide range of welding current. This system may be classified according to its principle of operation as multi-input multi-output adaptive control system, the block diagram of which may be shown as Fig. 2. In this system the output signals are not only fed back to the comparator, but also to an indentifier which can judge the situation of the arc operating point and regulate both input signals and parameters of controller.

Although above mentioned developments have played significant role in the automation of welding process, but it is still far away from full automation of welding process. Complicated factors and un-

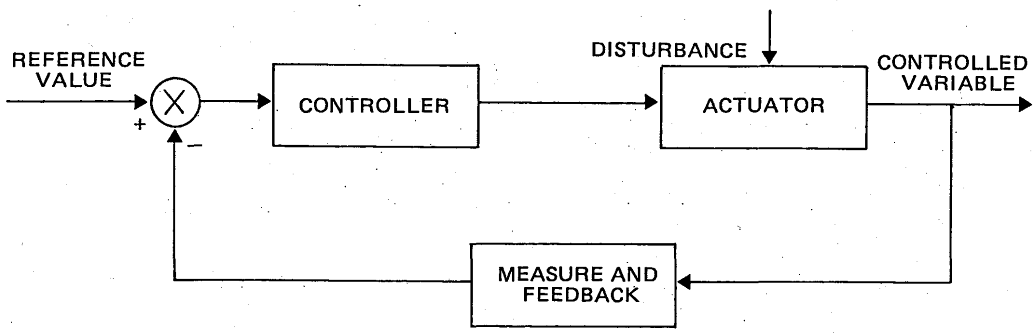

Fig. 1

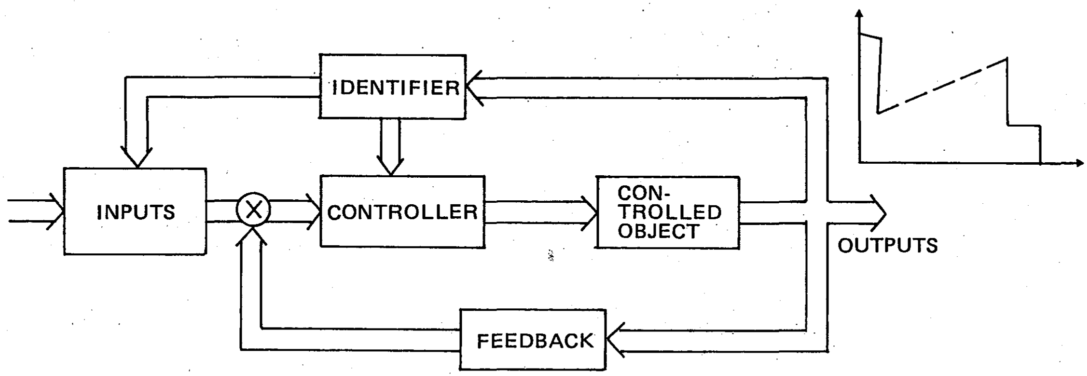

Fig. 2

predictable phenomena which may happen in random way during the welding process require the control system to change its input signals adaptively, so that to keep the welding process in optimun conditions. This type of control may be classified as multi-input and multi-output intelligent control system the block diagram of which is shown in fig. 3. During welding the system measures all necessary parameters which have effect on or reflect the weld quality, such as voltage, arc length, pool width, penetration, torch position and angle, temperature distribution etc. All measured signals are fed back to comparator on one hand, and to a computer of expert system on the other hand. The expert system analyses these signals, calculates, infers and makes decision to change the inputs or parameters of controller in an proper way to adapt to any randam interference occurs during welding.

One of special feature of welding production which should be considered is the large size of the products. Due to this reason the welding process offen has to be performed on site in open area. In order to automate the welding process in such condition new ideas of welding machine should be concieved.

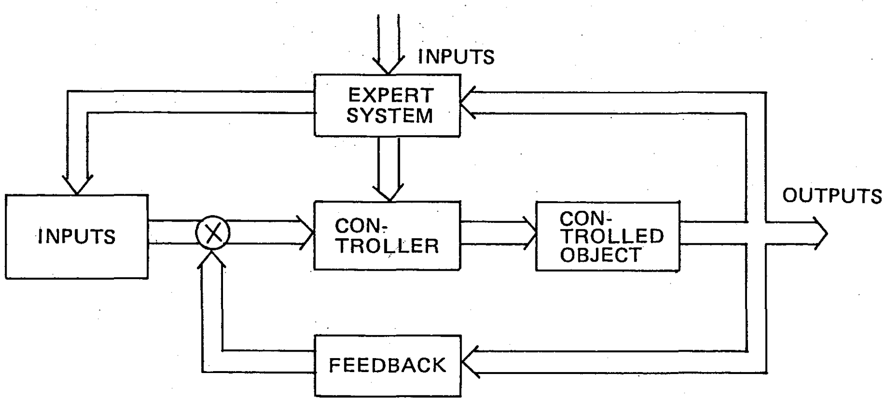

Fig. 3

Figure. 4 shows one example of the welding machine design supposed by the authors. The portable arc welding robot is mounted directly on the product by magnetic fixtures or on the platform of an elevator. It can be moved flexiblely to any position to approach the joints it welds. Due to difficulties arised from large size element assembly and the inevitable phenomena of themal deformation during the welding process the robot has to be adaptable to randam change of the groove position and size. Therefore it should be intelligent controlled with automatic seam tracking system, etc.

In order to realize this goal, there are two important fields to which efforts should be devoted, first, to find out most effective sensors and sensing technique, second, to develope a smart and fast expert system.

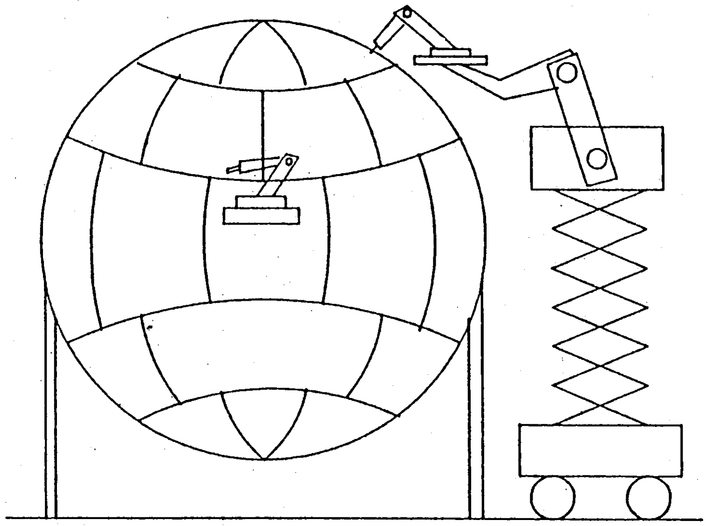

Fig. 4

3. EXPERT SYSTEM FOR WELDING ENGINEERING

Expert systems, with the capacity to offer "intelligint" advice, are currently the subject of intensive research in the field of artifical intelligent (AI). According to reports, the value of AI industrial output in United States is 563 million USD in 1986. The output values of the expert system, natural language processing, computor aided teaching (CAT), image recognition, sound recognition are seperately 126, 117, 40, 210 and 70 million USD. It is estimated that the value of AI industrial output in 1990 in USA will amount to 3156 million USD and the output values of the expert system, natural language processing, CAT, image recognition, sound recognition will amount to 1017, 832, 195, 770, 342 million USD separately. Thus it can be seen that the expert system is growing by the fastest speed and will be the most important part of AI.

Why will the expert system be a subject of intensive research for AI? The reasons are that the complex problem can be solved by using the expert systems in computor without human expert just the same as done by human expert so that the lack of human expert may be overcome. Besides the expert system also helps human expert to deal with complex problems, so that may avoid some mistake and may offer more "intelligent" advice because the knowledge included in which is from human experts of various field and practical experience. So that expert systems will take important part for complex engineering.

The expert system consists of five elements, a knowledge base, an inference engine, an expert interface, an explanation facility and a user interface (see Fig. 5). The knowledge base includes knowledge contained in the welding engineer's memory which was learned at college and from subsequent practical experience at first hand and from discussions with colleagues, as well as useful data for taking decision. The inference engine emulates human expert to offer advice and take decision. The expert interface is one through which the specialist knowledge encapsulates in knowledge base from human experts. The explanation facilities can offer an explanation of its reasoning in the same way as a human expert explains his line of reasoning.

According to the function, the expert systems can be classified into three types. 1) Diagnosis expert system with the capasity to give advice reasoned out by expert knowledge based on given data used for forecast or diagnoses. 2) Design expert used for solving· design and plan problems on the basis of given factors. 3) Real-time control expert system, which using human expert knowledge and based on measured data can forecast or estimate how the control system will be, estimate the unmeasurable condition variables and thus make out decision to perform the real-time control. This type of expert system will solve various problems including those solved by above mentioned two types of expert system. Above three types of expert system will have wide range of application for welding structure construction in the field or design, manufacturing, quality control, evaluation of service life, etc. An example of application of realtime control expert system has been mentioned in last paragraph (see Fig. 3). The expert system encapsulates the expert's knowledge in a form that can be used to give advice based on the inputs and to adjust the parameters of the controller. So that the welding process is conducted as if by a most experienced expert.

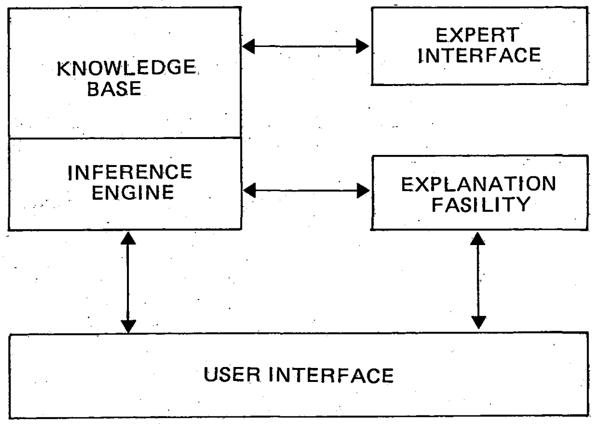

Fig. 5

Diagnoses expert system can be used, for example, to estimate life and evaluate the safety of welded structures, which is of great significant in the construction of important structures wording in critical condition, such as heat or nuclear power plant. This type of expert system should synthesize the expertise of many scientific fields such as fracture mechanics, failure assessment, weldability, etc. In practice it is difficult to find an expert who is familier with all above mentioned knowledge. Using this expert system a common technical person can offer correct evaluation and important decision for the complex engineering ploblems.

Design expert system can be used to offer important advice in the design of welded structure or its manufacturing process and planning. If combine it with CAD, then complete technical drawings and set of welding procedure specification can be obtained. With assistance of this type of expert system one can obtain the best design of the structure and manufacturing process, thus the best quality of weldment and the highest efficiency of manufacturing.

4. AUTOMATION OF WELDING STRUCTURE PRODUCTION

The welding structure is noted for its single piece or small quantity production. Due to serious competition on the market its strategic program and production organization should be made on basis of new management concept adopted already in other manufacturing industries, i.e. PIMS (Profit Impact of Market Strategy). In order to obtain maximum economic effect all the raw materials, semi-products and products should be provided JIT (Just in Time) and JIC (Just in Case). This type of production organization is realized with the aid of computer technique. Figure. 6 shows schematically how the computers could be used for the manufacture of welding structures, in which.

CAD-Computer Aided Design and Drafting. The welding structure and its elements can be designed by CAD with the drawings stored directly in the computer, so that paper drawings may be avoided.

CAP-Computer Aided Planning, with which technology card, inspection card and plan of auxiliary equipments (e.g. jigs and fixtures) could be worked out.

CAPM-Computer Aided Production Management.

CAM-Computer Aided Manufacturing.

To synthesize the control of complete production line in workshop of an element or a structure as a whole is called FMS (Flexible Manufacturing System), which is shown diagramatically as Fig. 7, FMS controls simultaneously processing and material flow system, it increases the flexibility of production, utilization coefficient of equipment, shortens production period, reduces circulating capital and labour

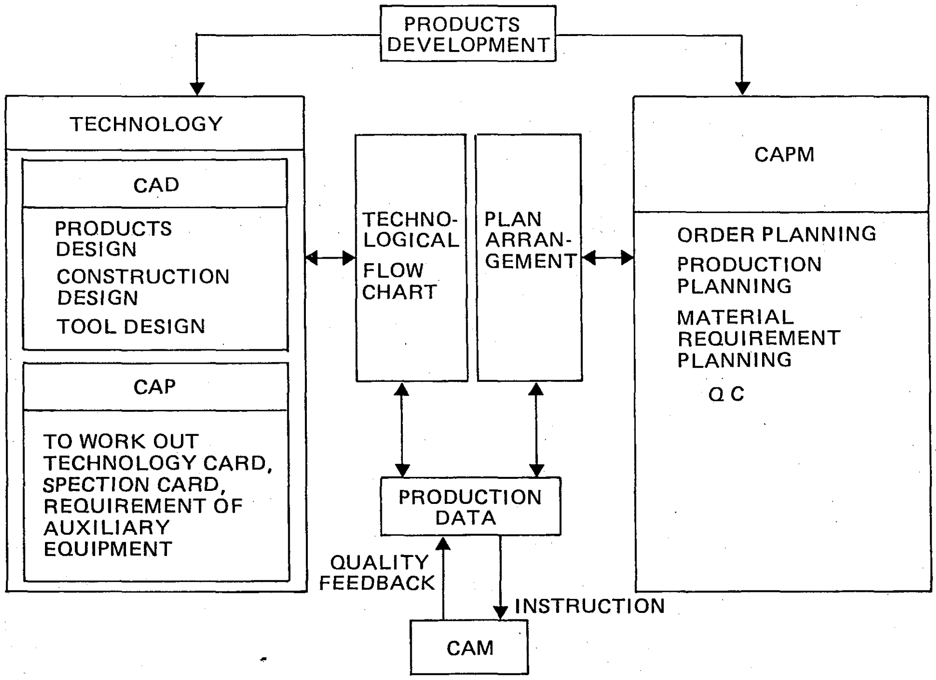
PRODUCTS DEVELOPMENT
TECHNOLOGY
CAD
PRODUCTS DESIGN
CONSTRUCTION DESIGN
TOOL DESIGN
CAP
TO WORK OUT TECHNOLOGY CARD, SPECTION CARD, REQUIREMENT OF AUXILIARY EQUIPMENT
TECHNO-LOGICAL FLOW CHART
PLAN ARRAN-GEMENT
CAPM
ORDER PLANNING
PRODUCTION PLANNING
MATERIAL REQUIREMENT PLANNING
Q C
PRODUCTION DATA
QUALITY FEEDBACK
INSTRUCTION
CAM

Fig. 6

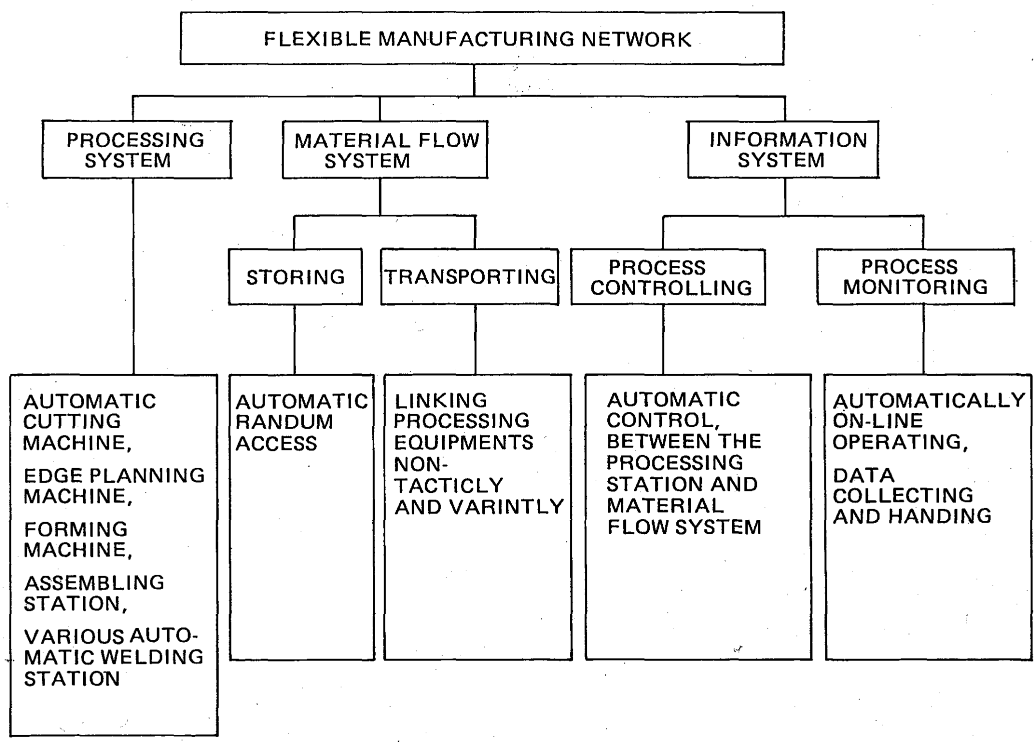
FLEXIBLE MANUFACTURING NETWORK
PROCESSING SYSTEM
MATERIAL FLOW SYSTEM
INFORMATION SYSTEM
STORING
TRANSPORTING
PROCESS CONTROLLING
PROCESS MONITORING
AUTOMATIC CUTTING MACHINE,
EDGE PLANNING MACHINE,
FORMING MACHINE,
ASSEMBLING STATION,
VARIOUS AUTO-MATIC WELDING STATION
AUTOMATIC RANDUM ACCESS
LINKING PROCESSING EQUIPMENTS NON-TACTICLY AND VARINTLY
AUTOMATIC CONTROL, BETWEEN THE PROCESSING STATION AND MATERIAL FLOW SYSTEM
AUTOMATICALLY ON-LINE OPERATING,
DATA COLLECTING AND HANDING

Fig. 7

cost.

Further development of manufacturing industry of welding structures in the near future would be CIMS (Computer Integrated Manufacturing System) in which the "islands of automation" and subsystems are intelligently integrated under the guidance of new management model and new manufacturing technology on the basis of information technology, automation technology and the computer support software. As shown in Fig. 8 it controls all aspects of the manufacturing process, including processing, material flow and management. This system of production would assure high quality, high efficiency, low cost and high flexibility.

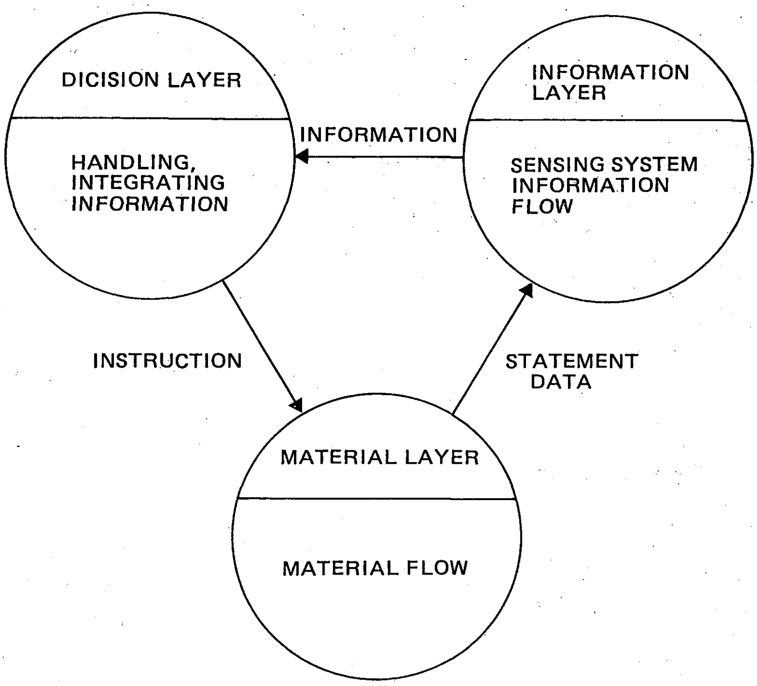

Fig. 8

5. CONCLUSION

To realize the automation of welding structure production is much more difficult than to realize automation of other kind of metal processing. Above mentioned technology is a goal we should make effort to pursue. In fact there is still a distance to go for reaching the goal even in most industrilized countries. At the moment the follow projects could be emphasised in China.

1. Intelligent control of welding and cutting process.
2. Sensing technique for measuring parameters reflecting the weld quality during welding process.
3. Adaptive controlled seam tracking system.
4. Various type of expert system.
5. Various welding and cutting system used for robot.

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