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Computer-aided Production Planning and Control in Shipbuilding

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〈Abstract〉

Some manual and computer-aided approaches to production planning and control were discussed. Approach to successful production planning should be done with an emphasis on maximising utilisation of production resorceslabour, facility and time. Powerful planning tool of maximising facility utilisation is the key to obtaining higher total utilisation of resources. An experimental program was developed and tested. An interactive graphics system on a desk top microcomputer was proved successful to the approach.

COMPUTER를 이용한 선박건조계획 관리

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(1982. 10. 30 접수)

〈요 약〉

선박건조계획관리에 채용되고 있는 수동식 및 COMPUTER이용 기법을 검토하고 생산자원의 사용율을 극대화하는 COMPUTER를 이용한 계획관리 방안을 제안하였다. 선각블록조립공정의 시설사용계획에 적용할 PROGRAM을 작성 시험하여 소형 다상 COMPUTER를 사용한 상호연관 GRAPHICS기법이 효과적으로 이용될 수 있음을 확인하였다.

I. Introduction

In the old days, most shipyards were interested in how to build a better ship. Nowadays when fierce competitions are prevailing in ship market, most shipyards are forced to trim its production cost to the extreme. One of the most powerful tool for this objective is successful production planning and control system. In conventional managerial concept of shipbuilding, production planning and control was merely considered to plan a sequence of work contents with its time values and to implement control to keep the sequence. This approach was simple and practical when time values of work contents of whole production process were known and could be considered fixed. However aship grew bigger and became more sophisticated, its large number of work contents became hard to estimate and extremely variable during the courses of its progresses, and eventually leads to under-utilisation of production resources. This drawback is more prominent when we build multi-product mix on multi-berth. Therefore it is worthwhile to approach the task from the viewpoint of maximising the utilisations of the resources, which in turn leads to cost-effective production planning and control. Large number of structural parts and complexity of work contents can be dealt effectively by computer-aided system. Highly advanced interactive computer graphics on micro computer adds further benefit on this approach.

Ⅱ. Review of current methods

1. Conventional manual planning

General procedure of manual planning adopted by modern established shipyard can be described as follows. This procedure begins of breaking down the hull structure into erection unit into sub-assembly units and the erection or sub-assembly unit into fabrication units. At this stage planner should estimate, utilising existing information and experiences, steel weight, labour hours and production duration of each unit. Actual planning begins of preparing erection sequence and proceeds backward to unit assembly planning, fabrication planning and steel plates order planning. Erection sequence is worked on after all the major erection units are defined and the task begins of determining the best way of put them together. Realistic estimates of minium times required between the erection dates of two adjacent units are determined on the basis of keeping efficient erection process. After this erection sequence is determined, accumulated erection weight curve (S-curve) is drawn on week-scale time axis. This curve is compared with standard S-curve which is usually provided from past operation experiences, and adjusted properly so that the work load be evenly leveled. In some shipyard, labour hours is used instead of steel weight as the labour hours is considered more realistic to control the production progress. Finally, erection schedule is provided in a form of Gantt chart. Unit assembly planning is made based on the erection schedule. Completion date of an assembly unit is placed a certain length of time ahead of its scheduled erection date. This buffer time is estimated to be sufficient for painting, staging and advanced outfitting. Assembly duration of each unit is estimated based on records of previously built ships and establishes the starting date of the assembly, which is turn determines the sequence with which the parts fabrication should be completed. Overall assembly sequence is produced in a form of Gantt chart. Next step is to place, on assembly shop area, the units which are to be simultaneously built at a time and chek the suitability of shop flcor layout. Availability of crane operaticn is also checked. If not suitable, adjustment are made until it becomes suitable, and the assembly schedule is finalised. Fabrication planning is produced based on the assembly schedule allowing also certain buffer or lead time between adjacent work stages. As tco many pieces are involved at this stage, pieces are dealt in batch basis. Convinicntly, if possible, all identical parts of a unit or two can be formed one lot. After estmating time duration of the lot on its concerned machine or work station, its starting date is established. As a number of pieces passes through a number of work stations, series of schedule for each work station of the process line is produced. By summing up all the schedules of work stations for all lots of parts of all units, the planner can obtain work load curves for all machines and work stations, check overloaded or underloaded, adjust the schedule and finalise the overall fabrication schedule. Steel ordering and stockyard storage planning are performed based on the fabrication schedule. Steel ordering needs lead time requested by the steel supplier and some allowance for sorting and storing. Steel should be received in accordance with its starting date of fabrication a safe time ahead of disbursement to the first processing. Basic tcol utilising on this overall planning is network technique. The success of this manual planning depends absolutly on the accuracy of estimation and/or assumption made on the work contents and time duration of various units on various production stages. This manual approach to overall production planning is regarded reasonable in a viewpoint that it can incorporate the individual characteristics of each production unit and allows planner's intuitiv decision so that he can utilise much of his own experiences. However, as ship becomes larger and more complicated, this manual approach revealed many serious shortcommings. Firstly, it takes long time when incorperating the detailed individual characteristics of units, which leads to long lead time for work commence. When ship market is in recess, it is serious disadvantage. Secondly, manually planned schedule hardly meet the dynamic situation of production progress. When the schedule is being implemented, deviation occurs between estimated and actual requirements on production resources. In order to meet the dynamic progress, some allowances or buffer are inevitable on estimated production resources which in turn lead to less utilisation of production resources.

2. Computer-aided system

Computer is an ideal tool to deal with the complexity of ship and dynamic characteristics of the production process. During recent years many approaches to the task have been attempted and succeeded in solving many parts of the problems. And many programs are currently in use in many established shipyards. Reference(2) presented well-established integrated overall planning system by extending aforementioned overall manual planning procedure coupled with computer-aided refinement to the detailed fabrication schedules. It also endevoured to provide maximum amount of information from structural breakdown. It's computer application was batch system. But the approach was principally based on mass production which can be best met when building serious of standard ship. Drawback of this approach is it failed to consider the dynamic feature of production process and still requires lot of time consumming manualworks. Some approach to production control technique in job shop manufacturing can be found in Reference(3). This approach was demonstrated on centralised machine shop. Planning starts with rough schedule based on preset target completion dates of production units and the detailed refined schedule are made on the latest possible day so that the planner can be equipped with as much information as possible required for planning the tasks. For the purpose of updating the status of production progress it utilised computer program named Management Activity Reporting System which provides a weekly report on the production progresses of every units. It's utilisation is confined to centralised machine shop. Reference(4) presents also integrated overall planning system fully utilising computer programming on all production stages. Network technique was employed on unit erection scheduling. Unit assembly schedule is made by allocating units on assembly area-time plane so that its space utilisation be maximised. For this purpose, simplification was made that only the length of assembly hall and the length of hull unit are considered as acting parameters so that the length of a hull unit can be allocated on the length axis of assembly hall disregarding it's width. And the schedule produced is adjusted by leveling the work load against its manpower restriction. Fabrication schedule is made by grouping the contents and defining its fabrication routes. Programming employed is bath system. This approach again did not fully utilised assembly shop space by failing taking into account the varying width and variety of the units shapes. A more improved approach to unit assembly production planning was presented in Reference (6) which attempted to allocate rectangular unit on two dimensional shop floor area. Particularly, it defines the area in three demesions-length, breadth and time-just neglecting the hights of the shop and hull unit. Some searching technique was used in placing a hull unit in three dimensional shop area under given constraints of work forces. Although this approach employed clearly more sophisticated technique than that employed in Reference(4) it still failed, by employing only rectangular shape of hull unit, in maximising the utilisation of shop space. Heuristic method of allocating three dimensional box of hull unit on shop space was attempted in Reference(7). But the actual procedure of the approach is to place two dimensional rectangle of a unit on shop floor and in later stage formulate the height restriction to a test for each hull unit on transportation route on the way of finishing production. The occupation of the shop floor was represented by four dimensional matrix using X and Y position coordinates of shop floor, time and hull unit number. This approach again by employing rectangular shape of hull unit couldn't obtain maximum utilisation of shop space. All the approaches so far examined sticked in batch type computer programming trying to get the maximum utilisation of resources. The result of the planned schedules are lack in flexibility during the courses of its implementation.

Ⅲ. Suggested approach to assembly shop production planning and control

1. Criteria for successful approach

The maxim in production planing "place right material on right place on right time" is never changed even now a days when planning environment has become extremely complicated. But direct apprcach toward this objective can never succeed and results in time consuming tedicus job for both planner and controller. Keeping it in our mind we can set up general criteria for successful production planning and control as follows.

(1) Maximum utilisation of production resources.

The ultimate goal of ship production management is to minimise total production cost. Therefore the planning and control should be performed in a way of maximising utilisations of production resources which contribute to the production cost. The cost is divided into material, labor and overhead cost. The material cost and labour cost are straightforward and directly controllable. However the overhead cost is rather complicated and mixed. Therefore, for the planning and control purpose it is resonable and practical to define the production resources as material, labour, facility and time. The material contributes to prominent part of the cost but its utilisation is not a thing to be controlled by planning and control. Labour is most important item to be controlled by planning and control and its improved utilisation directly contributes to decreasing cost. Production capacity of a shipyard is primarily constrained by the capacity of its facility. Increased utilisation of facility directly decreases cost and indirectly contributes to increasing utilisation of labour. The time is also most important item to be controlled and its utilisation directly contributes to decreasing cost. It's utilisation is highly dependent on utilisations of both labour and facility.

(2) Minimum work task

Primary intrinsic work task in ship production is controlled by design and production technique. But large portion of the work task is made of auxiliary works which are created during the course of production process. Most prominent items to be controlled against these auxiliary works are as follows.

1) Minimum transfer of material

Number of handling and distance of transportation should be minimum. In particular, overloaded crane transportation provokes congestion in material flow which in turn creates idle time of both labour and facility.

2) Minimum transfer of manpower.

Frequent transfer of manpower from one place to another not poorly produces manpower-idle but also affects productivity of manpower owing to deteriorated learning effect. This problem becomes serious when implementing tightly organised schedule with overloaded manpower.

3) Minimum material in process.

Increased buffer storage between work stations helps decrease idle time of both manpower and facility but on the other hand produces congestion in material flow and also increases capital burdon as well. Therefore optimum buffer storage on each interim work stage should be defined after careful study based on planner's own experience.

4) Flexibility Schedule carefully made should be flexible so that it can be properly controlled during the course of its implementation. An important in planning is the exact definition of work task or work breakdown by structural contents, job interdepency, resources requirements. Because of the inevitable deviation estimated and the implemented, fixed-time based schedule cannot be properly implemented or, if implemented, produces high degree of under-utilisations of resources. Some information feedback and resources updating ability should be provided.

2. Criteria for computer-aided system

Computer is the best tool to perform the optimisation by interative searching. And the continuous information feedback and resources updating operation are impossible without computer application. The criteria for this system can be set up as follows.

(1) Reliability

Computer-aided approach normally replaces maximum amount of manual work with automatic data processing. The established system requires a lot of data input and result output. The system designer is one person and the user is another. Reliability of the data input is the principal concern when designing an automatic processing system. Input data and input commended should be secured. Program and data in memory should be protected. Appart from securing completness of the data processing structure some error message and error quiding device should be provided to ensure the reliability of overall design process.

(2) User-machine interaction

Some heuristic method in planning multistage production process with various form of data can be benefitted by adopting system consisted of several steps of process branching with optional data input so that sequential stepwise optimisation be obtained. This system seemingly simulates manual planning procedure. And one of the most important factors dictating the success of this system is the user's familierity with the program and machine. User-machine communication should be simple and straightforward. For this purpose stepwise guidance and error message again are useful. Suficient information should be provided at each step so that the user can make optimum decision for the next step. And clear route to go next should be indicated so that the user should not go out of build-in route of the system. Two ways are available for this objective. One is to provide user with a manual instruction which gives detailed presentation of work procedure. And the other is to provide appropriate built-in guidance within the system so that he be instructed as he works on it.

(3) Visualisation

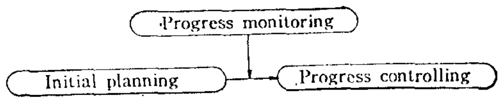
In a planning system adopting certain type of user-machine interaction, it is of great help to have some visual aid presented in alphanumeric and graphical form. Ship production planning which involves various form of data handling can be benefitted by use of graphics resentation. Especially, assembly shop space planning requires handling shape of shop floor area and shape of hull unit. Size and shape of hull unit cannot be properely described;simply by numeric method. Generally in iteractive system, visual presentation on screen gives the user more perspective information in short time.

(4) Economy

Any new system which is to be developed should be assessed of it's easiness of accessing to the machine. Cost involves in developing software and purchasing or hiring machine for its implementation. Bigger capacity and higher quality is more expensive and smaller capacity and lower quality is less expansive. At this stage, we should keep in our mind that recently developed desk top computers are on the way of rapidly increasing its capacity and broadening its functions. One of the best way of increasing its economic advantage is to develop a more sophisticated and more compact software which can be implemented on less expensive small deck top computer. The benefit of small deck top computer comes to this highlight when used interactively in continuous control of production progress. It is because the user can monopolise the cheap machine without excessive cost burdon.

Ⅳ. Suggested approach

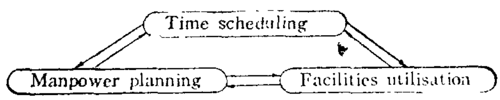
Successful production management on unit assembly shop work process can be done through effective initial planning and appropriate production progress control. And in order to make possible the appropriate progress control, we need also adequate progress monitoring system which timely provides us with properly formulated information on work progress.



All these management activities should be designed in consistent way to secure effective overall management.

(1) Initial planning

Initial planning should be done in a cost-effective way to maximise, within given external constraints, utilisations of three available resources-manpower, facilities and time. These long term three resources planning interact are another and, therefore, should be designed in integrated manner.



(2) Progress monitoring

In order to support proper production progress control, accurate information on present progresses of the three resources should be available on time. And the informations should be in formats easy to handle and make it possible to predict the reqirement of the future resources consumption.

(3) Progress control

Progress control system should be provided so that, by utilising above mentioned informatios, we can maintain balanced production progresses of all work units. As all work unit embodies a lot of uncertainty factors, the overall production progress is a dynamic movement of manpower allocation and facilties allo cation on variable time scale. And any change on progress of one resource affects progress of the other. Therefore, production control should be performed in a dynamic mannor of balancing the three resources progresses, with a view of maximising the resources utilisation both in short term and long term. Optimisation used on this resources utilisation planning is performed in following sequence. Firstly, for some time period individual maximisation of each resources utilisation is independently performed, and next, by combining these resources plans, check the compatibility of each resources utilisation with other two and other constraints until global optimisation is obtained. Of the three resources plannings, manpower and facility are constrained by existing capabilities and the time is an acting variable to be controlled. Among the resources, facility is the most rigidly constrained one that actually dictates the production capacity of the work station involved. Rigidness of the resource is the prime obstacle to improving overall resources utilisation. The prime task of achieving the optimisation at higher overall utilisation is to provide a way of increasing the flexibility of facility capacity allowing some overload even though it requires some cost or a certain degree of sacrifice in its efficiency. In the task of assembly shop space allocation it becomes possible by the use of interactive computer graphics. Heuristic method using interactive computer graphics on stand-alone desk top computer was proved succesful.

V. Experimental program

In order to support, although partially, the suggested approach to hull unit assembly shop facility utilisation planning, an experimental program(FLAR) was developed and tested. The program can be used in allocating hull units with preliminary assembly time schedule, on unit assembly shop floor. The planner can find an optimum hull units arrangement on shop floor by adjusting the location and orientation of each unit on a simulated model shop floor displayed on screen. A set of predefined polygon model of hull unit shopes is used. The program was developed using small desk top computer, Hewllet Peckerd 9845(64 K bytes), in which CRT screen, lightpen, menu button, internal printer, hard copy plotter and cassette tape or data storage are incorporated. Keyboard and light pen are used for inputting data. Menu buttons are used for inputting commend, which actually branches operation route. CRT screen and internal printer are used for outputting result. Cassette tape is used for program storage. Structure of the program is presented in flow diagram in Fig. 1. It is done in BASIC language. And advantage in programming was appreciated from the variely of built-in language within the machine, A number of functions employed in the program can be discussed as follows.

(1) Shop floor drawing

Equally space grids are drawn on screen, on which the planner can draw a outline of shop floor in arbitrary scale using light pen.

(2) Scaling

Planner inputs the length of shop floor, then automatically scaled floor outline is drawn utilising the maximum length of CRT screen. This automatically set scale is used during the whole course of operation.

(3) Loading and unloading unit on floor

Planner can type in the name of new unit and point with light pen the location to be loaded, then the unit is displayed on the location and automatically put on operation. On selecting ERASE from MENU, the unit on operation is erased and deleted from the set of on-screen units.

(4) Transformation

After selecting TRANSLATE from MENU, the planner can translate the unit from one location to another by locating with lightpen two points in sequence. The unit follows the light pen whenever the light pen is pressed. After selecting ROTATE from MENU, the

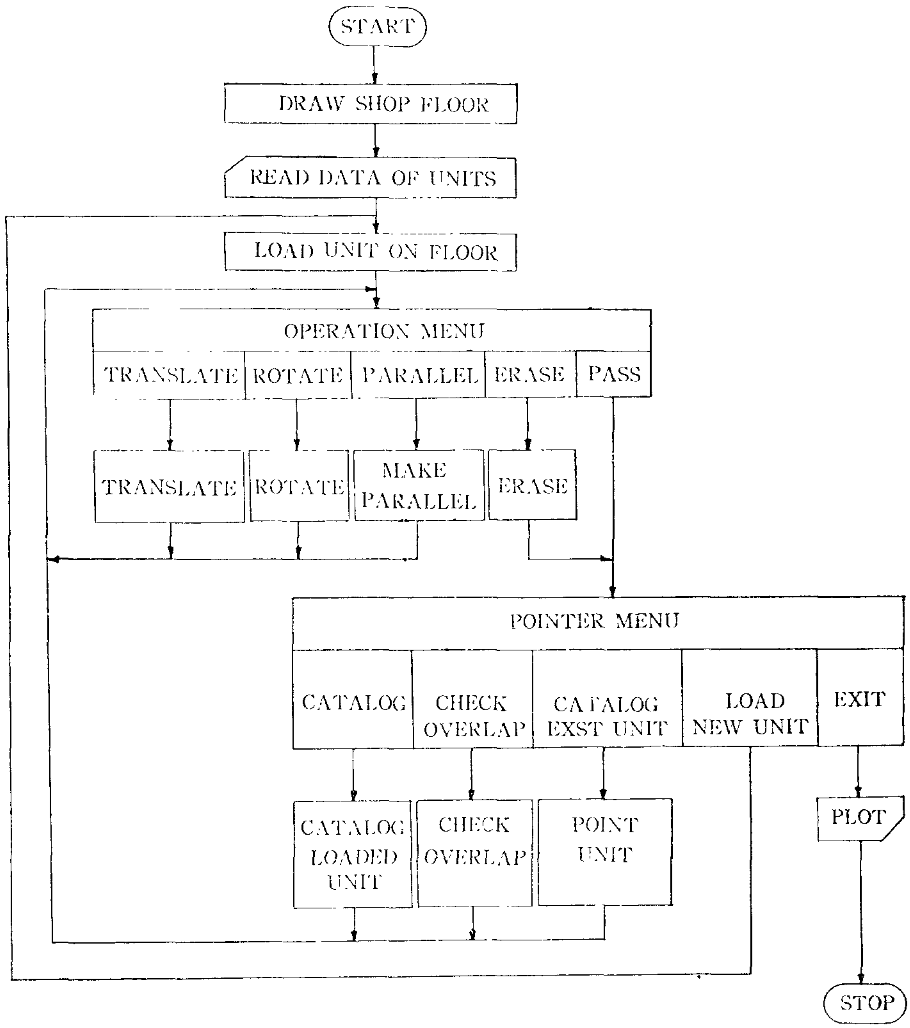


Fig. 1. Flow diagram of experimental program

planner can rotate the unit by locating two point so that the unit can rotate to the angle made by first located point-center of unit-last located point. On selecting PARALLEL, longitudinal side of the unit is adjusted to be parallel to the longitudinal side of shop floor.

(5) Checking

After selecting OVERLAP fromMENU, the planner can poing with light pen two adjacent unit, then alarm sounds if the two are overlapped. CATALOG outputs the list of units that are already loaded on the shop.

(6) Branching

MENUS are used for branching user's operation route. OPERATION MENU offers choice of transformations to be executed on the unit on operation. POINTER MENU offers choice of hull units on which next operations are to be executed.

Test of FLAR showed quite satisfactory in obtaining high utilsation of shop space. Result showed that both the visual aid of CRT screen and pictorial handling with a light pen are essential tools in dealing the task. Built-in menu function contributed to simplifying user's interative operation. However, shortcommings were found as follows. Firstly, the CRT screen was not big enough to accommodate sufficient number of units to be worked simutaneously. Difficulties were found when trying to display shop floor layout and guidance instructions on screen simultaneously because of the limitted space of screen. Secondly, when adjusting the locating and orientation of an unit the spot on line once overlapped with another line and removed later was erased, which resulted in not-clear final picture. Thirdly the small capacity of 64 K bytes memory is anticipated to impose some difficulties on developing further detailed integrated program. Tremendous effort should be exercised in seeking and designing more compact and sophisticated program to meet the machine capacity.

Ⅵ. Discussion

Some criteria for ship production planning and control system were set up. An approach to successful integrated ship production planning and control, with emphasis on maximising utilisation of resources time, manpower and facility was proposed. Test of FLAR, although not complete to demonstrate whole process, showed quite satisfactory in obtaining high utilisation of assembly shop space. In spite of the shortcommings discussed in previous chapter, highly sophisticated and compact desk top computer was confirmed to be a powerful tool to implement the proposed approach. The result of this work strongly supports the possibility of performing integrated ship production planning and control with the aid of small desk top computer.

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