ESTIMATING MAN-HOURS TO CONSTRUCT A SHIP'S BLOCK USING WORK MEASUREMENT

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Abstract

Estimating the man-hours required to construct a ship's block is not a straightforward process; often, it can be highly speculative. Blocks, by their very nature, differ from each other in many aspects of construction and design. The different parts that compose a block usually require different methods of construction and will have different work content.

Using work measurement methods for all aspects of a block's construction, together with data gathered for several projects, a probabilistic model for the construction man-hours can be built. This model may be used to give better estimates of the man-hour content of a block and, hence, a project. Such information is very valuable for a good look-ahead planning and scheduling.

Introduction

There are many issues involved in estimating the construction man-hours for a ship's block. The construction of a ship's block is not like a continuous production process where all operations are repeatable and, hence, detail timings are possible for the whole process as a sum of the individual operations.

A ship's block is not like a building construction where, although each building is different, the estimation of the construction time follows set rules. There are many commercially available software packages that aid in the estimation of construction times and any *Google* search will readily confirm.

Ship's blocks differ from one another. The weight of the block is not an accurate guide line as to the construction man-hours. Even though two blocks may be similar in weight, as well as the thickness of the steel plate used, the number of component parts can differ significantly. The footprint of the block, which is another method that is used for estimating the labour content of the block, is not suitable for the same reasons as the weight of the block is not suitable.

A method to estimate the construction man-hours for a ship's block, not based on the physical characteristics of the block, such as those adumbrated above, is required. The use of a man-hour quota (Min et al, 2011) for discrete manufacturing processes is useful to a point. Whereas man-hour quota is concerned with the time necessary to complete a single product and single process, the concern here is for the completion of a single generic product part.

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Block Construction Stages

There are several definable stages in the construction of a block. Initially, a steel sheet is marked and then cut. The cut parts are often stored as the cutting process is a much faster process than almost any other process. The marking and cutting processes are not of a concern in this study. Since the processes are so much faster than any of the other processes, a large panel is able to mark and cut many parts within an hour. Following the marking and cutting, items are usually stored ready for later use.

Parts are moved from a store to a work area where they are laid out ready for the fitting process. Following fitting, the parts are then welded, after which they are stored. Parts are finally moved from the store area to an assembly area where all parts are assembled into a finished block.

Work Sampling

The work sampling used in this pilot project was confined to the assembly area only. Timings for other stages of the construction were arrived at by interviews with the experienced actors involved in the processes. Where the processes are automated, such as automated welding, the welding speed of the equipment was used.

The derivation of some *standard time* or *average time* is not necessarily an "accurate" time, as has been highlighted (Dossett), "There is no such thing as an "accurate" labor standard time. Human workers come in at least a billion models with varying physical, mental, and emotional specifications and work under varying environmental conditions. This variety makes "average" or standard times extremely difficult to determine." Further, the work observed was fitting, that is the tacking of two or more pieces of metal together. The cycle time for this process can be quite long, running to about 1 hour. It has been noted (Best) that different welders can take different times for the same type of weld. This is due to the welders' personal welding technique, or art. The recommended minimum number of observations of 10 per variable per operator (Kilgore) has not been possible due to the long cycle times involved and the often, single occurrence of a particular type of work.

The method used for the work study was video recording of various fitting processes over a period of 4 weeks, with 1 or 2 recordings each week; over 8 hours of work activity was recorded. The recordings were made at different times during the working day, which accords with the recommendation of having random samples (Heiland & Richardson). The videos were later analyzed to identify the work process and time taken to fit different shapes and types of parts.

The work sample covered 5 main types of fitting: rings, T-pieces of different sizes, linear profiles and intersecting profiles, T-pieces with curved profiles. Rings are composed of two semi-circular pieces of steel joined together, and usually fitted in a hole in a plate, thus forming a flange. T-pieces are steel pieces joined orthogonally. Linear profiles are steel profiles fitted to a plate that do not intersect with any other profile. Intersecting profiles are profiles that join or touch one or more of other profiles. Profiles of different lengths and sizes were observed.

The main assumption made in the observations was that all fitters were of equal ability and were assumed to be at the same place on a learning curve. No allowance for fatigue was made, even though the working environment was hot at times (Karger & Hancock).

With work sampling, the times for a process can be better ascertained. Having the timing for each step of the construction process, the total time to construct a block is the sum of the steps involved.

The total man-hours required for a block construction is given by

$$\sum_{j=1}^{m} P_j . \sum_{i=1}^{n} R_i . O_i . T_i$$

Where

O_i = Operation i
P_j = Subassembly/Part j
T_i = Time taken for operation i
$R_i = \begin{cases} 1 \text{ if } O_i \text{ is required} \\ 0 \text{ if } O_i \text{ is not required} \end{cases}$

Video Analysis

The video analysis adapts the analysis of a cyclic activity from Ogselby et al and Parker and Oglesby in identifying the various activities that go to make up a fitting event. A special computer program was developed to aid the analysis. With the program, it was possible to easily identify not just the total lapse time for the process, but also the percentage of the time spent on each part of the process.

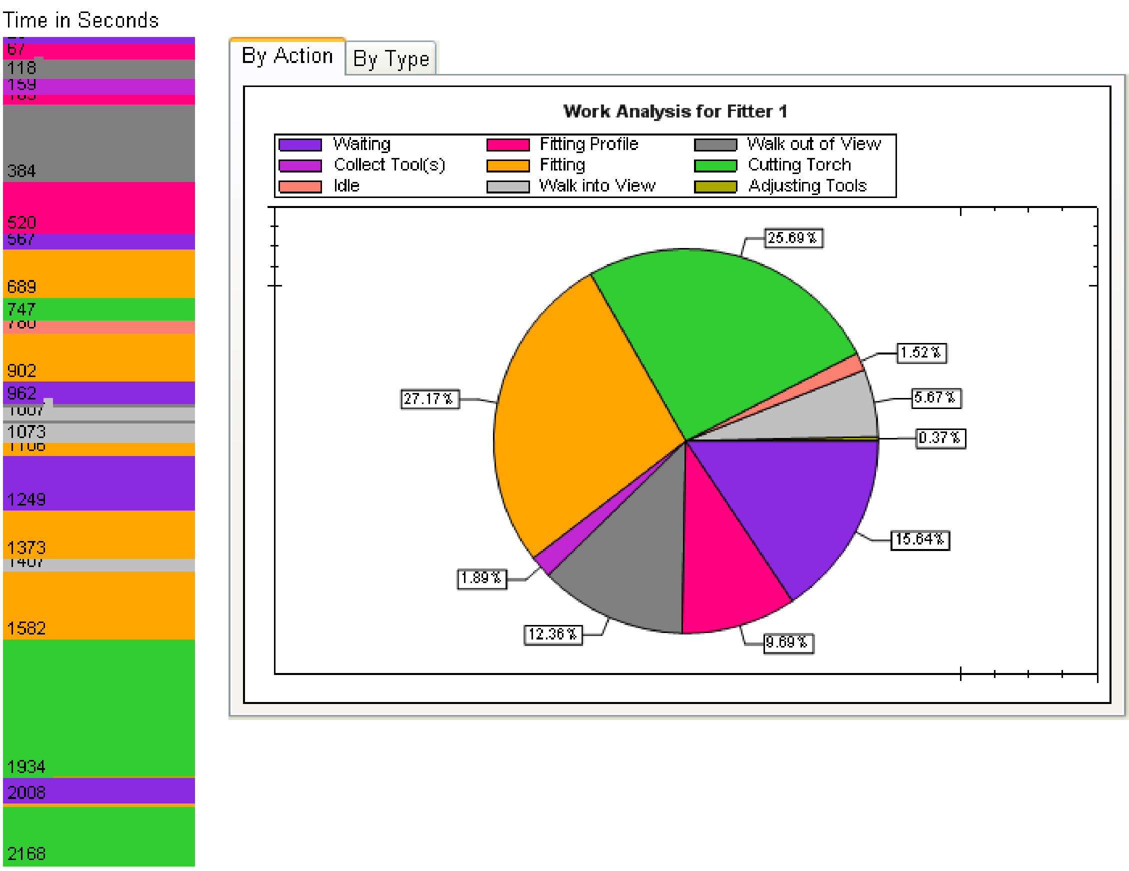


Figure 1: Example of Video Analysis Output

The video analysis was revealing, in that it highlighted activities that may not normally be considered when estimating the time taken for a fitting process. One incident will serve as an example. Two fitters had to stop work at various times when large parts were being transported by a crane near to them. The stopping of work for safety reasons accounted for 40.56% of the time spent by one fitter in the fitting process and 8.89% by the partner fitter. The total observed time was 1 hour, 12 minutes, 42 seconds. Of course, with such a limited observation time, it is not possible to say whether this is a frequent occurrence. No other set of video observations showed any stopping of work for safety reasons.

To calculate the number of observations in hours that is required to see if this is usual, the formula found in Doty is used.

$$N = 1600\frac{(1-p)}{p}$$

Where
N = number of observations
p= ratio of occurrences

The time taken for stopping for health and safety reasons was 0.48 + 0.11 =0.59 man-hours. The total time for all video observations was 8.35 hours or 16.70 man-hours, based on the observation that the men worked in pairs mostly. $p = \frac{0.59}{16.70} = 0.03533$, *N*=43688. To observe for nearly 43,688 man-hours to see if the stopping of health and safety reasons is really 3.53% of man-hours of production is not realistic. For the purpose of deriving the number of man-hours required for the construction, a modest intuitive value of 1.5% is used, until further observation confirms a different value.

The various activities and actions recorded and analyzed were:-

- Adjusting tools
- Clearing Work Area
- Collecting/Moving Equipment
- Cutting with a Gas Torch
- Fitting
- Grinding
- Idle
- Moving or Positioning Parts to be welded
- Tack Welding
- Waiting
- Walking into/out of view

Not all these activities are applicable to all the observations made at the various work stations.

Fitting Rings

The video recording was not able to record the complete process of fitting a ring. The arrivals at the observation station were not timed to coincide with any particular process. The process of fitting rings had started. The wall-clock time recorded for one ring from start to completion was 65 minutes. It is assumed that the average time for completing a ring is more than this. Conversations with an experienced fitter confirm that the rings can take half a day to complete, if the ring has fault carried forward from a prior operation.

For the purpose of calculation, the total man-hours required to fit a ring is taken as 2 x 90 minutes or 3 man-hours. The assumption here is that there are always 2 fitters working as a team. The wall-clock time is 1.5 hours.

Fitting Profiles

Profiles, or stiffeners, are of differing lengths and sizes. The fitting of long profiles, 3m or 4m in length and about 200 mm high, requires a different technique to the fitting of shorter profiles of 1m to 2m and 100 mm high. The shorter profiles are held in place by hand whereas the higher profiles are 'clamped' into position to hold them steady prior to fitting.

The average time for fitting a large profile, without interruptions, was 6 minutes. The average time for fitting a short profile that did not intersect with any other profile was 13.23 minutes, and for those that intersected other profiles was 13.01 minutes. As these times are close, the time for fitting profiles, irrespective of whether they intersect with outer profiles or not, is 13 wall-clock minutes or 26 man-minutes.

Fitting T-pieces

The fitting method for T-pieces depends on the size of the T-piece. The work study showed that height, length and thickness determine the work content of the process.

The vertical section of the T-piece has to be secured while the fitter tack welds it. Several methods are employed to support vertical section. If the vertical section is less about 500mm high and about 12mm thick, then simple external supports are used to hold the section into position while the fitters tack weld. If the section is thicker, about 25mm, it is able to stand without external support, other than that of a fitter. One fitter holds the vertical section while the other tack welds. If the vertical section is a large one, then the securing in the vertical position requires the welding of supports to hold the section into position while it is being tack welded. The positioning requires a crane and, of course, the pre-welding of the supports.

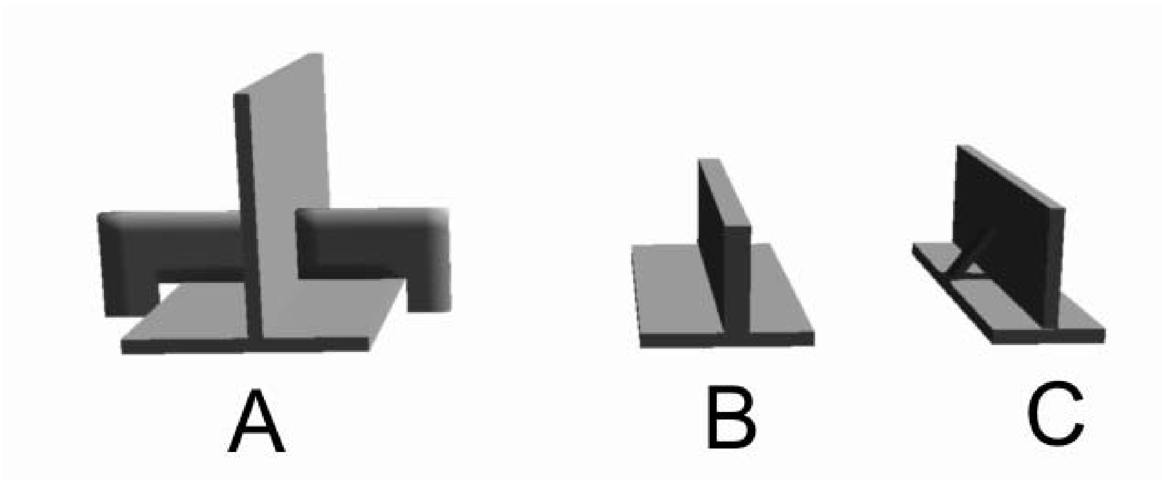


Figure 2: Example of T-pieces with different types of supports

T-Type	Support Setup Time	Fitting Time	Total Time
A	29.38	9.55	29.92

B	0	22.28	22.38
C	5.00*	10.00*	15.00*

Table 1: Summary of Fitting/Setup Times for T-Types

Note 1: Items marked * are estimated from expert views.
Note 2: Timings given are in wall-clock minutes

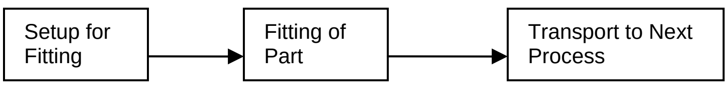
Fitting T-pieces with Curved Profile

Not all T-pieces are simple straight pieces. Some T-pieces have a curved profile. When this is the case, the securing of the vertical to the horizontal can be a long process. The pieces have to be securely held together prior to tack welding the parts. At the same time, the alignment, both vertical and horizontal, have to be maintained. This is done by various clamping techniques. The setup and fitting time for this is 65 minutes.

Figure 3: Example of Curved T-piece

Estimating Man-Hours for Construction

To estimate the man-hours required for construction of a ship's block is a matter of identifying all the components that are in the block and accumulate the man-hours for all the stages.



Expert opinion gives the transportation time for moving the item to the next process as 7 to 10 minutes.

Identifying Topological Relationships

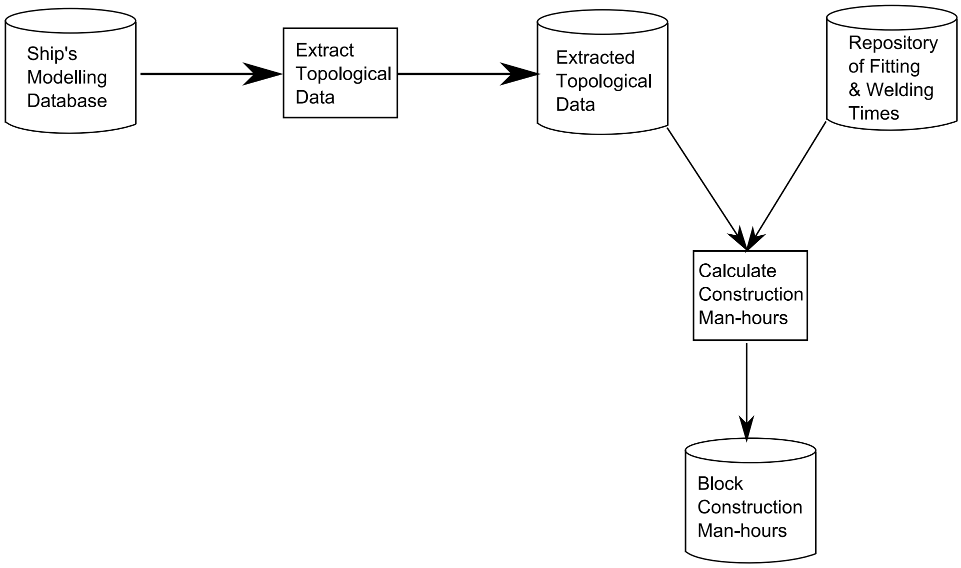


Figure 4: Process Flow for Estimating Construction Man-hours

Data is extracted from a ship's modelling database and this is used to construct an external database containing the various parts that constitute a ship's block. The relationship between the various parts is identified. This identification is at the lowest level and commensurate with the fitting process.

The part types are categorized into four main types.

- Curved plates. This is for rings which are constructed from 2 semi-circular plates.
- T-pieces of various sizes. The size and type of the T-piece determine the method of fitting and welding.
- Curved T-pieces of various sizes.
- Profiles of various sizes. The size, i.e. height and length of the profile, determines the method used for fitting and welding.

By using these 4 basic types of construction, and applying the timings obtained from work measurement, along with the timings for welding and the timings given by expert opinion for the parts that were not measured, the total effort required for constructing all the parts for the block may be derived.

Future Work

The research here is still very much 'work-in-progress'. Further research is required to confirm the information given by expert opinion.

The work here has concentrated on the fitting of four types of construction. In order to estimate the total time required to construct a block, additional information is required on the final construction time of the sub-assemblies. The welding times for the sub-assemblies may be calculated, since the majority of the welding is by automated welding machines whose welding speed is known.

Manual welding is required in some cases for the completing of a sub-assembly. Additional research is required to capture the timing for each part type, size, thickness and shape for the manual welding.

The work observed was largely problem free. Additional research is required to determine the level of problems encountered by the fitters due to errors down stream, such as cutting profiles of the wrong size.

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