12. PRODUCT WORK BREAKDOWN STRUCTURE

12.1 Background and Conformance with Group Technology

Traditional shipbuilders employ work subdivisions by ships’ functional systems which are natural and appropriate for estimating and for early design stages. However, system orientation for planning, scheduling and execution is unnatural and inappropriate because it leads to poor co-ordination of work and generally results in work packages which are too large for effective control of material, man-hours and schedules.

As explained in Chapters 3-9, ships are produced by initially procuring ore fabricating parts and joining them to create sub-assemblies. These are then combined through several manufacturing levels to produce increasingly larger assemblies and modules. Thus the ideal way to subdivide ship construction work is to focus on the needed parts and sub-assemblies, i.e. the actual interim products that pre-occupy workers. A scheme to sub-divide work in accordance with an interim product view is a product-oriented work breakdown structures (PWBS).

Unlike system-orientated methodologies, product orientation facilitates identifying work by classes of problems. This implies the use of Group Technology principles. The basis for groups or families is through the common processes for the manufacture of all parts within the group. Thus parts are classified by both design and manufacturing attributes which are reflected in the coding schemes. Unique classification by certain product aspects conventionally relate a part of sub-assembly to a system or zone in a ship design context and also to work processes by problem area and by work stage. This concept, combines with a greater degree of interaction between design and production, has proven to be a powerful means for improving productivity – see Figure 12.1.
12.2 Work Package Classifications

Logically, the PWBS first divides the shipbuilding process into three basic types of work, namely hull construction, outfitting and painting. Further each is readily subdivided into fabrication and assembly types of work. It is these assembly subdivisions that are naturally linked to zones and which are the basis for zone dominance in the management cycles of the most competitive shipbuilding firms.
Figure 12.1: Characteristics of the Modern Shipbuilding Method
Secondly, PWBS classifies interim products according to their resource needs:

- Material: eg. steel plate, machinery, cable, oil, etc.
- Manpower: eg. welder, fitter, rigger, transporter, etc.
- Facilities: eg. buildings, docks, machinery, tools, etc.
- Expenses: eg. designing, transportation, sea trails, etc.

The third classification relates to four “product aspects”. Two of these, system and zone, are related to the ship design function while the other two, area and stage, are related to the production function.

- System: A structural or operational characteristic of a product such as longitudinal or transverse bulkhead, deck lighting system, etc.
- Zone: This relates to a geographical division of the product such as engine room, cargo hold, operations room, etc.
- Area: This concerns division of the work process into similar types of work problems.
  - by feature (eg. curves vs. flat panel)
  - by quantity (eg. batch, vs flow line)
  - by work type (eg. welding, burning, marking)
- Stage: This relates to various sequences in the production cycle such as preparation, assembly, fabrication, etc.

Figure 12.2 illustrates the three dimensional nature of PWBS.

12.3 Aspects of Work Package Definition

This section considers the link between “product aspects” outlined above and the ship production process itself. Because inherently different types of work are required, a product-oriented breakdown of ship construction work should anticipate:

- Hull Block Construction Method (HBCM)
- Zone Outfitting Method (ZOFM)
12.3.1 Hull Block Construction Method (NBCM)

Blocks should be designed such that:
- for block assembly purposes, they are assignable to one of a minimum number of work package groups considering similarities in problem area and the need to minimise variations in working times,
- for block erection purposes, they will be stable configurations requiring no temporary support or reinforcement and otherwise shaped to achieve minimum working times,
- for on-block outfitting and painting, they are sized for maximum space (area and/or volume).

Further there should be similarities in volume, weight, shape, etc. even at the expense of design convenience, in order to distribute work evenly throughout the fabrication and assembly levels which precede block assembly.

Typical groupings by product aspects are presented in Figure 12.3. The horizontal combinations characterise the various types of work packages that are requisite and sufficient for the work to be performed for each level. Vertical combinations of the various types of work packages denote the process lanes for hull construction work flow which correspond to those illustrated in Figure 12.4.

(A) Part Fabrication

As shown in Figure 12.5 (and from Chapters 4 and 5), part fabrication is the first manufacturing level. It produces components for hull construction which can be subdivided further. Typical work packages are grouped by zone and:

- by area, for associating raw materials, finishing fabrication processes and relevant facilities separated for parallel/non-parallel/internal parts from plate and parts from rolled shapes.
Elements of the Three Dimensional Product Work Breakdown Structure (PWBS) and their relationships to each other. The three types of work are each subdivided into fabrication and assembly classifications which are normally associated only with hull construction and outfitting. Within the painting classification, fabrication applies to the manufacture or preparation of paint and assembly means its application.

Figure 12.2: Elements of PWBS
- by stage, after having performed grouping by zone, area and similarities in part types and sizes for plate joining, bending, marking and cutting.

Typical grouping of work packages for parts fabrication are illustrated in Figure 12.5.

**(B) Part Assembly**

The second manufacturing level is special and outside the main work flow. Typical work package grouped by area are as:

- similar size in large quantities exemplified by large transverse frames, girders, floors, etc.
- similar size in small quantities piece-parts for seatings for (a few) winches or motors.

The former, regardless of design differences, can be mass produced on process lanes whereas the latter would require a job shop approach. Figure 12.6 illustrates typical examples of this.

**(D) Semi-Block, Block and Grand Block Joining**

A block, which is a key hull construction zone, may be planned in three assembly levels depending upon circumstances. A semi-block serves the need to assemble a partial zone separate from other to avoid disruption of work. When this is employed, the block assembly level is where it joins its “mother” block. Grand block joining involves combining a few blocks either in a module hall or at an open site near the building berth/dock. It should be noted that only the block assembly is in the main work flow.

The semi-block assembly level is divided by problem area in the same manner as for the sub-block level.
### Typical Classifications of Product Aspects for HBCM

<table>
<thead>
<tr>
<th>PLAN LEVEL</th>
<th>MFG LEVEL</th>
<th>PRODUCT ASPECTS</th>
<th>STAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>SHIP</td>
<td>TEST</td>
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<tr>
<td></td>
<td></td>
<td>FORE HULL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CARGO HOLD</td>
<td></td>
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<tr>
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<td></td>
<td>ENGINE ROOM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>AFT HULL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SUPERSTRUCTURE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BACK PRE-ERECTION</td>
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</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>JOINING</td>
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</tr>
<tr>
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<td>6</td>
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<td>BACK ASSEMBLY</td>
</tr>
<tr>
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<td></td>
<td>CURVED PANEL</td>
<td>ASSEMBLY</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SUPERSTRUCTURE</td>
<td>FRAMING</td>
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<td></td>
<td></td>
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<td>SUPERSTRUCTURE</td>
<td>PLATE JOINING</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>NIL</td>
<td>BACK ASSEMBLY</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SIMILAR SIZE IN A LARGE QUANTITY</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>SIMILAR SIZE IN A SMALL QUANTITY</td>
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</tr>
<tr>
<td>5</td>
<td>3</td>
<td>NIL</td>
<td>ASSEMBLY</td>
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<td></td>
<td></td>
<td>SUB-BLOCK PART</td>
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<td>2</td>
<td>NIL</td>
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</tr>
<tr>
<td>7</td>
<td>1</td>
<td>PART</td>
<td>BENDING</td>
</tr>
</tbody>
</table>

**Figure 12.3:** Typical Classifications of Product Aspects for HBCM
Simplified integrated processes for simultaneous hull construction and outfitting. Painting would appear as additional processes in additional sub-stages in the various flow lines (e.g., between block assembly and on-block outfitting). Sub-stages, such as block turnover when outfitting on block, are also omitted.

Figure 12.4: Construction Lanes for Hull Block Construction
Figure 12.5: Parts Classification by Area

Figure 12.6: Sub-Assembly by Area
The block assembly level is divided by problem area using distinguishing features of the panel needed as a base for attaching parts, assembled pars of sub-blocks and uniformity of working times involved. These characteristics determine whether platens or pin jigs are required or whether the blocks are to be assembled in a flow where work starts and finishes in unison.

At the grand block joining level, three classifications by area are normally required – namely flat panel, curved panel and superstructure.

Figures 12.7-12.9 illustrate some of the relationships between semi-blocks, blocks and grand blocks for a 22,000 DWT general cargo ship.

12.3.2 Zone Outfitting Method (ZOFM)

In a manner similar to that for hull construction, zone divisions for outfitting are tailored to fit a new contract design. The basis could be previously-built similar ships. ZOFM considerations need to be considered carefully, alongside those of HBCM, when planning and defining the work sequence for the new construction.

ZOFM can be conducted on-unit, on-block and/or on-board (see Chapter 8 also). Typical groupings of the product aspects are given in Figure 12.10.

(A) Component Procurement

As indicated in Figure 12.10, this is the first manufacturing level. This enables production of interim products of zones for outfitting for which no further sub-division is needed by the shipyard. Typical wok packages and material requisitions are grouped by zone and area to address:

- in-house manufacturing,
- outside, sub-contracted work,
- purchasing off-the-shelf products.
Figure 12.7: Semi-Block and Block Assembly
Figure 12.8: Block Assembly and Grand Block Joining

Block Assembly and Grand-block Joining — Cast Block. Attaching a semi-block to a mother block which is classified by area as SPECIAL FLAT is an exception. Also, providing for a part during grand-block joining is planned as an exception.
Figure 12.9: Grand Block Joining
These problem areas can be further classified by requirements for manufacturing drawings, purchase order specification and raw materials.

(B) Unit Assembly and Grand-Unit Joining

As shown in Figures 8.3, 8.4 and 8.5, unit sizes can vary significantly. Therefore two problem areas are designated at the unit assembly level – namely large and small sized units. The distinction is principally by lift capacity – eg. units that weigh more or less than, say, 1T.

Problem areas at the unit level could be further subdivided into:

- machinery unit (machinery combined with all adjacent components including foundation, pipes, valves, ladders, supports, etc) – see Figure 8.5.
- pipe unit (no machinery, just pipe pieces combined with valves, supports, etc). – see Figures 8.3 or 8.4.
- other (hatch covers with coamings, accommodation/cabin modules, etc) – see Figure 8.7.

The grand unit joining level, which enables combining two or more units, enables

- reduction in working times on berth and afloat in the basin.
- production of more stable assemblies for erection purposes.

Classification by area is limited to availability of adequate covered building space and availability of lifting capability.
<table>
<thead>
<tr>
<th>PLAN'S LEVEL</th>
<th>MFG LEVEL</th>
<th>PRODUCT ASPECTS</th>
<th>CODES</th>
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</thead>
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<td></td>
<td></td>
<td>ZONE</td>
<td>AREA</td>
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<tr>
<td>1</td>
<td>6</td>
<td>SHIP</td>
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<tr>
<td>7</td>
<td>1</td>
<td>COMPONENT</td>
<td>MANUFACTURING</td>
</tr>
</tbody>
</table>

Figure 12.10: Typical Classification of Product of Aspects of ZOFM
Typically, the divisions by area address problems which are inherently different so that each work package for outfitting can be assigned to the appropriate team of assembly specialists for deck, accommodation, machinery or electrical. These classifications can be further subdivided according to the work being in small or large quantities.

On-Board Outfitting

Much outfit work at this level progresses simultaneously with hull erection and, ideally, should be limited to:

- fitting components, units and/or grand units that are too large or heavy to fit on-block (e.g. main engines, generators, etc)
- fitting fragile or weather-vulnerable or sensitive components that could be damaged if installed before compartments are enclosed (e.g. joinery, electronic equipment, etc)
- connecting between components, units and grand-units that are fitted on-block or on-board.

12.4 Relevance to Contractual Context

The principal objective of PWBS is to increase productivity and quality. This objective has to be conveyed to the “customer”, i.e. the ship owner, in a formal, contractual context as well. This is done through a Build Strategy Document which is prepared at the outset and before commencement of the build programme.

The early specifications ought to refer to the build methods to be applied and should define a shipyard’s intention to maximise the use of modules, orthogonal pipe runs, or pipe banks with allocated ducts for pipe and cable runs. The build strategy forms the basis of all planning and scheduling for the building programme. It is designed to provide a co-ordinated approach for all departments.
Figure 12.11 shows an extract from a typical build strategy defining aft end breakdown after considering and modifying engine room layout to obtain optimum breaks not just to steelwork but also to enable maximum advanced outfit to be possible. Figure 12.12 shows a further extract which defines the plate nesting policy to be followed for a 60,000 DWT Products Tanker. The build strategy is supported by timetables for (see Figure 12.13):

- key events from contract to delivery,
- material definition, ordering and delivery,
- manufacturing information release from Technical Department.
Figure 12.11: Build Strategy Definition of Aft End Module
Figure 12.12: Build Strategy for Plate Nesting
Figure 12.13: Key Dates Plan