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DESIGN FOR PRODUCTION AND PERFORMANCE : A PROPOSED CONCEPT FOR STEEL STRUCTURES

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ABSTRACT

As is well known the concepts of the overall design are : design for production and performance; design for minimum weight; design for minimum cost; design for operation and design for repair and maintenance. However, the main goal of our paper is to deal with the design for production and performance.

Two main important principles of design for production and performance are considered in this developed research. Those two principles are, the available characteristics of the workshop facilities and the concept of simplicity.

The paper terminates with a case study for the application of design for production and performance in building steel body of a floating unit in order to illustrate the potential of the proposed concept using the current facilities of Egyptian workshops for manufacturing such structures.

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1. INTRODUCTION

In these competitive days, production cost is of greater importance in structural optimisation work. The objectives of applying design for production and performance techniques is not only the reduction of production cost to a practical minimum but also adopting the ease of production, whilst meeting conceptual requirements and maintaining acceptable quality. This leads to consideration both reducing inherent work content and of adopting correct materials.

It is intended that the design for production technique may be of use to the conceptual design staff and to the production engineering personnel concerned with making the basic decisions which will affect the production departments.

There are two important principles of design for production which are developed in this research. Firstly, all design features must be compatible with the known characteristics of the workshop facilities. In this way, the most effective use of workshop facilities may be achieved. Secondly, all design features should be based upon the concept of simplicity. Through simplicity, the work content inherent in any design may be significantly reduced.

It is worthy to mention that the facilities of workshops have a major effect on the concept of design for production and performance. In this paper, the characteristics of current Egyptian workshops' facilities are considered.

To illustrate the proposed concept of design for production and performance as well as to show its applicability, a case study of building steel floating unit is considered.

2. CONCEPT OF DESIGN FOR PRODUCTION AND PERFORMANCE PROCEDURES

The presented concept of simplicity, as one of the two principles of design for production, has many of design for production procedures which may be applied irrespective of the level of production technology in any particular workshop.

It should be appreciated that, as the level of production technology in any given workshop is developed, application of the design for production procedures becomes of increasing importance in order to gain the maximum advantage from the production facilities available. In other words, for efficient design for production procedure, the designer must be well acquainted with the available material to be used and the facilities of the workshop in which the structure will be manufactured.

The relationship between design for production and performance procedures and the most common characteristics of the available workshop facilities, has been taken into consideration in the present studies. It should be mentioned that the common characteristics of the workshop facilities may include materials, processes and manufacturing equipment, materials handling and transportation, working areas, technical organisation, as well as management and control.

It should be noted that, in developing further procedures, the up-dated characteristics of the concerned workshop must be kept in mind. Therefore, the most common workshop characteristics to be considered in the manufacture of a steelwork are briefly summarised as follows:

a- Maximum dimensions and weight of available plates and sections (i.e. material) should be used.
b- Maximum utilisation of existing workshop's equipment and efficient manufacturing processes. This can be achieved through:
 -Optimum material sizes which may be cut in batches on plate cutting machines.
 -Maximum dimensions and thicknesses of plates which may be rolled or pressed by plate forming equipment.
 -Maximum sizes of frames which may be bent either singly or in pairs.
 -Edge preparation provided by plate cutting machines and required by welding equipment at fabrication stage.
 -Dimensions and weight of the maximum size of curved panel assembly which may be fabricated, possibly using a mechanised panel assembly line.
 -Dimensions and weight of the maximum size of curved panel assembly which may be fabricated, possibly using purpose-designed jigs.
 -Assembly sequences and orientation to provide the most advantageous positions for welding and other processes.
 -Dimensions and weight of the maximum size of unit and/or block which may be assembled and despatched from the various fabrication bays.
 -List and specification of all welding equipment, such as manual metal, submerged arc and CO_2, together with joint preparations required for each process.
c- The information concerning the material handling and transportation gives a big hand to the designer's decision regarding the establishment of the design for production procedure. These information may include:
 -Capacity of cranes available at the unit or different working areas (sub-assembly, assembly, erection, etc...) in terms of limiting load, size of lift, coverage and hook height.
 -Nature of any vehicle and/or trailer in terms of size, weight distribution and platform height above the ground, used to handle units or blocks and product.
 -Maximum dimensions and weight of unit or block which may be turned over using cranage at the construction stage.
d- Availability of suitable working areas for manufacturing of equipment and structure as well as adequate working space around and within the product for all operations engaged in its production are of great importance.
e- The technical organisation is able to prepare production information in the form necessary to manufacture the product.
f- The management and control has to organise the supply of material and equipment and to control the comolex process of assembly required to manufacture the product in the correct sequences.

3. APPLICATION OF THE CONCEPT OF DESIGN FOR PRODUCTION AND PERFORMANCE FOR BUILDING A HULL OF A SHIP

3.1 Simplified Hull Form

Where agreed by the ship designer, the lines of a ship should be formed from a combination of simple shapes so that the work content inherent in production of the structure forming the hull surface may be reduced. The basic concept is a preferred order of increasing complexity as follows :

straight lines or flat surfaces, and then, surfaces having curvature in one plane only, and finally, surfaces having curvature in two planes.

Available evidence from Ronald's studies [1] suggests that over simplification of hull form in ocean-going ships leads to penalties in performance which can not be balanced by savings in production costs. There are certain aspects of hull design, however, which can incorporate one or more of the principles and which may have little or no effect on performance. The ship designer must decide whether any particular application is acceptable. For example, for small vessels [2] , such as tugs and fishing vessels, sustained operation at maximum speed is only one criterion concerned with the effective use of installed power. This requires a greater extent of curvature in relation to the normal size of the shell plating for such units.

Simplified overall hull form is worth consideration and has found widespread acceptance. For example, where agreed by the ship designer, the sheer and camber may be eliminated completely with all decks parallel to the base line. Alternatively, the sheer may be straight in sections with one or more transverse knuckles across the deck; the knuckles, in this case, should be in line with plate butts. While, the other alternative for the camber is that it may be straight in sections, normally with one or two longitudinal knuckles along the deck. These knuckles should occur in line with plate seams.

Attempts to simplify the hull forms of small ships, such as tugs and fishing vessels, are sometimes made by incorporating one or more chines into the design of the lines, Fig.1. This enables simple shapes to be adopted for individual portions of the hull. There are two aspects which may be considered. Firstly, straight stiffening members are associated with twisted (double-curvature) plates; and secondly, formed stiffening members are associated with single-curvature plates. An example of the former is the design of topsided where some twist in the plating may be required due to increase in flare forward. Depending upon length, width, thickness and angle of twist, plates can sometimes be pulled into place onto the frames without special forming.

An example of the latter is the design of the forward lines below the lower chine. In this case, stiffening members are usually plate floors which can be profile cut to shape and consequently the shape of the plating may be based upon cylindrical or conical development, giving single curvature.

Chines are sometimes formed from solid round bars running fore and aft, giving natural V-edge preparation for the plate seams and sometimes formed from simple butt-welds along the plate seams. Another alternative is that the plate strake is bent along the chine. However, there is no obvious preference of one approach compared with the other except the availability of the bend equipment and its capability.

3.2 Structural Details

Steelwork design, at all levels of detail, should be directed towards effective use of facilities and manpower as they exist in a particular shipyard. For the proposed procedure concerning the structural details the following points must be considered carefully:

- Component design, wherever possible, should involve the use of straight piece parts, thereby eliminating the need for forming plate and profile

piece parts.
- Elements of structure should involve the minimum number of components, thereby reducing the work content at the assembly stage.
- Scantling designs should involve the minimum practical variety in material types, size and thicknesses in order that material handling operations may be simplified.

In the following some structural details related to ship's hull are discussed in order to illustrate the concept of design for production and performance.

3.2.1 Stiffener notches

In the case of stiffener notches a standard geometry is given, Fig.2, for four variations in stiffener profile with three variations in application. The ship designer should, where possible, consider design details similar to those given in Fig.2 with the object of decreasing work content.

For the design for production procedure of stiffener notches, the following aspects must be considered:

- Plate cut-outs should have agreed standardised geometry, approved by the Classification Society Rules for construction of steel vessels.
- All scallops cut out at the corners of plates should be the maximum allowable by Rules. This aids drainage, air passage, welding access and also reduces the overall joint length.
- The geometry of manholes or lightening openings should be standardised to ovals or circles in all cases, with a minimum size of man access.

3.2.2 Knuckle line

The deck knuckle line in a bulk carrier should be kept clear of the line of the wing tanks, thus reducing the amount of cutting and bending of internal structure, see Fig.3.

3.2.3 Deck transverses

Another example of the structural details is deck transverses in a tanker which are shown in Fig.4. Deck transverses should not follow the line of camber, if adopted, but be kept straightly leveld. This provides the opportunity to to standardise the geometry of all brackets in the area to 90° angles. It also aids quality control in piece part production and positioning in assembly.

3.2.4 Side transverses

Web frames should be designed with a straight inboard edge to reduce or eliminate the need to roll face flats, see Fig.5.

3.2.5 Stiffener end details

Stiffener piece parts, wherever possible, should have straight edge cuts at their ends, thereby simplifying work. as an example, brackets should be scarfed and designed with similar shapes, as shown in Fig.6, particularly if numerical control cutting may be used. Further, where possible, brackets should be flanged rather than fabricated.

3.2.6 Grillage intersections

Grillage is the term given to a structure of intersecting stiffening members. Grillage is particularly common in ship structures and its form of construction is also commonly used in the decks of bridges as well as in aerospace engineering structures. Therefore, the intersections of grillage are of importance to consider here.

The intersection of girders of equal height connection should be avoided if possible with respect to the design and production concept, thus allowing easy welded connections and avoiding complicated face flat connections. The main difficulties of such connections are; firstly, these connections require direct connection of the webs as well as the flanges of the two members; secondly, the butt weld between intersecting flanges of large sections is very expensive. Therefore, another alternative of girders of equal height is suggested and shown in Fig.7-a. The other alternative connection may cause an increase of the scantlings in order to satisfy the strength requirements.

On the other hand, for intersections of deep girders with normal stiffeners, the connections shown in Fig.7-b are commonly used in shipbuilding practice. Tests made on these intersections, with respect to the strength as well as the design for production concept, showed that [3] :

- A double-sided lug connection has a maximum stress that considerably less than half of that in a connection with one lug.
- The breadth of the cut-out in the web should be kept as small as possible with respect to fabrication in order to permit a direct transmission of force in the web of the transverse.
- In double-sided connections a symmetrical design is favourable with respect to a reduction of stress peak.
- The maximum stresses decrease considerably with increasing height of the lug.
- Stress concentrations at the ends of the weld can be avoided by soft noses in the cut-out in the lug.
- The lapped collar (type F) is the strongest connection and may be stronger than required in many cases; the work inherent in such connection is relatively high.
- Types C and D are the next strongest, where the bracket connecting flange of smaller member to web of larger member is a very efficient means of transforming shear load. Accurate cutting of opening is required for type D connection.
- Type B connection is probably adequate in many cases, and is simple to make. The lug should be designed to transfer the full shear load from the smaller member.
- Types A and E are undesirable for important structures, but may be used in areas of low stresses.

3.3 Welded Components

As is previously found, the welding cost represents a higher proportion of the total production cost [4] and [5]. Therefore, the overall economics of the completed weldment should be considered to assess the cost benefits of the reduced production time. In general, quality is improved by the absence of a weld which would have required quality attention in preparation fit up and welding; the distortion which may previously occured, resulting from welding processes, may be avoided.

3.3.1 Elimination of welding

The design of suitable components or sub-assemblies can be changed, so that the desired properties and configuration can be achieved without welding. Cold forming can be used to stiffen piece parts and produces shaped items without welding [5] and [6] ; and rolled sections, extrusions, forgings and castings can be used to eliminate a welded joint, see Fig.8. It should be noted that there are no need for new equipment to carry out the additional operations (e.g. cutting, stripping, machining, forming, etc...) in order to achieve the foregoing goal of eliminating welding.

3.3.2 Reduction of joint length

For a given weldment in specified scantlings, the length of welding can be minimised by design consideration. Weld length depends on the number and size of piece parts and the weld design. Direct application of the principle to panel design would suggest the use of the largest possible plates, particularly the longest possible, in association with a small number of stiffeners, widely spaced and intermittently welded [7]. But the design for minimum weight may be achieved by designing a panel with a large number of stiffeners, closely spaced and intermittently welded [8]. However, optimum design based upon both manpower and material costs, may lead to a compromise solution [4] and [7], see Fig.9.

Some important points should be mentioned in order to establish and excute the concerned design procedure, which are:

- Using fewer butt joints with longer edges, automatic welding may become viable.
- For intermittent fillet welding a special modification may be needed to an automatic tractor, although semi-automatic and even manual welding may become viable.
- Careful consideration of all the relevant factors is needed to select the optimum welding process.
- For intermittent fillet welds, greater care is needed to complete stop/ start positions satisfactorily.

3.3.3 Reduction of weld metal

Although the main object is reducing the volume of weld metal to a minimum, but in the case of butt welds the minimum cross-section area of joint needed to ensure that the joint is acceptable should be specified. While in the case of fillet welds leg lengths should be kept to the minimum by considering the design requirements, probable fit up conditions, weld penetration and possible part or full preparation.

The appropriate edge preparation must be specified to give the required strength, to permit the use of a high penetration weld process and to give the minimum joint gap and chamfer angles, see Fig.10. The following points may be of importance to be listed in the case of the concerned procedure:

- Weld metal from automatic processes costs less than manual arc weld metal.
- For fillet connections, reducing the weld volume also reduces the risk

of lamellae.
- The automatic welding processes which give deep penetration will be used to the maximum extent.
- Manual metal arc is a low penetration process and needs wide joints for access, with low deposition rates.
- Using automatic welding, extra handling and floor space may be needed to carry out downhead welds.
- Resulting from the mechanised processes and the increased manipulation, a slightly greater demand on the management and service trades may be needed.

3.3.4 Reduction of pre-weld work

Dimensional tolerances, assembly sequences, assembly procedure and manipulation should be considered in order to ensure that the edge preparation is correct for actual assembly position in production. Effective application of the principle depends upon knowledge at the design stage of production processes and associated tolerances, together with machining and edge preparation equipment capacity, Fig.11.

3.3.5 Proper weld joint design

Economy and quality depend to a large extent on good access to the joint by the welder and also for the electrode and the equipment. However, in some cases access by others is also important. To apply this principle, no new equipment is needed unless the electro-slag processes are not otherwise used.

A double-sided weld preparation that may appear economic according to other principles may involve extra production work in obtaining access to the more difficult side. A one-sided welding techniques may give a better solution, Fig.12.

4. CONCLUSIONS

This paper has attempted to show that
- A proposed concept of design for production and performance procedures has been developed where there are two main important principles considered; those two principles are the available characteristics of the workshop facilities and the simplicity.
- Closer and more formal liaison between the designing and construction functions in workshop is essentially required. The information flow from construction to design should include data about procedures; this is simply to develop designs which take full advantage of the production facilities and capabilities of the workshop.
- Features which will simplify and reduce the work inherent in the construction processes of a product should be incorporated in the design of the product, wherever possible.
- Structural reliability is affected particularly by detail design, and especially by the qualities of design and construction of the structural connections. High reliability generally involves increased costs; cheap connections can be unreliable. Aproper balance must be found between simplicity of construction and reliability in service.
- Welding is a key production process which has very wide flexibility. Very few applications cann't be welded as drawn but the degree of difficulty and time as well as cost involved depend almost entirely on the

major pre-welding activities of design, production planning and prefabrication. Optimisation of welding activities can be achieved by considering the basic objectives of reducing the work content and increasing the working efficiency of the welding process during the design and production planning processes.
- Some typical applications in shipbuilding practice are discussed in order to illustrate how the objectives of the developed procedures of design for production and performance may be achieved.

Clearly there are much more to be done, and the paper has perhaps posed more points to be considered for further investigation.

Probably, for the time being, it is very urgent to identify and quantify the various influences of production methods on structural strength. This needs particularly statistical information about constructional defects in order to establish ways of assessing capability distributions of complex assembies of elements whose individual capability distributions are known. This important point will be considered in further work by the authors.

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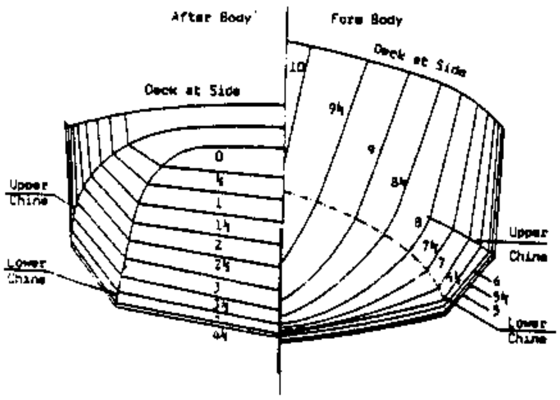
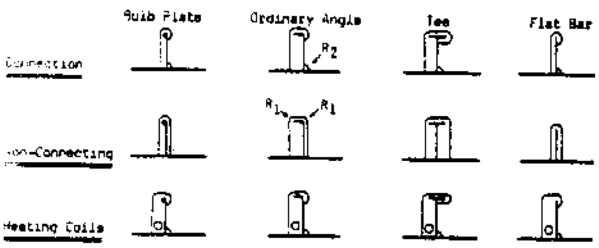


Fig.(1) Body Plan for Simplified Hull Form



(In all cases radii R_1 and R_2 are constant)

Fig.(2) Stiffener Notches

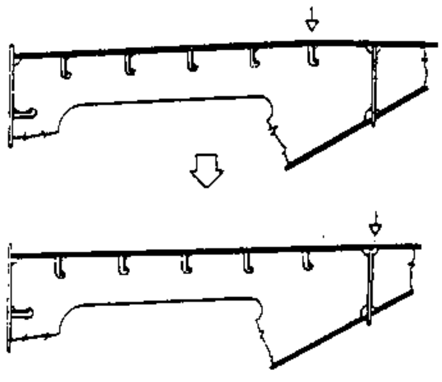


Fig.(3) Position of Knuckle Line

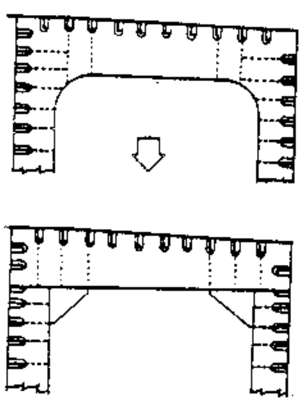


Fig.(4) Line of Deck Transverses for Tankers

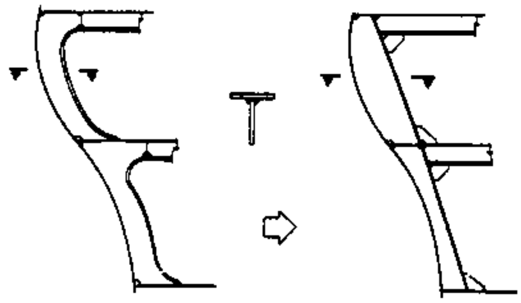


Fig.(5) Side Transverse

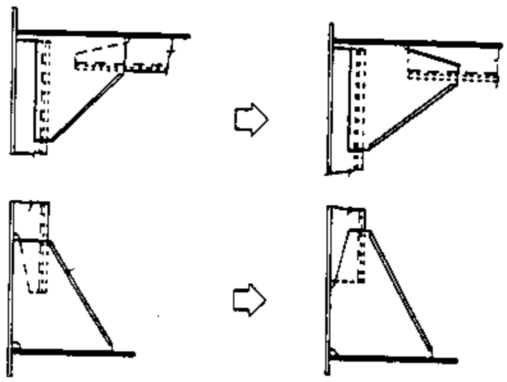
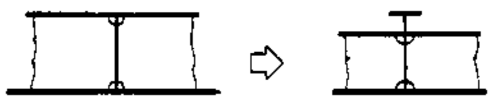
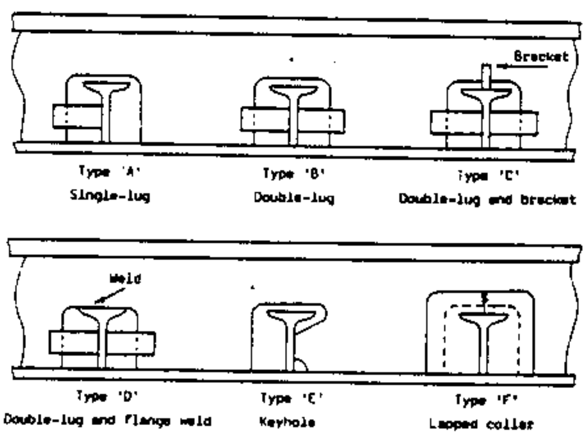


Fig.(6) Stiffeners End Detail



a)- Intersection of Girders of Equal Height



b)- Intersections of Deep Girders with Normal Stiffeners

Fig.(7) Grillage Intersections

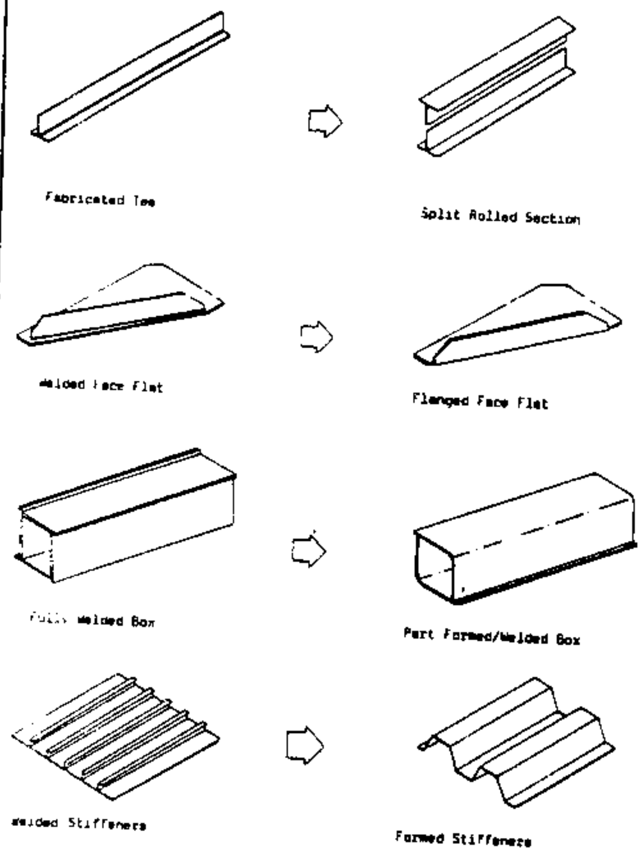


Fig.(8) Elimination of Welding

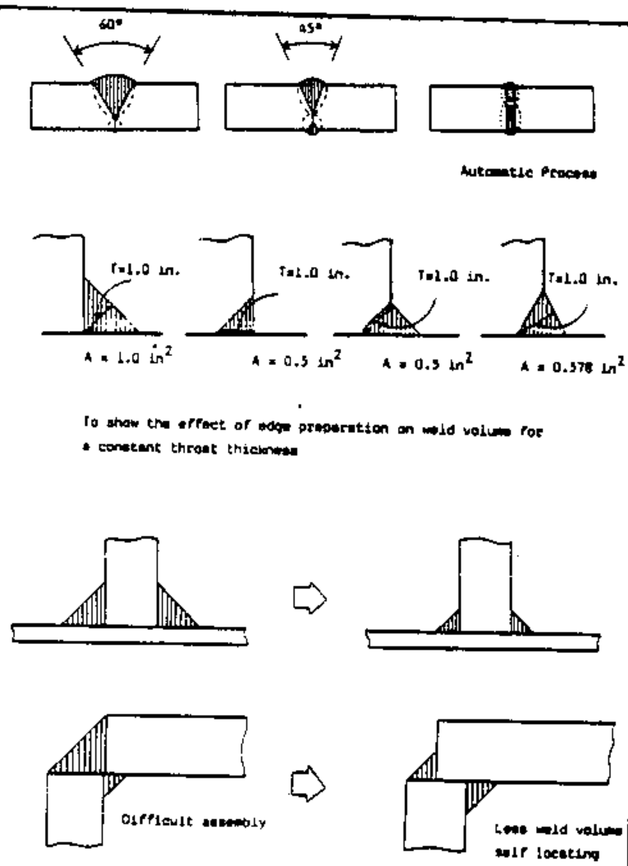


Fig.(10) Reduction of Weld Metal

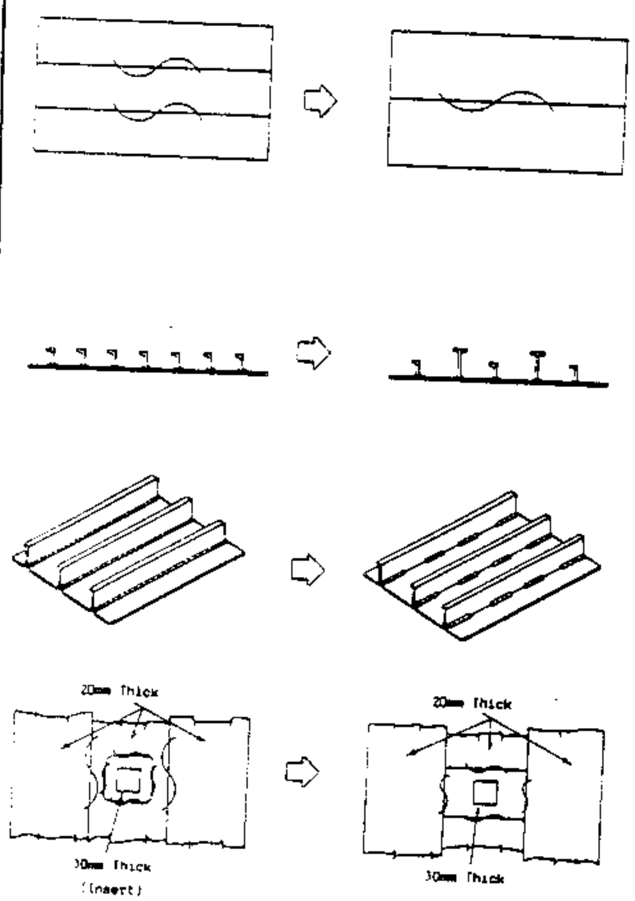


Fig.(9) Reduction of Joint Length

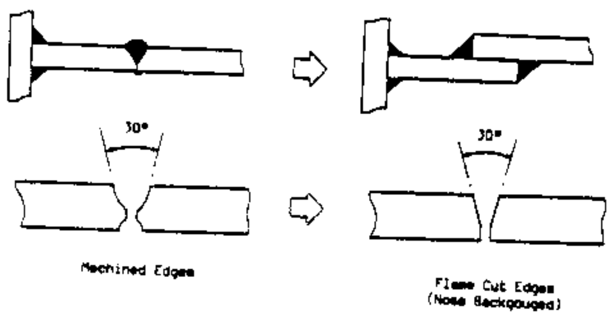


Fig.(11) Reduction of Pre-weld Work

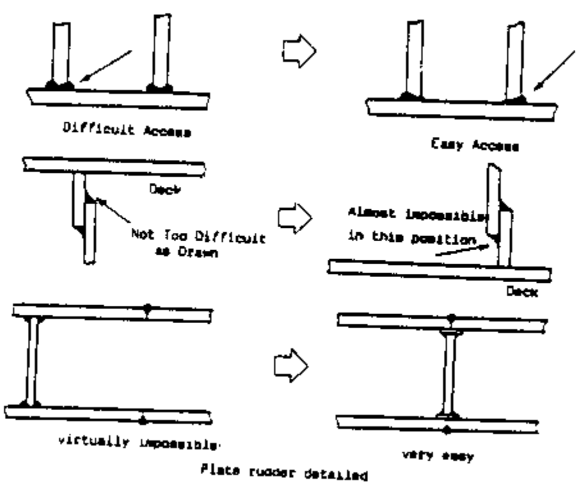


Fig.(12) Proper Weld Joint Design