Design for Assembly Understanding to improve Malaysian Office’s Furniture Assembly ergonomically

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Abstract

This paper will discuss and explain on the importance and understanding of Design for Assembly (DfA) principles and guidelines which would contribute to the improvement of product development and ergonomics factors within Malaysian office furniture. A common failure among manufacturer in product development process is making products that work but difficult to fabricate and assembly. Difficulties in fabrication involved many aspect of manufacturing difficulties including factors such taking longer time to fabricate involving extra time which is unreliable, the requested designed geometry is hard to built and requires extra care in production which is normally hard to maintain. Difficulties in manufacturing and assembly overall will increase the production cost and all these factors will definitely makes product more expensive. This paper will also emphasize details on ‘Design for Assembly’ guidelines and examples case study of Open Plan System (OPS) and proposal to enhance the improvement of quality of products to be manufacture in Malaysian office furniture industries.

Keywords: Design for Assembly(DfA), Ergonomics, Open Plan System (OPS) and Office Furniture
1.0. INTRODUCTION

Design for manufacture and assembly analysis and synthesis is, as with many design process methods, appropriate during many phases of a production design process. It can use in benchmarking analysis in simplifying new concepts not yet build, and in simplifying fully embodied designs. There are two main components, Design for Manufacturing (DfM) and Design for Assembly (DfA).

DfM entails primarily minimizing parts count but as well as making attachment directions. For example, one can make a designed plastic part easier to injection moulding process by changing its draft angle. The angle form by a difference in wall thickness from the part at the inside of a mould compared with a wall thickness at the end of the mould. Small draft angle makes difficult part ejection. ‘Design for Manufacture’ involves application of part forming models, whether they are basic rules, analytic formulas or complex finite element process simulations.

DfA entails making attachment directions and methods simpler, for example making a part easier to attach by using snap fits instead of machine screws. Design for Assembly involves application of attachment time and complexity models, whether they are basic rules, table based on simplified time studies or full time and motion industrial engineering studies. This paper would be focussing more on assembly principles rather than design for manufacturing principles but without neglecting both are related and contributes much to product and components design improvement.

1.1. THE IMPORTANCE OF DESIGN FOR MANUFACTURING (DfM) AND DESIGN FOR ASSEMBLY (DfA)

DfM and DfA are rarely important in product design process and manufacturing process due to its 3 beneficially impacts (Crowe & Feinberg, 2001).

First and foremost because it reduces parts count. From that, definitely it will reduce cost. A design that is simple and easy to fabricate and assembly, it can be manufactured easily and cheap. Design for Manufacturing and Design for Assembly should then be used for that particular reason if not other (Abdul Rahman, 2002).

Secondly, as a second beneficial, for example consider products that are used in extremely critical application and where cost is basically not an issue. For instant, satellites used in exploratory NASA interplanetary missions that need to have system that must work, saving even thousand of dollars on assembly or part costs is meaningless if it doesn’t work appropriately. What is important here is the reliability issue (Crowe & Feinberg, 2001). Therefore, any design activity that can increase reliability will be applied and this again will benefit to DfM and DfA principles. Motorola as another example has already conducted a research showing that adopting DfM and DfA has totally reduced their product function failure (Corbett, Dooner, Meleka & Pyn, 1991). This will somehow increase the reliability of the product. The reason behind all this improvement on reliability is basically that if the production process is being simplified, then there will be less opportunity for the product to perform outright errors and reduce failure.

Thirdly, is because by adopting DfM and DfA in product development process, proven established to increase the product excellence, whether its in design or within its production quality. If product is easier to fabricate, then less complicated machine is involved and less machine capability is requires to achieve same tolerances and accuracy. A part that is easier to eject from mould does not requires extra tight process control of pressure, time and temperature to accomplish required dimensional tolerances. Generally, for the same machine capability, the easier to produce design will have tighter tolerances.

Minimize number of parts as changing multiple parts into single parts. The industrial designers or product planner could propose a simplest way to joint parts. Minimise parts count by incorporating multiple functions into single parts.
4.0. ERGONOMIC INJURY IN FURNITURE MANUFACTURING INDUSTRY

Ergonomic injuries are related to the design or workplace conditions that put workers in awkward position and expose the worker to injuries (Goetsch, 2002). Ergonomic injury is one that occurs as a direct or indirect consequence of the nature and demand of the person-working task, rather than as a result of some hazard to which the person is exposed, during the course of his or her work, but which is not intrinsically part of the working task itself (Pheasant, 1996). Ergonomic injuries include:

i. Lifting and handling.
ii. Work related upper limb disorder.
iii. Musculoskeletal pain and dysfunction resulting from unsatisfactory working posture.

According to Mirka, Smith, Shives and Taylor (2001), the furniture manufacturing industry has struggled with problems associated with low back pain and other musculoskeletal illnesses. Workers are exposed to a number of recognized risk factor for low back injury, physically heavy work, highly repetitive bending and twisting, frequent lifting, sustained awkward posture and dynamic movement.

2.0. DESIGN FOR ASSEMBLY GUIDELINES

There are five guidelines to better parts assembly, which benefits both users and manufacturers (Corbett, Dooner, Meleka & Pyn 1991). The first guideline is to reduce the number of parts through functional modularity. Always scrutinize each parts and ask how the parts purpose can instead be completed by a neighbouring part. Fabricators might wants to produce several parts as one part by applying other manufacturing process, such as plastic injection moulding process where intricate shape and parts can be incorporated or a sheet metal forming. Number of parts count can be reduce accordingly to changes on the jointing technique or involving of same materials which can be fabricated of from the same moulding process. These small changes will make big differences in fabricating and assembly speed and will reduce the cost.

The second guidelines are to reduce number of parts is through modularity kind of assembly method. In these assemblies activity, several difficult to control parts are bundled together into one single part. These modularity can benefit to reduce parts defects and makes quality problem identification easier as one can test subassemblies at early stage rather to diagnose the whole product.
The idea of reducing parts should always indicate a better ways of inserting parts into assembly activities. The third guidelines indicate that one should design the product so that it assembly outwardly. Steer clear of designing products that indicate parts to be fastened on the inside of enclosed space. This will invites difficulties in particular when involving cramming one’s hand and tools into tight spaces.

Fourth guideline is about designing parts so that they are easily oriented. Parts designed should have some sort of self-locating features so that precise alignment for the assembly process is not needed. Common example is when we’re inserting our electrical goods to the power supply. These elements of guidelines and understanding of Design for Assembly has been adapted from a number of sources such Andreasen (1983), Baldwin (1966), Digital (1993), Huthwaite (1990), Iredale (1964), and Xerox (1986). If these concept is realable and convenient, the manufacturers, industrial designers and design engineers can reasonably assured that the design will fairly well in the subsequence more advanced analysis.
Most of design for assembly guidelines emphasize on designing system for easy to assembly by taking into account ergonomics factors within design process before to taking into consideration on design for easy handling. These are list of main design for Assembly guidelines for which manufacturers and designer ought to consider within design process ease to improve ergonomics betterment.

1) Minimize parts counts – parts can be design in better quality and improvement on the concept of minimalism would contribute to easier assembly activities by incorporating multiple functions parts into one single part. To modularize multiple parts into single subassemblies would also generates better assembly activities. (Crow, 1988)

2) Assembly activities should be done in open space by many considerations on human factors including usability elements of effectiveness, efficiency, comfort ability and safety factors. Assembly process should never be done in confined space and importance components which improve assembly activities should never be bury and must be visual able and easy access for users and assembly team.

3) Standardize parts to reduce parts variety. Common examples are the important elements to joints components such as screws, bolt and nuts must be design and fabricate in standard size.

4) Eliminate and reduce tangly parts. Improvement on design and components details parts would reduce tangly parts and reduce difficulties to assembly the products and will creates ergonomically assembly for the product. (Iredale 1964, Paterson 1965)

5) Colour code parts that are implement different functions but similarities in shape and material. Always remember that assembly activities could be much difficult for first time users or consumers. Manufacturers and designers should be more aware and care if assemblies of components are to be made by users especially on products that are made for D.I.Y. (Do It Yourself). Implementation of wrong parts assembly could lead to an Accidents and product busted.

6) Always design and fabricate products, which can be assembly from above. Inserting product from the same directions would make assembly activities less difficult for users and assembly team. Never made assembly activities a disaster by creating multi directions of assembly or products have to be turned over. This is common failure during assembly activities and produce difficulties and energy consume for the users or assembly team.

7) The usage of easy jointing system and reducing on number of jointing parts would make components faster and economically to assembly such Eliminate fastener. (Iredale, 1964) These will reduce difficulties involving usability aspects. The new concept of using snap fit made from plastic on most of daily products such mobile phone housing, electrical parts and even on cars interior components proven to improve assembly activities much simpler and overall will reduce assembly cost.

8) Place fastener away from obstructions. Fastener and use of other jointing parts to join components should be design more free and do not too close to any other parts which make assembly activities exhausting and cost demanding. Always allow proper spacing allowance for fastening tools and made accessible.

3.0. CASE STUDY: OPEN PLAN OFFICE JOINTING SYSTEM

Almost all-modern offices in Malaysia prefer to use open plan office system due to the flexibility of the product (MIDA, 2003). The open plan office system (OPS) can be customized from low screen to high screen and can be installed and dismantled according to the office needs. Since the demand of OPS is increasing, effective ways of assembling the system is required. Most OPS uses bolts and nuts to join the panels. However, this jointing system requires many parts and the assembly process is time consuming.
Based on a survey carried out in this study on manufacturers of OPS, the effectiveness of the jointing systems design that can make the product easier, faster, increase efficiency and facilitate assembly were the main criteria identified. One of the important functions of the jointing systems is to ensure that the system can be provided with flexibility during assemblies’ processes.

5.0. WORKING POSTURE IN OPS ASSEMBLY

There are three sets of jointing are assembled for each medium frame, which is attached at the bottom, middle and top of the frame. Questionnaire analysis shows that 69.5% of the manufacturers agree that working posture should be one of priority design factor in developing the jointing system. Each installation process involves different working posture which shown in figure 5.

Figure 5 indicates the bolt and nut jointing position, which is at the top, middle and bottom of the frame. Jointing position at the frame consist of three different height which is 1240mm at the top, 740mm at the middle and 165mm at bottom.
Figure 6: Working posture

Figure 6 shows the three different working postures for installing the bolt and nut jointing system, which is at the top middle and bottom of the frame. Data from survey shows that each jointing took two minutes to join which makes the installers have to bend down for six minutes for each frame. Minimum movements are required to speed up the assemblies’ process that could minimize ergonomic injuries.

6.0. JOINTING ANALYSIS

The advantages and disadvantages of jointing system applicable in furniture industries were evaluated. It is important to select the right jointing concept to ensure that the selected jointing system concept can be used as a reference and guidance in developing the jointing system. The jointing system can be divided into three types that are adhesive, wood and mechanical jointing. Table 1 indicates the advantages and disadvantages of jointing system concept applicable in furniture industries.

The analysis showed that snap fit concept is the most suitable jointing system since it matches the characteristic identified by the respondents. Although snap fit concept involves customized manufacturing tooling to fabricate the part, cost as indicated by the respondents is not priority in developing the jointing system.

Table 1: Advantages and disadvantages of the jointing in furniture industries.

<table>
<thead>
<tr>
<th>Type of jointing</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Adhesives jointing  - Hot melt  - Polyurethane.  - Silicon</td>
<td>- Fast and easy to used.  - Bond to a wide range of material.  - Tough and flexible.</td>
<td>- Cannot be disassembled</td>
<td>- As a sealant.</td>
</tr>
<tr>
<td>2 Wood jointing</td>
<td>- Provide strength</td>
<td>- Suitable for wood-to-wood joint.</td>
<td>- Chair structure.</td>
</tr>
<tr>
<td>3 Mechanical jointing  - Staple and rivet</td>
<td>- Cheap, fast, joint different material, easy to use.</td>
<td>- Permanent joint</td>
<td>- Chairs, OPS panels</td>
</tr>
</tbody>
</table>
- Treaded fastener / bolt and nut.  
  - Cheap, joint different material, easy to use.  
  - Critical in tightening, many part, difficult to assemble and disassemble takes time.  
  - OPS jointing, chair, table  

- Snap fit  
  - Fast, cheap, reduce time, easy to use, joint different material, can replace bolt & nut, no fastener.  
  - Involved tooling, can be damage by mishandling.  
  - Caster wheel, door handle, chairs.  

- Metal bracket  
  - Joint different material, rigid  
  - Many part, difficult to assemble and disassemble, takes time, difficult to assemble and disassemble  
  - OPS jointing, chair, table.  


7.0. DESIGN PROPOSAL

The first idea in designing the jointing takes shape by freehand drawing to get the basic ideas. In other stage the design dimensioned, drawn accurately and coded into a surface 3D modeling. Nylon plastic is the chosen material to be used in designing the jointing system. Data gathered from literature reveal that nylon is the most suitable material to be use in developing furniture product due to its characteristic which is elastic, tough, recyclable, and widely used in furniture and many plastic industries (Ashby & Johnson 2002).

i. Design proposal 1  
Design proposal 1 is base on cylindrical snap fit joint. The cylindrical concept can be designed to dismantle with ease or not at all depending on the shaft lead and hub return angle as shown in figure 7(Pont, 1990) & (Lesko, 1999).

ii. Design proposal 2  
The design for design proposal 2 is base on cantilever lug snap fit concept. The cantilever lug concept is actually a spring application which is subjected to high bending stress during assembly. Same as the cylindrical snap fit, cantilevered lugs joint can also be designed to disassemble easily or not at all by adjusting the return angle(Pont, 1990)&(Lesko,1999).The basic design concept is graphically shown in figure 8.

Figure : 7  
Figure : 8
8.0. TESTING AND ANALYSIS
There are three different working postures for installing the bolt and nut jointing system which is at the top middle and bottom of the frame. Data from survey reveals that each jointing took two minutes to join which makes the installers has to bend down for six minutes for each frame that could expose to ergonomic injuries that are related due to working posture position of the workers (Goetsch, 2002). Minimum movements are required to speed up the assemblies’ process that could minimize ergonomic injuries.

Table 2: Working posture comparison

<table>
<thead>
<tr>
<th>Type of jointing</th>
<th>Handling time/part (second)</th>
<th>No of operation carried</th>
<th>Total time (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt and nut</td>
<td>120</td>
<td>3</td>
<td>360</td>
</tr>
<tr>
<td>Proposal 1 and 2</td>
<td>5</td>
<td>3</td>
<td>15</td>
</tr>
</tbody>
</table>

9.0. ASSEMBLE EFFICIENCY
Manual calculation was done to analyze the assembly efficiency of the new bracket design compared to bolt and jointing according to Corbett (1990) and Pugh (1991) formula. The calculation is based on single medium screen frame that consist of three jointing per frame which is at the top, middle and bottom of the frame.

Assembly efficiency = \( \frac{3 \times \text{NM}}{\text{TM}} \)

Note: \( \text{NM} = \) Minimum Number of part.
\( \text{TM} = \) Total assembly time.

Table 3: Bolt and nut jointing.

<table>
<thead>
<tr>
<th>Joint no</th>
<th>No of times Operation carried</th>
<th>Handling times per part(second)</th>
<th>No of components</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1</td>
<td>120</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>120</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>120</td>
<td>4</td>
</tr>
</tbody>
</table>

\( \text{Design efficiency} = \frac{3 \times 12}{360} = 0.10 \)
Table 4: Plastic bracket – proposal 1 and 2.

<table>
<thead>
<tr>
<th>Joint no</th>
<th>No of times Operation carried</th>
<th>Handling times per part(second)</th>
<th>No of components</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1</td>
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<td>1</td>
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<td></td>
<td>15</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TM</td>
<td>NM</td>
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</tr>
</tbody>
</table>

Design efficiency = \( \frac{3 \times 3}{15} = 0.60 \)

From the calculation indicates that assembly efficiency for bolt and nut jointing was 10% and assembly efficiency for plastic bracket jointing was 60%. As the result show that the new jointing system is more efficient compared to bolt and nut jointing.

10.0. CONCLUSIONS

The application of Design for Assembly guidelines overall can reduce manufacturing and assembly cost and increase of quality and ergonomically wise. With awareness from product designer and manufacturers top decisions maker, assembly of components can be made much simple and easier, benefit both manufacturers and end users in term of cost, time and quality.

This research has proposed potential jointing system that could contribute for a better assembly process compared to bolt and nut jointing. Many design factors have to be considered before starting to redesign the jointing system. By identifying the suitable design process, design concept and manufacturing process are the main design factor that could contribute to the success of the product.

The manufacturers have to focus on having the highest quality of jointing system performance, the highest level of functionality and features, to ensure the jointing system is efficient that can increase productivity and to facilitate assembly that could contributed to a better working activities. It depends on the manufacturers to select the most suitable design process, design concept and manufacturing process that could increase efficiency and to facilitate assembly process in producing quality product that could to improve Malaysian office’s furniture assembly ergonomically.
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