Simulation and Design of Jigs for Bus's Chassis Production

Somsak Siwadamrongpong and Usawadee Ongarjwutichai

***Abstract*—** Bus manufacturing is one of important automobile industries. In small enterprise, bus chassis is based on manually production. The manual production is low production rate and long throughput time. Moreover, the manual processes are also difficult to make standardization and lead to maintenance difficulty. Therefore, this study aims to design production jigs for bus chassis and use finite element method to analyze the jigs. Production rate with various production scenarios also analyzed. 2 models of Chassis technical data and information was collected from bus manufacturer. The chassis was break into sub-assemblies. 4 Jigs were designed for production of all sub-assemblies. Jigs design was built and assembled on SolidWork, finite element method was carried out by using ANSYS Workbench. Simulation results show that the minimum safety of factor occurs with factor 1.94. Re-design of jigs yield an improvement on the weak point with safety of factor 4.20. Standard time for production of each sub-assembly was calculated. It was found that production rate of 2.3-2.8 chassis/day is achieved based on 2-man working with 4 jigs. The 4-man working yields about 75% increasing in production rate with also increase of %idle time compared to 2-man working scenario. 6-man working with additional 2 jigs found that production rate of 5 chassis/day.

***Keywords*—** Bus, Chassis, Jig, Fixture, Standard time, ANSYS

I. Introduction

Bus manufacturing is one of important industry among automobile industries. The buses that using in Thailand comes from both importing and local manufacturing. The local manufacturing sometimes uses chassis from well known bus manufacturer, thus only bus body and interior are manufactured. The rest local manufacturing is based on used chassis. The used chassis will be modified and maintenance, then body and interior are rebuilt [1] [2]. Recently, some bus manufacturers, i.e. Cherdchai Industrial who is one of the biggest bus manufacturers in Thailand, plan to produce chassis themselves. However, the chassis manufacturing processes is quite very long throughput time, such as chassis platform assemble and welding, which lead to low production rate. It should be advantage in bus manufacturing processes if jig and fixture are available. The jig and fixture may lead to standardization of production, low defect and lower throughput time. Therefore, this study aims to design production jigs for bus chassis and use finite element method to analyze the jigs. Production rate of various production scenarios will be analyzed by varying number of manpower and number of jig. The idea of this study is to divide chassis platform into sub-assemblies. The sub-assemblies are produced and move to assemble together on the main jig platform. This study focuses on only jigs for preparation of sub-assemblies [8] [9].

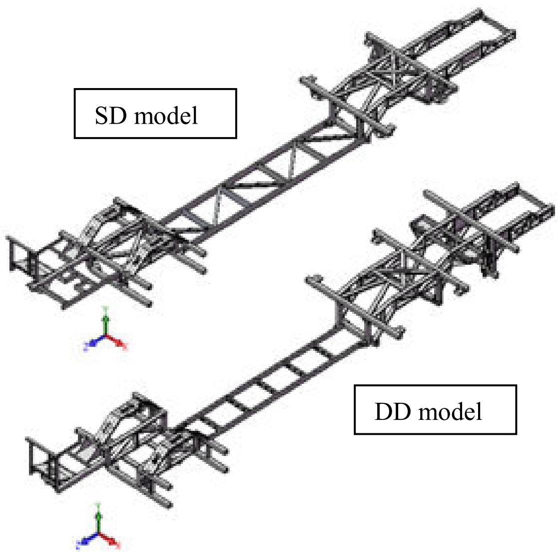

Fig. 1 Bus Chassis Platform configuration 2 models

Chassis platform of 8-wheel Double Decker bus, noted as DD model, is shown in Fig. 1. The platform sizes of DD are approximately 2.3 m width, 11.8 m length and 0.86 m height. Chassis platform of 6-wheel Single Decker bus, noted as SD model, is shown in Fig. 1. The platform sizes of SD are approximately 2.35 m width, 11.8 m length and 0.77 m height. Both models are conformed to Thailand's regulations by Department of Land Transport 2009. The chassis platforms are made from various size of stainless steel rectangular tube RST 4003, such as 80x80x4, 80x40x4 and 50x50x4.

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II. Procedure

A. Studying on chassis platform

The structures of chassis platforms 2 models are similar to each other. The chassis platform was divided into 3 zones, front, middle and rear zones. The chassis platform in the front and rear zones is quite symmetry along the longitudinal axis. Moreover, the front and rear zones are rarely changed by customer order. Unlike the middle zone, bus length may be changed by customer requirements, and it leads to some changes in middle zone. Therefore, the middle zone of chassis platform is not considered as sub-assembly.

B. Dividing and grouping the platform into sub-assemblies

The front and rear zones of DD model was divided into subassemblies as illustrated in Fig. 2 and Fig. 3, respectively. The SD model can be divided same as DD model, as shown in Fig. 4 and 5, both front and rear zones. The subassembly consideration and grouping was based on similarity of shape and size of each portion.

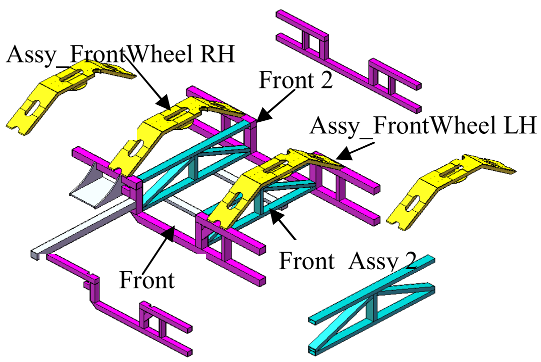

Fig. 2 Sub-assemblies of front zone; DD model

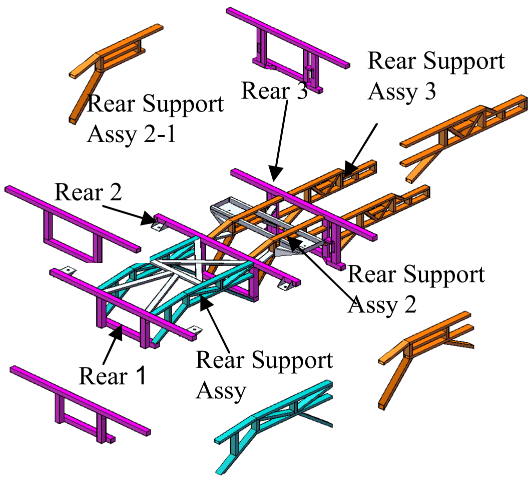

Fig. 3 Sub-assemblies of rear zone; DD model

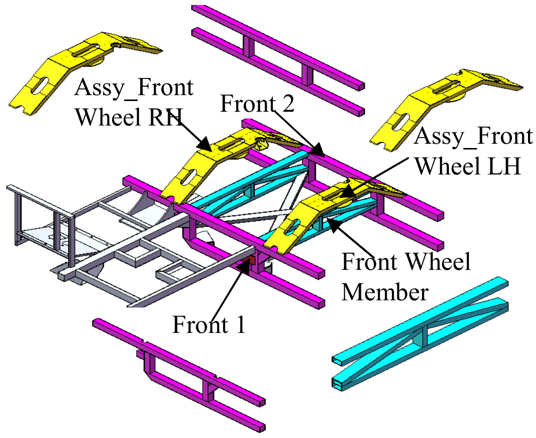

Fig. 4 Sub-assemblies of rear zone; SD model

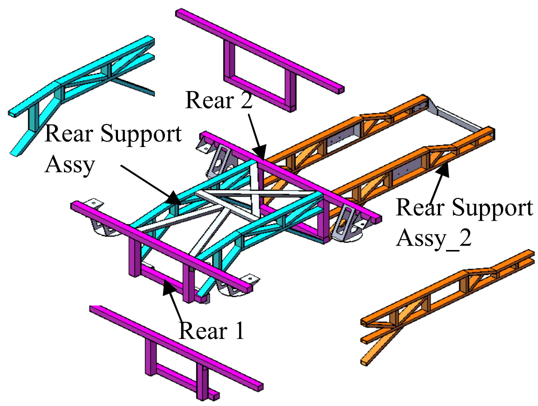

Fig. 5 Sub-assemblies of rear zone; SD model

C. JIG Designing

Jigs were designed for each group of sub-assemblies. The jig composed of supported structure and assembly table with clamps, as illustrated in Fig. 6. The supported structure contains 2 important features. Firstly, supported columns have adjustable slot for table height setting. Secondly, manual rotation device was installed to the structure that make the table is 360 degree rotable on horizontal axis for easier manual welding process. Clamps were installed on the table at designed point to fix sub-assembly's part elements [3].

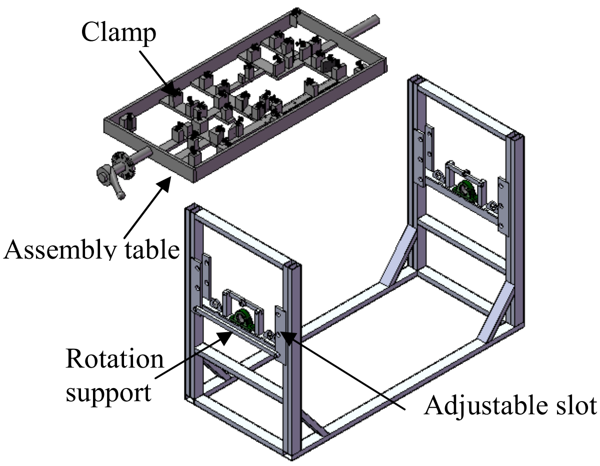

Fig. 6 Configuration of jig's supported structure and assembly table

D. Analysis and Material

Analysis of Jigs model was carried out to determine the stress and deformation by using commercial software, SolidWork and ANSYS Workbench. Jigs were designed based on 2 types of material. Assembly table is used of Structural Steel AISI 1020 and Support Structure is used of Stainless Steel RST 4003, as indicated in Table. 1. Finite element method was applied to analyze structure stress, deflection and safety of factor in 4 cases.

TABLE I
THE FEATURES OF THE MATERIAL

Properties	AISI 1020	AISI 4142	RST 4003
Modulus of Elasticity(GPa)	200	220	220
Poisson's Ratio	0.25	0.3	0.3
Weight Density(kg/m^3)	7860	7860	7740
Yield Stress(MPa)	390	1720	320
Tensile Stress(MPa)	470	1930	450

CASE 1 Analyze stress of Assembly table

This case considers load of sub-assemblies that lie on the assembly table. Load figure of case I is illustrated in Fig. 7 and maximum load of each jig is shown in Table 2.

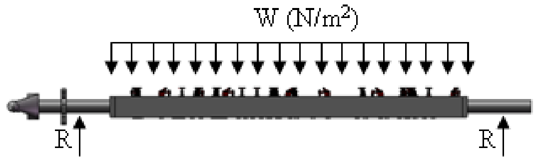

Fig. 7 Load on Assembly table in case 1

TABLE II
LOAD ON ASSEMBLY TABLE IN CASE 1

JIG	1	2	3	4
Maximum Load of Sub-assemblies (N)	645.79	388.25	462.78	415.62
Support Area (m^2)	0.76	0.41	0.59	0.23
Maximum Load of Sub-assemblies (Pa)	849.72	946.95	784.37	1807.04
Reaction force (N)	322.9	194.13	231.39	207.81

CASE 2 Analyze stress of assembly table

This case considers load of sub-assemblies and the table itself that applied to the assembly table. Load figure of case II is illustrated in Fig. 8 and maximum load of each jig is shown in Table 3.

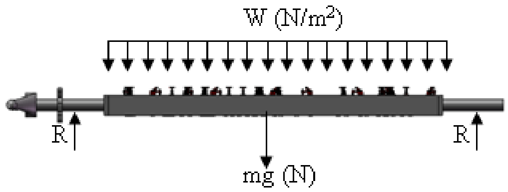

Fig. 8 Load on Assembly table in case 2

TABLE III
LOAD ON ASSEMBLY TABLE IN CASE 2

JIG	1	2	3	4
Maximum Load of Sub-assemblies (Pa)	849.72	946.95	784.37	1807.04
Load of Clamp and Screw(N)	75.62	82.06	67.01	6.34
Load of Assembly Table(Pa)	3156.14	2288.58	2957.45	879.83
Reaction force (N)	1938.71	1379.44	1743.62	650.9

CASE 3 Analyze stress of Supported Structure

This case considers load of sub-assemblies and table that loaded on supported structure. Load figure of case III is illustrated in Fig. 9 and maximum load of each jig is shown in Table 4.

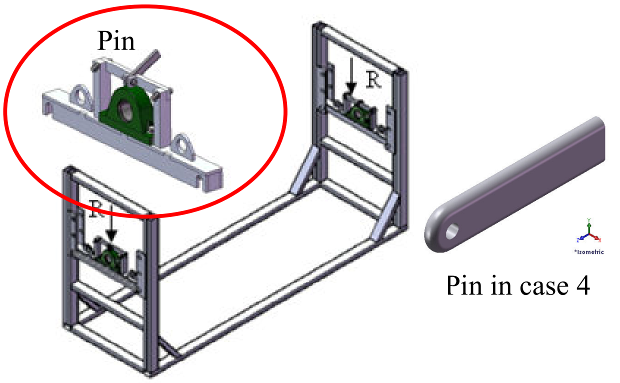

Fig. 9 Load on Supported Structure in case 3

TABLE IV
LOAD ON SUPPORTED STRUCTURE IN CASE 3

JIG	1	2	3	4
Total Maximum Load (N)	4268.29	3140.33	3859.3	1780.1
Reaction force (N)	2134.15	1570.17	1929.65	890.05

CASE 4 Analyze stress of Pin when the maximum load is applied (about 4268.29 N). Figure of loading and pin is shown in Fig. 9.

E. Standard Time

Flow Process Chart analysis was carried out to analyze the working processes of each sub-assembly [3]. This analysis has concerned the whole processes including operation time, inspection time, delay time, storage time and moving time. Pre-Determined Standard Time Technique and Rating of Westinghouse System were employed to estimate Normal Time (NT) of each process, as displayed in equation (1)[3] [5].

$$NT = (1 + R)CT \qquad (1)$$

$NT = \text{Normal Time (minute)}$

$R = \text{Rating}$

$CT = \text{Cycle Time (minute)}$

The Cycle Time (CT) was obtained from Pre-Determined Standard Time Technique, except welding time. The welding time was determined by welding test of the company's workers. The Westinghouse System Rating Techniques was used by considering skill, effort, working conditions and consistency of workers and working environments. Standard Time (ST) can be calculated by equation (2). Allowance is percent allowed for some idle situations such as meeting time, breaking time and tired of worker. This study has used 9% of allowance for further calculation, 4% for tired of worker and 5% for daily idle activities [6].

$$ST = (1 + A)NT \qquad (2)$$

$ST = \text{Stardard Time (minute)}$

$A = \text{Allowance}$

$NT = \text{Normal Time (minute)}$

III. RESULT AND DISCUSSIONS

The 2 models of chassis platform were considered and divided into sub-assemblies. The DD model was separated into 15 portions, 12 different sub-assemblies and the SD model was separated into 12 portions, 9 different sub-assemblies, as shown in Table 5. Each sub-assembly was illustrated above in Fig. 2-5. Similarity of sub-assemblies leaded to 4 groups of sub-assemblies and 4 jigs were assigned to such groups.

TABLE V
WEIGHT AND STANDARD TIME OF SUB-ASSEMBLY

JIG	Sub-Assembly	Standard Time (minute)			
		DD model	Weight (N)	SD model	Weight (N)
1	Front 1	25.65@[1)]1	390.51	23.46@1	435.96
	Front 2	23.65@1	468.06	20.13@1	493.78
	Rear 1	20.23@1	403.50	20.23@1	403.50
	Rear 2	20.12@1	411.61	20.12@1	411.61
	Rear 3	31.04@1	645.79	-	-
2	Front Assy 2 , Front Wheelmember	20.47@2	297.05	20.47@2	283.50
	Rear Support Assy	27.15@2	388.25	27.15@2	388.25
3	Rear Support Assy 2	23.52@1	272.49	31.20@2	462.78
	Rear SupportAssy 2-1	22.52@1	222.05	-	-
	Rear support Assy 3	31.33@2	273.26	-	-
4	Assy_FrontWheel,RH	43.80@1	415.62	43.80@1	415.62
	Assy_FrontWheel,LH	43.80@1	415.62	43.80@1	415.62

[1)] *@ show the number of sub-assembly in the chassis*

The finite element analysis results of case I, II and III were presented in Table 6-8, respectively. It is set in ANSYS to display safety of factor equal to 15 in case that its factor higher than 15. Results of case I and III showed that the jigs can be safely used with low deformation and quite high safety of factor. However, results of case II analysis showed the highest risk on Jig#1 with high deformation and low safety of factor. The weakest point is pin use for locking adjustable slot on assembly table as shown in Fig. 10 and deformation of the table is shown in Fig. 11. It is considered that re-design of this part may yield better safety of factor. It was found that, the re-design yield higher safety of factor from 1.94 to 4.20 as shown in Table 9. The analysis results for case 4, maximum stress 730.24 MPa, strain 0.0033193 and deformation 1.2449 mm are obtained and shown in Fig. 12. The pin may be safely used with safety of factor 2.36. Re-design of either pin size or material should yield improvement of safety factor.

TABLE VI
ANALYSIS RESULT OF ASSEMBLY TABLE (CASE 1)

JIG	1	2	3	4
Maximum Stress (MPa)	36.42	25.32	27.42	29.07
Maximum Deformation (mm)	0.18	0.10	0.30	0.12
Safety of factor	10.71	15	14.22	13.42

TABLE VII
ANALYSIS RESULT OF ASSEMBLY TABLE (CASE 2)

JIG	1	2	3	4
Maximum Stress (MPa)	200.78	114.03	167.58	53.12
Maximum Deformation (mm)	1.06	0.60	1.90	0.27
Safety of factor	1.94	3.42	2.33	7.34

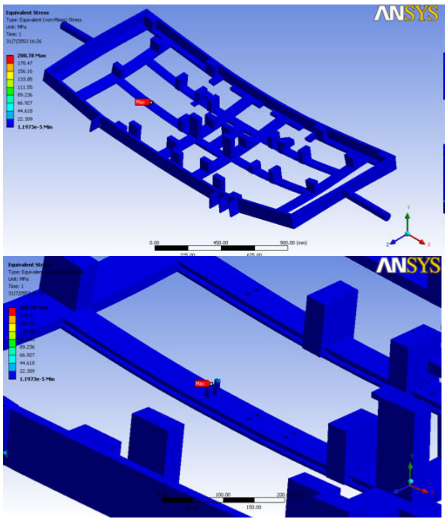

Fig. 10 The maximum stress point (case 2)

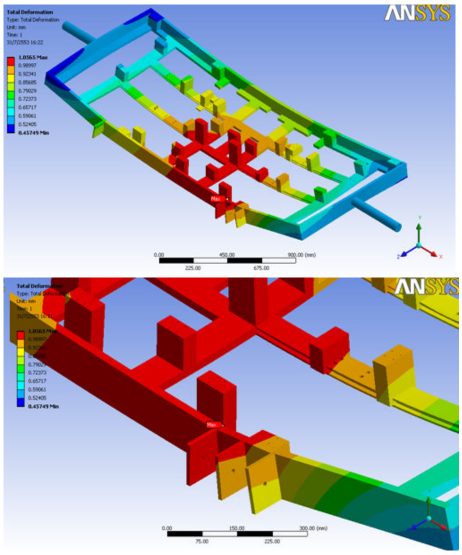

Fig. 11 The deformation point (case 2)

TABLE VIII
ANALYSIS RESULT OF SUPPORT STRUCTURE (CASE 3)

JIG	1	2	3	4
Maximum Stress (MPa)	18.99	14.85	17.87	7.68
Maximum Deformation (mm)	0.023	0.017	0.021	0.009
Safety of factor	15	15	15	15

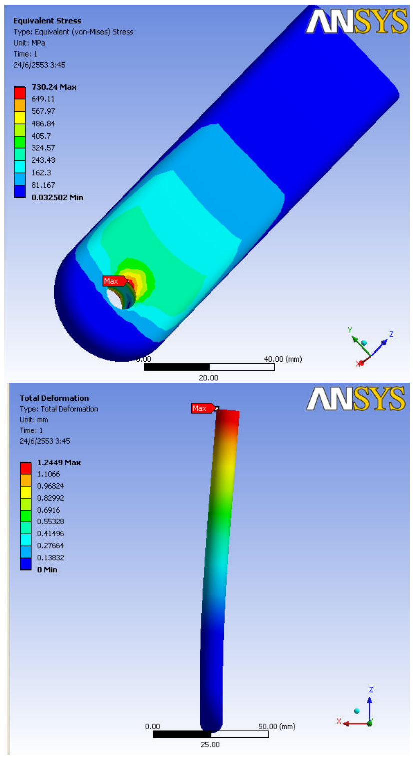

Fig. 12 The max stress and deformation point (case4)

TABLE IX
ANALYSIS RESULT OF SUPPORT STRUCTURE (CASE 3)

JIG	1
Maximum Stress (MPa)	92.94
Maximum Deformation (mm)	1.50
Safety of factor	4.20

The standard time used in the production for each sub-assembly is expressed in Table 5. It was seen that preparation of sub-assemblies of 1 bus consume about 412 minute for DD model and 329 minute for SD model. On the other word, it can be notified that preparation of sub-assemblies for bus chassis platform can achieve approximated 1.2 bus/day for DD model, and 1.5 bus/day for SD model, based on 8 hours working per day, as shown in table 10 and 11.

TABLE X
TIME OF OPERATION THE CHASSIS, DD MODEL

Operator	1	2	4	6
Standard Time (minute)	412.23	208.29	120.69	95.24
Production Rate/Day	1.2	2.3	4	5
% idle	-	1.04	6.85	8.61
Production rate/day/man	1.2	1.15	1.0	0.83

TABLE XI
TIME OF OPERATION THE CHASSIS, SD MODEL

Operator	1	2	4	6
Standard Time (minute)	329.18	171.54	95.24	-
Production Rate/Day	1.5	2.8	5	-
%idle	-	4.05	8.62	-
Production rate/day/man	1.5	1.4	1.25	-

In case that 2-man working for chassis sub-assembly production, the 1st man work at jig No. 1 and 4 and the 2nd man work at jig No. 2 and 3. For further analysis of production capacity, 4-man working and 6-man working scenario were also considered. In case of 6-man working, additional 2 jigs (jig#1 and #3) are needed. Table 10 and 11 showed standard time, production rate and %idle time on each scenario of DD model and SD model, respectively. It was seen that production rate for DD model and SD model are 2.3 bus/day and 2.8 bus/day, respectively, for 2-man working scenario. It was about 90% increasing while double workforce is used. It can be considered that %Idle in the 2-man working scenario may be the cause of less than double production rate. That result is also implied in reduction of production rate/day/man. It was found that, generally, increasing of number of worker tend to higher production rate, higher %idle time and lower production rate/day/man as shown in table 10 and 11. In case of 6-man working scenario of DD model, 5 bus/day with 8.61% idle time is obtained. It should be trade-off between number of worker, production rate and %idle time for desired production capacity.

IV. CONCLUSION

This study aims to design production jigs for bus chassis and use finite element method to analyze the jigs. Production rate of various production scenarios will be analyzed by varying number of manpower and number of jig. The structures of 2 bus models, Double Decker (DD model) and Single Decker (SD model), of chassis were studied. The DD model was separated into 15 portions, 12 different sub-assemblies and the SD model was separated into 12 portions, 9 different sub-assemblies. 4 jigs were designed for 4 groups that have high similarity of shape and size. Finite element analysis was employed to analyze the jigs in 4 cases. It was found that Jig#1 was the weakest in stress analysis with safety of factor 1.6. After redesigning of part in that jig, safety of factor is improved to 3.2. The pin of rotation table might also under risk of using with safety of factor 2.36. Re-design of either pin size or material should yield improvement of safety of factor.

Standard time for production of each sub-assembly on specified jig was calculated. In case of 1-man working, it was found that the production rate of chassis platform are approximated 1.2 bus/day for DD model, and 1.5 bus/day for SD model, based on 8 hours working per day. Furthermore, in case that 2-man working, production rate for DD model and SD model are 2.3 bus/day and 2.8 bus/day, respectively. The double workforce yield about 90% increasing in production rate. Although the idle time make it loss in 10% workforce, higher production rate is quite interesting alternative for manufacturer. The 4-man and 6-man working will result higher production rate. However, increasing of %idle time and lower production rate/day/man are important trade-off.

There may make more advantage to study more complicated alternative such as, more jig set compared with various workforce levels. The jigs are during fabrication, on the job investigation for jig performance will be carried out later.

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