A Study on The Development of Tunnel Type Locating Drill Jig by Practical and Adaptive Tooling System

실 적응성 툴링 시스템에 의한 터널 타입 로케이팅 드릴지그의 개발에 관한 연구

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by

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A Dissertation

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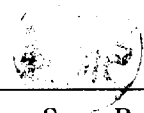

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December 24, 2001

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연 구 개 요

Drilling Jig는 생산 현장의 요구에 따라 놀라운 비율로 증가하고 있는 장치이다. 즉, 대량생산을 위한 jig와 fixture의 사용은 설계나 공작기계가공, 용접, 조립 등의 분야에서 특별한 장치이다. 이때 생산제품의 결함을 방지하기 위해 제품의 최적 설계에 jig와 fixture를 적용하는 것은 매우 중요한 제조 방법이다. 이러한 jig와 fixture는 이론과 실제 공작기계의 작동과정과 현상, jig와 fixture의 구조, 기계상태, 공구제작 및 공구 재료, jig 및 fixture 구성품의 열전달, know-how 등등 여러 종류의 중요한 인자들의 분석을 요구한다.

본 연구에서는 Window 환경에서의 Auto CAD와 Auto LISP을 이용 대량생산용 drilling jig의 설계 및 tryout을 시도했다. 특히 tryout의 결과와 그것의 분석은 본 연구의 특징이며, 이런 형태의 연구 방법은 이전에는 볼 수 없었던 것이다.

본 연구의 결과는 생산현장이나 실험실에서의 새로운 jig 및 fixture의 개발에 고 능률과 정밀도 향상의 면에서 좋은 기초자료로 활용될 수 있다고 사료된다.

1. Introduction

The jig and fixture perform a series of machine tool working for mass production. Among them, the jig is a special device that supporting, locating, and clamping components are placed on a part to be machined. It is a product tool so made that it not only locates and holds the workpiece but it also guides the drill, reamer, tap, boring tool, etc. during the operation is performed. Jigs are usually fitted with hardened steel bushings for guiding drills or other cutting tools. As a rule small jigs are not fastened to the drill press table. However, the holes above 13mm are to be drilled, it is usually necessary to nest or to securely fasten the jig to drilling machine table. Due to small jigs are usually necessary to product manufacturing industrial. In this paper, we designed one of a small jigs also production planning. So, the goal of this study is the accomplishment to the least defects of small size drill jig design and making the practical and adaptive drilling jig by the theoretical background, database, experiences, with Auto-Lisp under the Auto-Cad and Window environment. This study revealed production system, production plan, jig making and its tryout result analysis.[1~4)]

2. Theoretical Background

2.1 Production System and Jig Planning of Process.

Fig. 1 shows the organization in product manufacturing field. In this figure, we can find the important activity of tool manufacturing department.[1~4)]

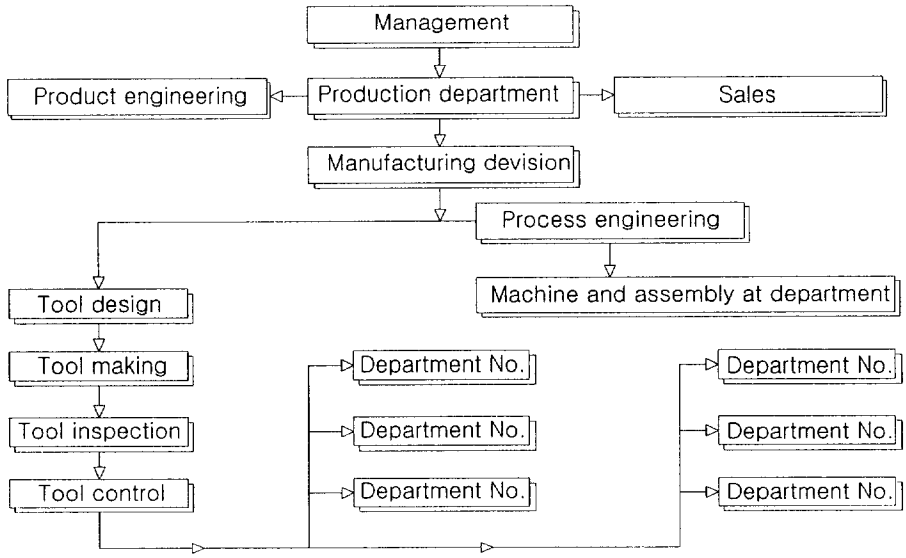


Fig. 1 Organization of product manufacturing field.

Fig. 2 shows the outline of the jig and fixture planning of process. In this figure, we consider the jig and fixture development through the many kind if influence factors. Among those influence factors, the cost analysis and evaluation is critical event factor.[1~3)]

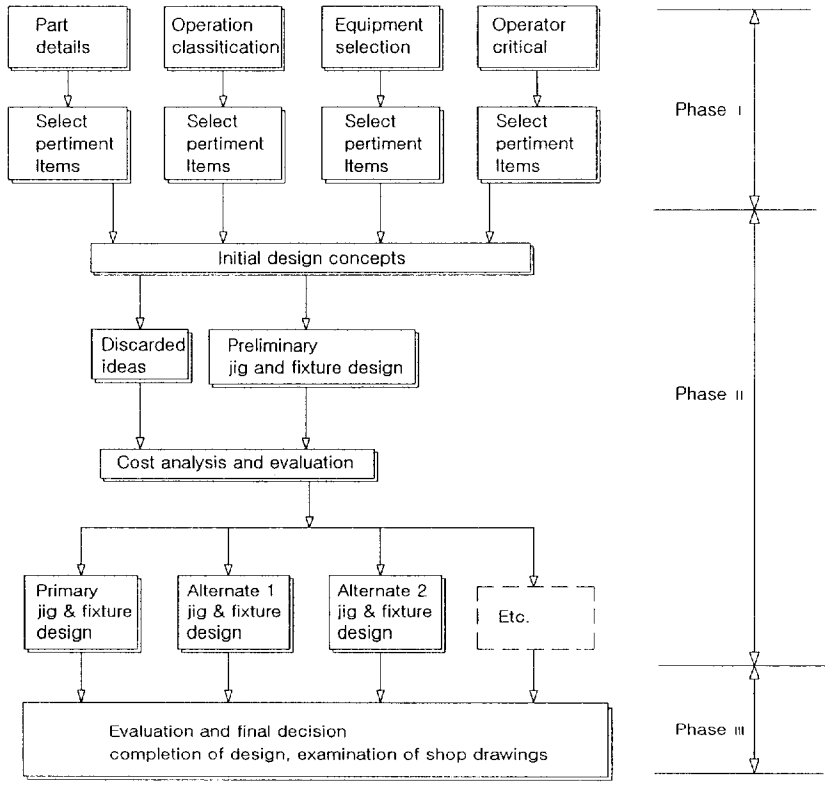


Fig. 2 Outline of the jig and fixture planning of process

Fig. 3 shows the out line of considerations in jig and fixture design. In this figure we can consider the important point of loading and unloading, locating, clamping, safety of work and operator, cutting tool, coolant, and chip removement etc.[5~7)]

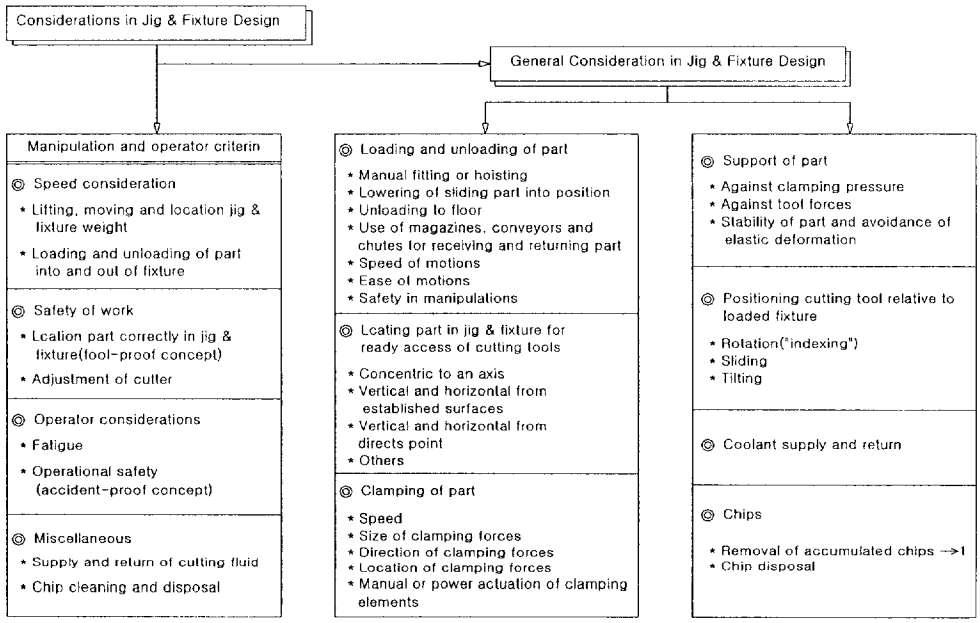


Fig. 3 Outline of considerations in jig and fixture design

2.2 Locating System.

Fig. 4 shows an object that is unrestricted movement occur. This object is free to move in any of twelve possible directions. To visualize this, the lanes have been made X-X, Y-Y, and Z-Z. The directions of movement are numbered from one to twelve.[1)]

Fig, 5 illustrates the principle of restricting movement. By placing the part on a three pin-locator base, five direction of movement(#2, #5, #1, #4, #12) are restricted. Flat bases may also be used, but these should be installed rather than machined into the base. To restrict the movement of the part around the Z-Z axis and in direction #8, two more pin-type locators are positioned. To restrict direction #7, a single, a single-pin locator is used. The remaining directions, #9, #10, #11 are restricted by using a clamping device. This 3-2-1, or 6-point locating method is the most common external locator for square or rectangular part.[1)]

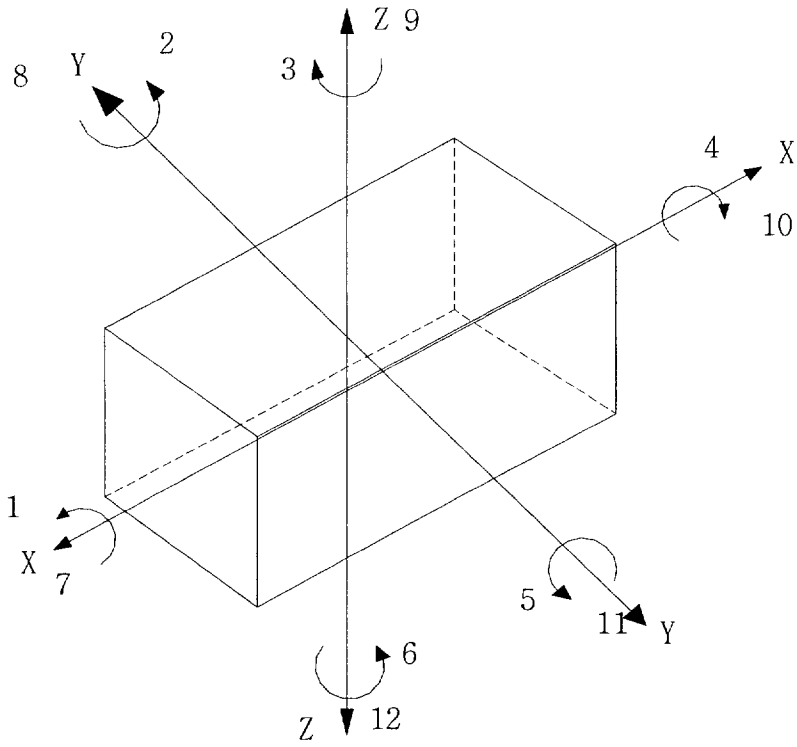


Fig. 4 Planes of movement

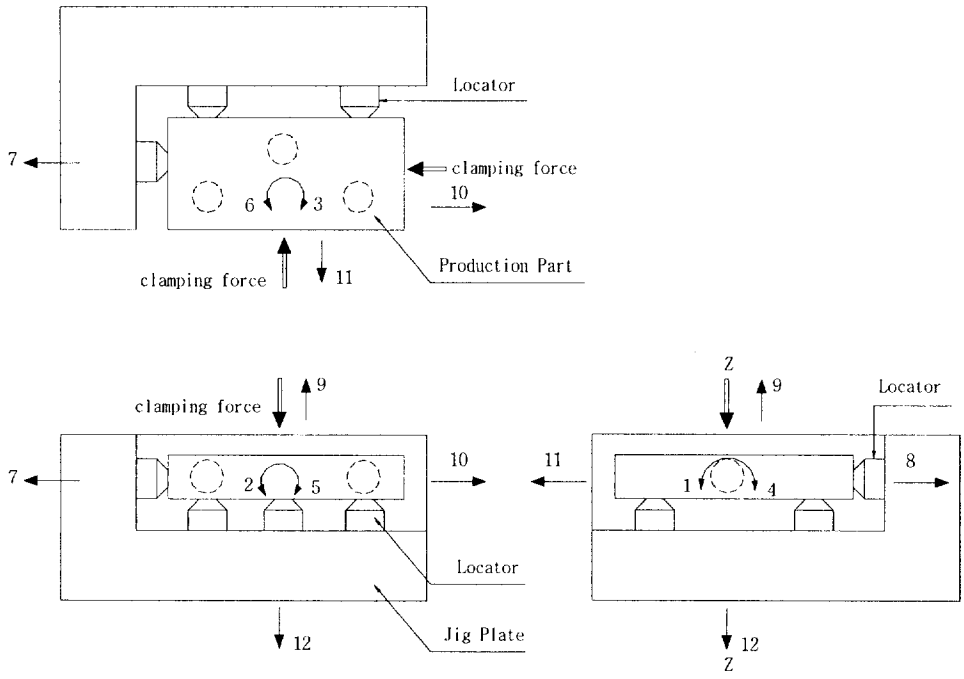


Fig. 5 3-2-1 locating system

2.3 Jig Bushing for Drill Jig Design

The jig bushing for drill jig design require the following for preliminary consideration.

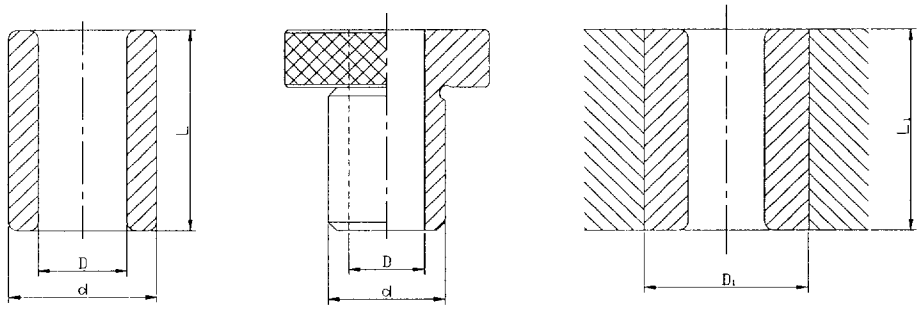
- Size of hole or holes to be drilled
- The type or types of bushings required for drilled holes (head or headless press fit; stationary renewable, or slip renewable, with liner bushings) and reamed, counter sunk, counter bored, or tapped holes(slip removable with liner bushings).
- The outside diameter must be confirmed for ground to press fit size, oversize for fitting and ground for slip fit in liner bushings, the length of drill bushings must be considered among short, medium, long or special size, also special type bushings too with standard bushings altered by grinding or bushings made to specifications.[1)]

We must decide the bushing type for special purposes such as index pin holes or pilot bushings for reamers and boring bars. When installing bushing, another important factor to consider is burr clearance. In any drilling operation two kinds of burrs are produced, primary and secondary. The primary burr is made on the side opposite the drill bushings. The secondary burr is produced at the point where the drill enters the work. These burrs most be considered and sufficient clearance provided.

Fig. 6 shows the profile of fixed and renewable bushing. At this time, the size of D in Fig. (a)(b) means the hole size.

Table 1 shows the symbols of tolerances in bushing assembly.

Table 2 shows the fitting tolerances of representative in bushing assembly.



(a) Fixed bushing (b) Renewable bushing (c) Bush fitting

Fig. 6 Profile of fixed and renewable bushing[1~4)]

Table 1 Tolerance of bushings

unit : 0.001mm

Purpose	Fixed bushing			Renewable bushing		Jig body	
	d	D	L	d	D	D_1	L_1
Drilling bushing	p6	G6	0	m5	G6	H7	+500 0
H7 hole reaming bushing	p6		0 -500	m5		H7	+500 0
Bushing for renewable bushing	p6		0 -500			H7	+500 0

Table 2 Fitting tolerance of representatives.

unit : 0.001mm

Kind-ness Grade \ Size		1 to 3	3 to 6	6 to 10	10 to 18	18 to 30	30 to 50	50 to 80
Shaft	p6	+16 +9	+20 +12	+24 +15	+29 +18	+35 +22	+42 +26	+51 +32
	m5	+7 +2	+9 +4	+12 +6	+15 +7	+17 +8	+20 +9	+24 +11
Hole	G6	+10 +3	+12 +4	+14 +5	+17 +6	+20 +7	+25 +9	+29 +10
	H7	+9 +0	+12 +0	+15 +0	+18 +0	+21 +0	+25 +0	+30 +0

3. Design of Jig

3.1 Part Drawing and Its Production Plan

Fig. 7 shows the experimental production part drawing.

Table 3 shows the chemical composition of SM20C as a production part material.

Table 4 shows the mechanical properties of SM20C as a production part material.

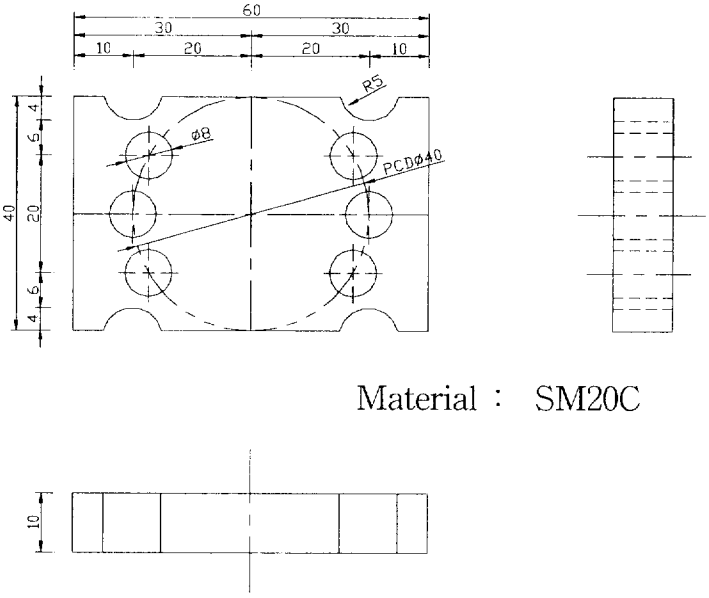


Fig. 7 Production part drawing

Table 3. Chemical composition of SM20C (wt.%)

C	Si	Mn	P	S
0.19	0.25	0.33	0.025	0.032

Table 4. Mechanical properties of SM20C

Tensile strength(kg/㎟)	Yielding point(kg/㎟)	Elongation (%)	Hardness (H_B)
45.1	39.1	32.0	137

According to this part drawing. We made production plan as the Table 5 showing. In the Table 5, the drilling jig operation is performed at the operation number 4.

Table 5. Production Plan

PRODUCTION PLAN			
Part No.		Part name : Precision bracket	
Operation No.	Description	Department	Machine tool
1.	Cut off-Ⓣ×Ⓦ stock to Ⓛlength with cutting allowance	#○○ cut off room	Abrasive cut off saw #○○-○○
2.	Drill-ØD hole thru	#○○ Drilling	Drill press #○○-○○
3.	Mill- t×w×L Two side of length direction.	#○○ Milling	Horiz. Mill #○○-○○
4.	Drill-ØD	#○○ Drilling	Drill press #○○-○○
5.	De burr	#○○	Tumbler
6.	inspect-visual and dimensional	Finishing	#○○-○○ None
Operation No.	Tool description	Size	Spec. Tool
1.	Cutt off wheel	○×○×○mm	None
2.	Drill	ØD1 mm	#J-○○○-1 Jig #F-○○○-1
3.	Milling cutter(2)	w×t×d	Fixture #J-○○○-2
4.	Drill	ØD2 mm	Jig #G-○○○-2
5.	Plug gage(2)	ØD1, ØD2	#G-○○○-1

3.2 Decision of Locator Diameter Bushing Diameter and Holes Distance

Fig. 8 shows the decision of locator diameter, bushing diameter and hole distance.

When the production part drilling diameter is $D_1 \pm 0.1$mm, the bushing size must be taken down +0.1mm therefore it should be decided precision tolerance in D_4 G6(Ø 6 G6 : $\varnothing 6\ ^{+0.012}_{+0.004}$)

At this time, the drilling diameter is not over size Ø 6.012. Also, the locator size D_3 must be lower than lowest tolerance -0.1mm, hence we decided 0.1-0.02=0.08, also, the machining tolerance ± 0.01mm. According to these calculations we can decide the locator diameter D_3(Ø5.88$\pm$ 0.01). By the Hoffman's theory,[1] the jig hole distance tolerance must be followed in 20~25% of production part tolerance. So, in this paper production part distance can come out $W_1 \pm 0.02$(20% of ± 0.1) $W_2 \pm 0.04$(20% of ± 0.2) as a minimized percentage.

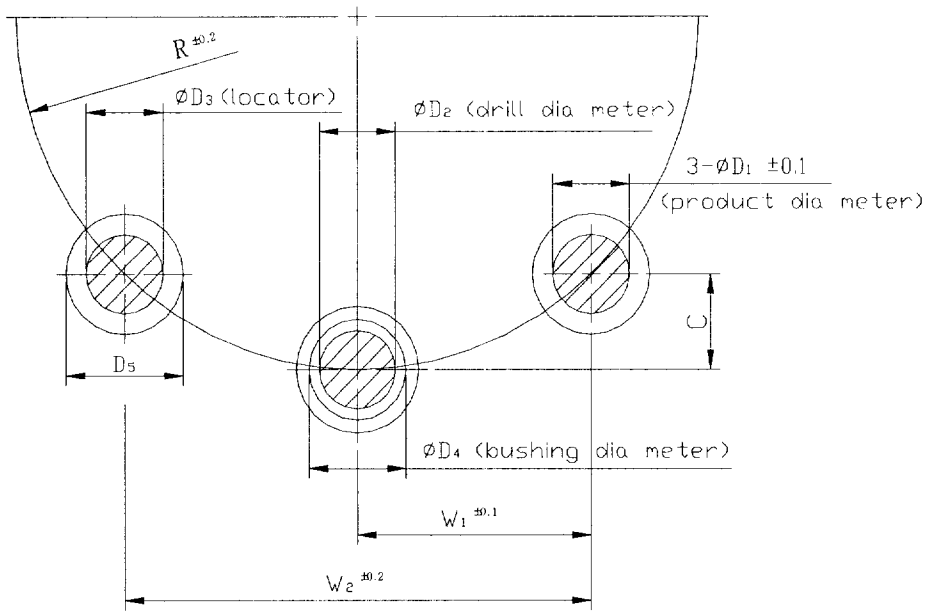


Fig. 8 Decision of locator diameter, bushing diameter and holes distance

4. Auto-Lisp Programming and Application for Jig Design

Upper principle, instructions and whole of the data base were foundation of the Auto-Lisp programming. Fig. 9 shows the one of a part from Auto-Lisp programming procedures of the jig bushing among the all of components. Fig. 10 shows the one of a results of Auto-Lisp programming. We used this programming to the several kinds of jig components for the rapid jig design.

```
defun lbush ()
        (setvar "aunits" 1)
        (setvar "osmode" 0)
        (setvar "cmdecho" 0)
        (setq data_file "/JF/data/liner.dat")
        (load "/JF/dlist1")
        (graphscr)
        (lbush_dcl)
        (cond ((= lhbush "1") (Lhbush_draw))
        (cond ((= lpbush "1") (Lpbush_draw))
```

Fig. 9 Procedures of Auto-Lisp programming for jig bushing

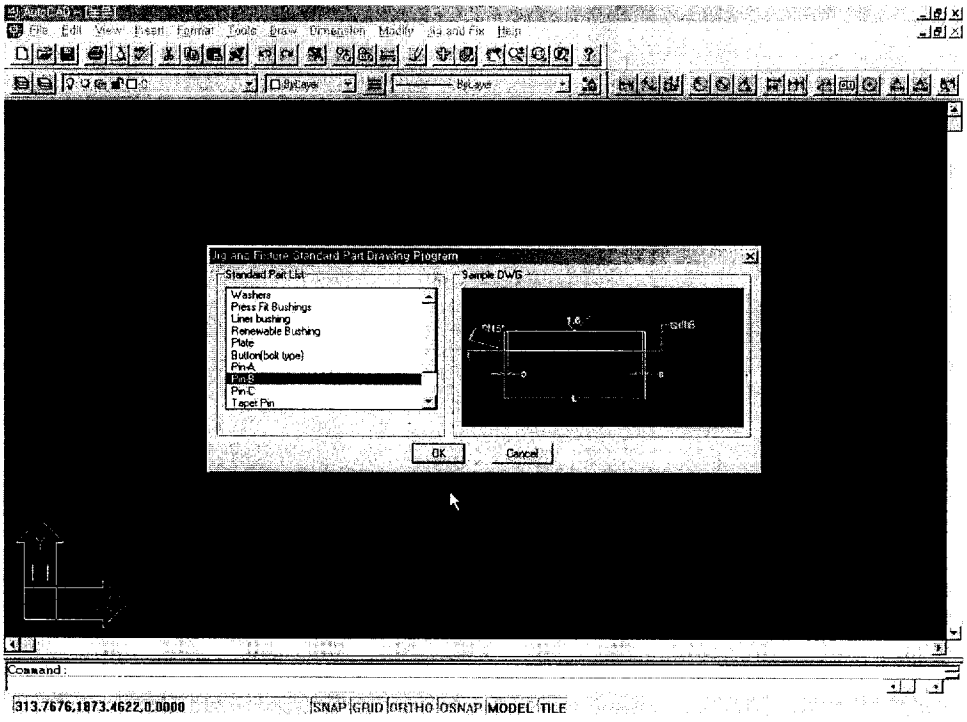


Fig. 10 Result of Auto-LISP programming

Fig. 11 shows the press fit bushing DCL of Auto-Lisp programming result.

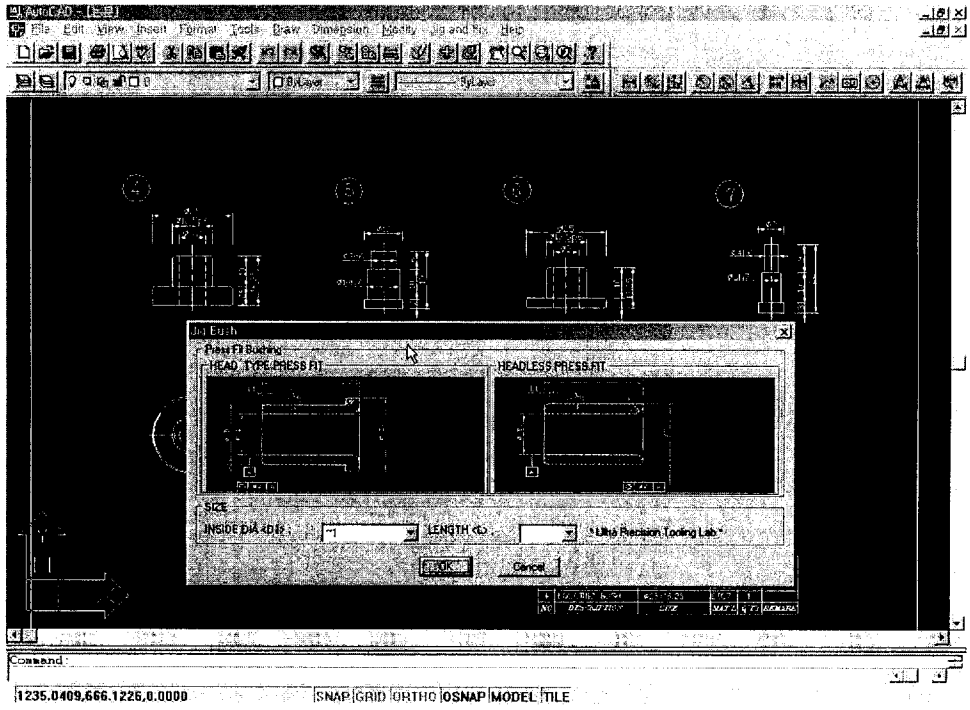


Fig. 11 Press fit bushing DCL of Auto-Lisp programming result

Fig. 12 shows the renewable bushing DCL of Auto-Lisp programming result.

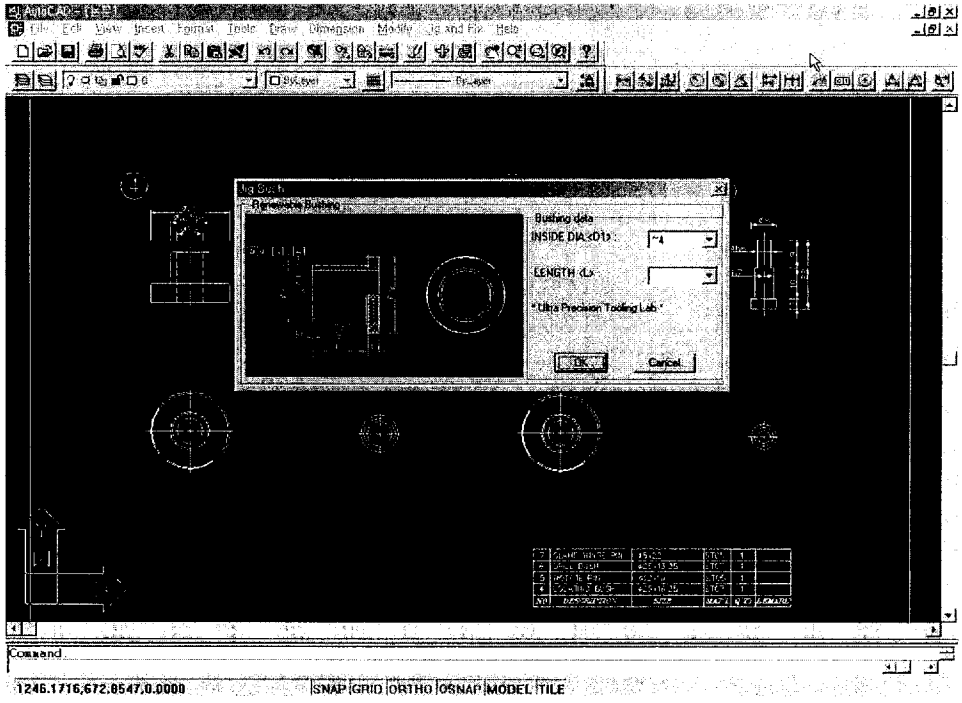


Fig. 12 Renewable bushing DCL of Auto-Lisp programming result

Fig. 13 (a) shows the liner bushing DCL of Auto-Lisp programming result.

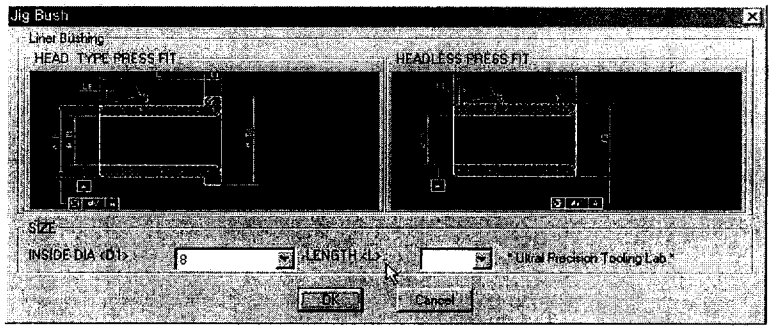


Fig. 13 (a) Liner Bushing of Auto-Lisp programming result

Fig. 13 (b) shows the V-block DCL of Auto-Lisp programming result.

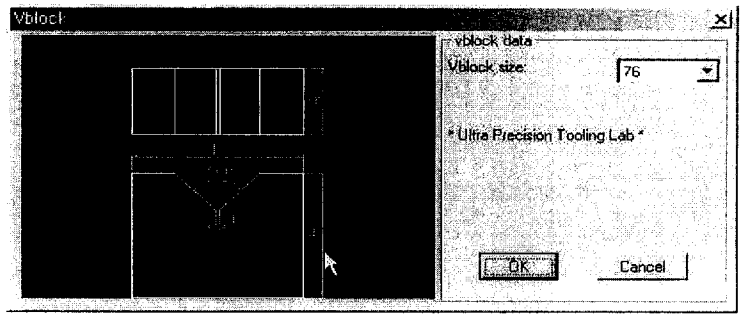


Fig. 13 (b) V-Block DCL of Auto-Lisp programming result

Fig. 13 (c) shows the taper pin DCL of Auto-Lisp programming result.

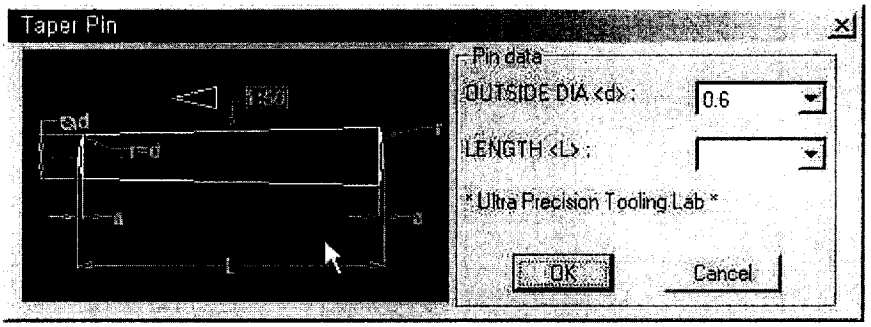
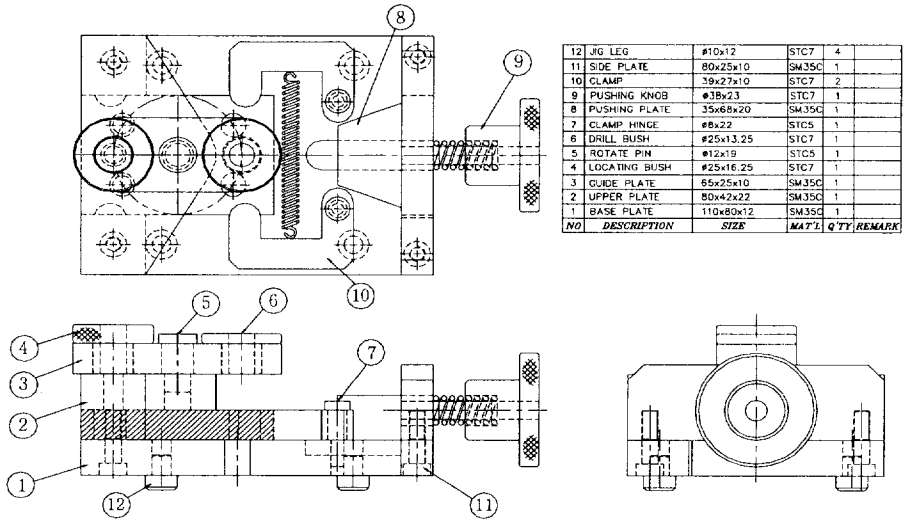


Fig. 13 (c) Taper Pin DCL
of Auto-Lisp programming result

Fig. 13 Auto-Lisp programming result

The Assembling drawing of drill jig design result is shown in Fig. 14.

In this assembling drawing, the 3-2-1 locating system was used through the alternating of component number ①(base plate), ②(upper plate), and ⑩(clamp).



NO	DESCRIPTION	SIZE	MAT'L	Q'TY	REMARK
12	JIG LEG	ø10x12	STC7	4	
11	SIDE PLATE	80x25x10	SM35C	1	
10	CLAMP	39x27x10	STC7	2	
9	PUSHING KNOB	ø38x23	STC7	1	
8	PUSHING PLATE	35x68x20	SM35C	1	
7	CLAMP HINGE	ø8x22	STC5	1	
6	DRILL BUSH	ø25x13.25	STC7	1	
5	ROTATE PIN	ø12x19	STC5	1	
4	LOCATING BUSH	ø25x16.25	STC7	1	
3	GUIDE PLATE	65x25x10	SM35C	1	
2	UPPER PLATE	80x42x22	SM35C	1	
1	BASE PLATE	110x80x12	SM35C	1	

Fig. 14 Assembling drawing of drill jig design result

Fig. 15 (a) shows the drawing of base plate among jig components. The base plate is installed all of jig components.

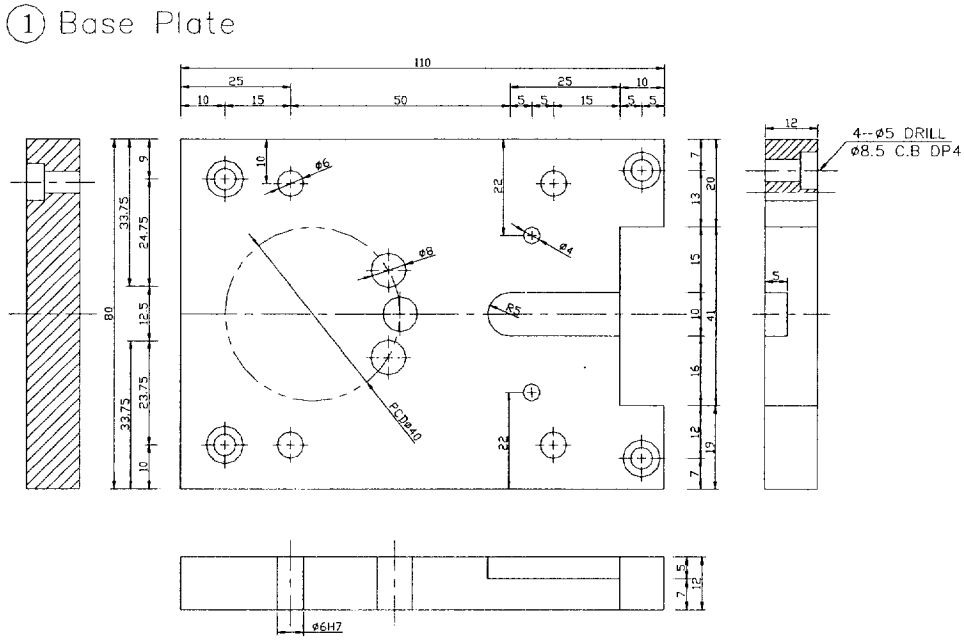


Fig. 15 (a) Drawing of base plate among jig components

Fig. 15(b) shows the drawing of pushing plate, pushing knob, and clamp. The pushing plate acts to push the clamp.

The pushing knob acts to push the pushing plate as connecting to pushing plate.

Also, the clamp is used to hold the production part.

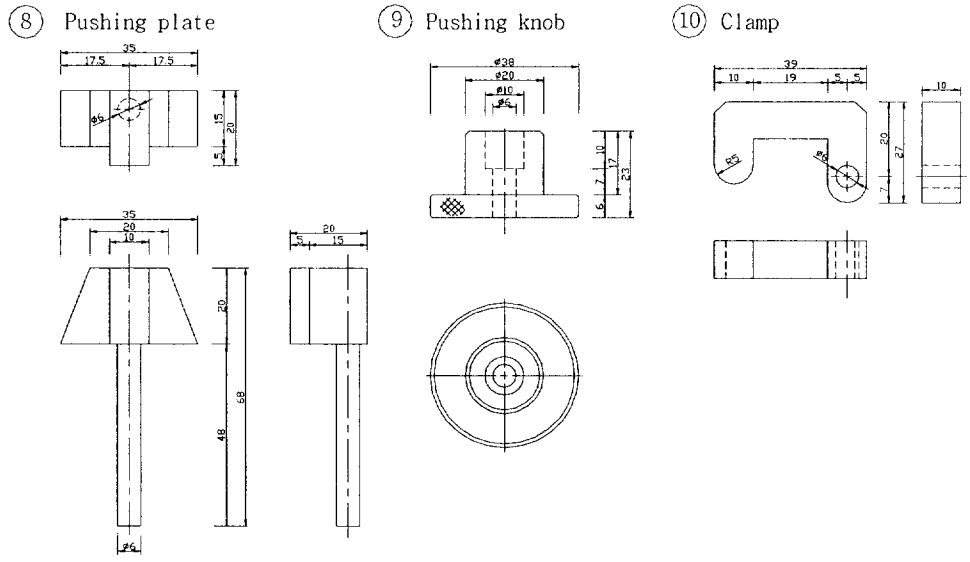


Fig. 15 (b) Drawing of pushing plate, pushing knob and clamp among jig components.

Fig. 15(c) shows the locating bush, rotate pin, drill bush and clamp hinge among the jig components.

In this figure, the particular factor is drill bush accuracy of Ø12.5 p6 of outer diameter

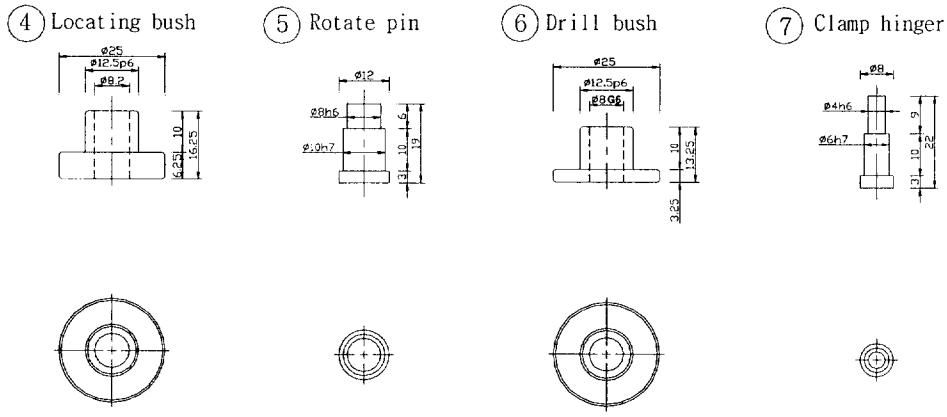


Fig. 15 (c) Drawing of locating bush, rotate pin, drill bush and clamp hinge among jig component.

Fig. 15(d) shows the guide plate and upper plate among the jig components.

The upper plate acts locating function and installing of pin and guide plate.

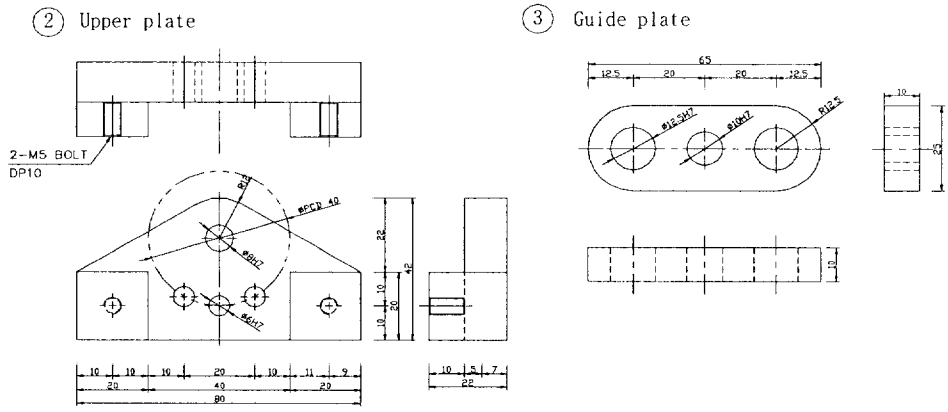


Fig. 15 (d) Drawing of guide plate and upper plate among jig components.

Fig. 15(e) shows the drawing of jig leg among jig components.

The side plate performs the installing of pushing plate and pushing knob. Jig leg performs the supporting the base plate with a whole of jig components on the drill table.

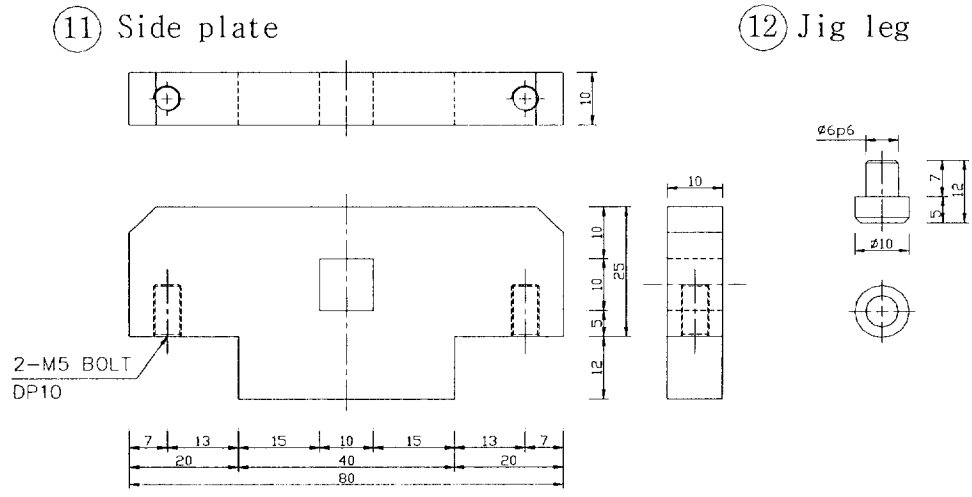


Fig. 15 (e) Drawing of side plate and jig leg among jig components

Fig. 15 Components drawing of experimental drilling jig

5. Jig Making System

The classification of type of machines and other equipments is show in Table 6.

At this time, fitting tolerances are concerned with its performing situation, We tried to take higher accurate fitting by field exercise with hand skilling, experiences and related instructions. (example: H7/h6, H6/h5, H7/m6, H6/m5, H7/m5, H6/n5, H7/p6, H7/p5 etc.)

Table 6 Classification of Type of Machines and Other Equipments

Material Removal Machine Tool		
Milling machine	Drill press	Boring machine
plain universal vertical, etc.	sensitive power feed multiple spindle, etc	vertical jig borer horizontal, etc.
Lathe	Liner motion machine tool	Gear cutting machine
engine lathe face plate lathe copying lathe turret lathe vertical boring mill, etc	planer shaper slotting machine broaching machine, etc.	gear hobbing machine gear shaper gear grinder, etc
Grinder	Abrasive machine tool	Honing machine
universal surface, etc.	abrasive belt abrasive disc, etc	
CNC machine tool	Non-chip cutting machine	Polisher
milling machine drill press lathe tube bender, etc.	chem mill ECM EDM, etc	wire brush felt or cloth wheel, etc.
Equipment for Manual Work Operations		
Heat-treating equipment	Plastic forming equipment	Surface treatment equipment types
furnace high-frequency current, etc		sand blasting equipment shot peening equipment, etc.
Surface coating equipment	Foundry equipment	
plating tanks painting booths drying and baking ovens, etc	sand preparation equipment molding machines core making machines mold and core drying and baking ovens casting machines, etc	
Joining Equipment		
Bonding equipment	Welder	Riveter
bonding press autoclave, etc	resistance arc welder electron beam laser, etc.	pedestal, etc.
Stapling machine	Stitching machine	Soldering and brazing equipment
		induction furnace, etc.
Automatic assembly machines	Other equipment for joining operations	
Inspection Equipment		
Optical	Inspection fixtures with indicating instruments	
comparator collimator laser operational stage area, etc.	mechanical(dial indicators) air gages hydraulic pressure gages electric meters electronic pickups, etc.	

From this actual jig, we took drilling experimental checking of the actual production part. Locator and jig bushing are main part in jig making, In this study, we decided the size of locator and jig busing depending on data base, theoretical back ground and our own field experiences. The machining of locator and bushing can belong to the precision machine tool working, continually raw material cutting, milling, turning, drilling, profiling and then heat freating, jig grinding, honning, especially, CNC machining and mirror machining. On the accuracy of each fitting components, the first factor is Drill bushing and locator's fitting tolerance H7, H6, H5(hole) and m6, m5, m4, n6, n5, n4, p6, p5, p4(shaft)for a tight fitting with a minor interference. The second factor is whole of hinges pin's fitting tolerance as a minor allowance for slide fitting tolerance H7, H6, H5(hole) h6, h5, h4(shaft). These fitting tolerances are very careful factors for jig making that the cause is whole jig assembling method must be within accurate central and parallel activities for production part tolerance.[4~7)]

6. Tryout

Fig. 16 shows the result tryout for experimental production part. Also we checked every dimension of production part with tolerance control. We could find the jig assembling function was minimized problems about the loading and unloading. This problem was improved into the passing zone by trouble shooting of jig component's repair and our own experience. Furthermore, the production part from tryout was so fine into the production part tolerances.

The sample part from try out was checked by fine instrument. The result of inspection of sample part was in its boundary of tolerances. Therefore this study of jig development have be come to fine result of all of discussion.

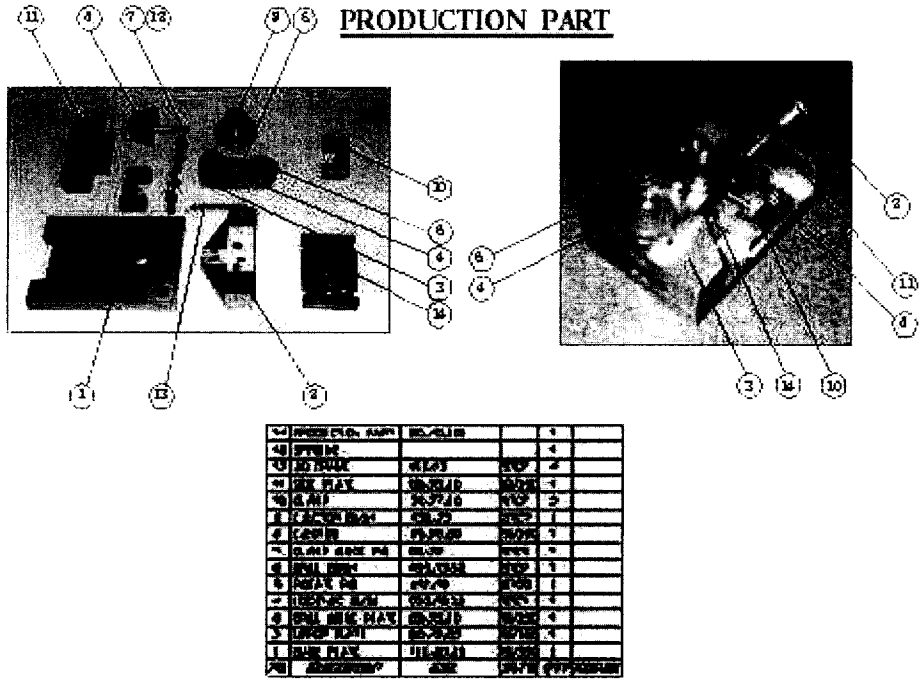


Fig. 16 Actual assembling of jig and its component by jig making

7. Conclusion

In order to prevent the defect of jig design and making, this study developed the practical and adaptive drill jig design, and its analyzing. This study could be carried out by the theoretical back ground, data base and our own field experiences.

The results of this study is as follows

(1) The data base and practical experiences were available for drill jig design as a comparison.

(2) The drill bushings and locators should be accurate a in those necessary making tolerances.

(3) 3-2-1 locating system could be transferred to tunnel or plane surface support.

(4) Also 3-2-1 location system was effective loading and unloading as well as accurate location for production part.

(5) The actual production part could be reviewed in adaptable tolerance to field application for assembling function.

(6) The result of tryout of experimental drilling jig could be possible to use in field as a passing the inspection of producted part.

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A Study on The Development of Tunnel Type Locating Drill Jig by Practical and Adaptive Tooling System

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Abstract

In order to prevent the production defects the optimum design of product, jig and fixture putting in the field is very significant manufacturing method. Drilling Jig is the device according to industrial demand for multi manufacturing products on the growing at alarming rate. In the field of design and making for machine tool working, welding, assembling with jig and fixture for mass production is a specific division. They require analysis of many kinds of important factors, theory and practice of machine tool operating process and jig & fixture structure, machining condition for tool making, tool materials, heat treatment of jig & fixture components, know-how and so on. In this study we designed and constructed a drilling jig of mass production and performed tryout under the Auto CAD, Auto Lisp with database, and window environment. Especially this study is reveals with the analysis of part drawing, jig planning, jig design etc, and then the result of drill jig's making and tryout was performed.

감사의 말씀

본 논문이 완성되기까지 석사과정동안 전 연구 활동을 지원해 주시고 이끌어 주신 심성보 지도교수님께 먼저 감사의 말씀을 드립니다.

아울러, 바쁘신 가운데서도 자세히 저의 논문 전반을 심사하여 주시고, 유익한 조언을 주신 오세규 교수님과 김광희 교수님께도 깊은 감사를 드립니다.

또한, 휴일도 없이 저의 논문이 완성되도록 도와준 실험실 송영석, 장찬호, 성열민 및 학부 후배들, 바쁜 생활속에서도 찾아주어 격려해준 소중한 친구 길태, 동헌이를 비롯한 사직고 6기 동기들, 그리고, 항상 곁에서 많은 관심을 가져준 수억, 진아, 형호 등 금형 연구회원들과 연신초등학교 1기 동기들과도 이 작은 결실을 함께 하며, 진심으로 감사 드립니다.

그리고, 항상 변함 없는 관심과 격려로 힘이 되어주신 호대 형과 종삼이 형, 남규 형께도 이 자리를 빌어 감사의 말씀을 드립니다.

아울러, 끊임없는 지도와 격려를 주신 기계공학부 교수님과 조교선생님께도 깊은 감사를 드리며, 항상 사랑과 온정으로 후원하여 주신 어머님과 믿음과 격려로써 지켜 봐준 사랑하는 동생 성애에게도 감사하며 이 기쁨을 함께 하고자 합니다.

2002 年 2 月

이 성 택 拜上