Structural Design and PLC Control of the Machine Tool Manipulator

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Abstract. A kind of hydraulic-driven manipulator for machine tool is presented in this paper. Firstly, the manipulator's structure is designed and 3D model is built by using solidworks software. Secondly, the hydraulic system diagram for implementing the manipulator's sequences is established. Finally, control system of the machine tool manipulator is implemented based on PLC, and the experimental results show the correctness and feasibility of our design and control programs. Therefore, this can provide a certain referencing value for the practical production application.

Introduction

The industrial manipulator is a kind of automatic equipment, which can simulate the hand gestures of human been and achieve the automatic motion of grabbing, carrying and manipulation, according to the preset sequences, tracks and demands [1]. It is one of the most important equipments, which can realize the industrial production mechanization and automation [1, 2]. Many applications demand manipulators with high degrees of repeatability, precision, and reliability. Therefore, some researches on the mechanical manipulator and its control have been done by many scholars [3-5]. In this paper, our designed the hydraulic-driven machine tool manipulator combined with CNC machine (machining centers, CNC milling machine, etc.) can form an automated production line to achieve processing (feeding, processing and automation of the cutting) without human interference.

Structural Design

The design technical parameters include: a) grasping weight: 5kg; b) degrees of freedom: 2; c) maximal work piece radius: 80mm. The movement parameters include: a) clamping stroke: 27mm; clamping speed: 0.054m/s. b) stretching stroke: 60mm; stretching speed: 0.06m/s. c) rotating range: 0°-90°; rotating speed: 45°/s. c) the finger gripping range: 60mm-80mm. d) buffering mode: hydraulic buffer. e) driving mode: hydraulic driving; f) control mode: PLC control.

According to the above technical and movement parameters, the 3D model is shown in Fig.1. Our designed machine tool manipulator has two degrees of freedom, the one is for horizontal stretching out and the other is for rotating in the vertical plane for the work piece. The finger is driven to achieve loosening and clamping movements by the first hydraulic cylinder (gray hydraulic cylinder). The stretching movement is implemented by the second hydraulic cylinder (purple hydraulic cylinder). The rotating movement in the vertical plane is driven by the third hydraulic cylinder (yellow hydraulic cylinder).

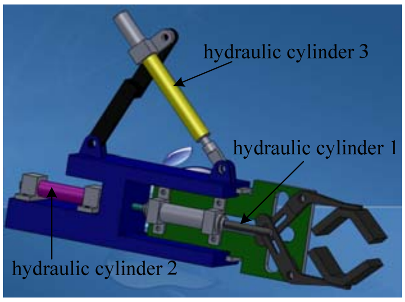

Fig.1 3D model of our designed manipulator

Hydraulic System Design and Implementation of Manipulator

The operation sequences of the manipulator are: original position →telescopic boom falling → fingers clamping → telescopic boom retracting → telescopic boom upward swinging → telescopic boom stretching out → fingers loosening → fingers retracting → waiting for finishing machining → telescopic boom stretching out → fingers clamping →telescopic boom retracting →telescopic boom downward swinging → fingers loosening →telescopic boom rising to the original position and stopping, preparing for the next procedure.

According to the above operation sequences of the manipulator, the hydraulic principle diagram of the movements of the manipulator is established by using FluidSim software, as shown in Fig.2.

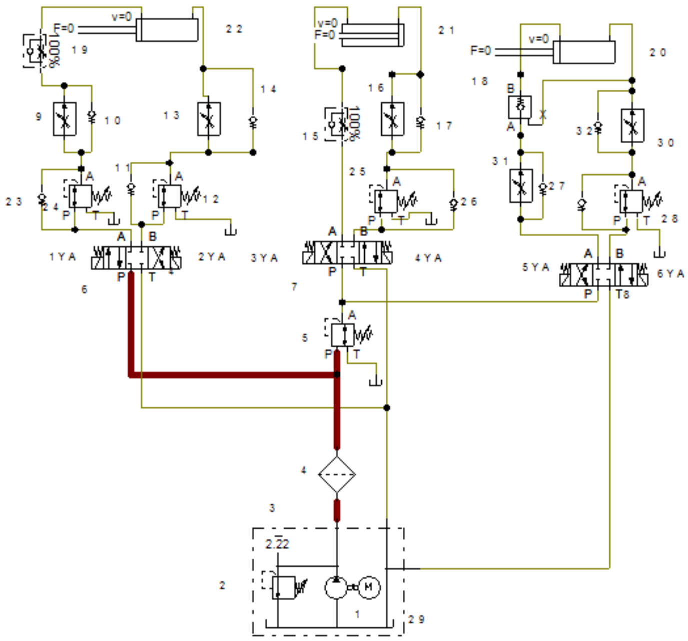

Fig.2 Hydraulic principle diagram

The manipulator's action sequences are shown in Table 1. The manipulator's stretching out and retracting movements are controlled by electromagnet 3YA, 4YA respectively, as shown in Fig.2. The manipulator's upward swinging and downward swinging movements are controlled by electromagnet 1YA, 2YA respectively. The manipulator's clamping and loosening movements are controlled by electromagnet 5YA, 6YA respectively. With the purpose of none mutual disturbances among multi-cylinder movements and realizing synchronous or nonsynchronous movements, three meso-position "O" mode electric-hydraulic reversing valves are adopted.

Table 1 the manipulator's action sequence table

Serial number	Action Name	Electromagnet					
		1YA	2YA	3YA	4YA	5YA	6YA
0	original position	-	+	-	+	+	-
1	stretching out	-	+	+	-	+	-
2	clamping	-	+	+	-	-	+
3	retracting	+	+	-	+	-	+
4	upward swing	+	-	-	+	-	+
5	stretching out	+	-	+	-	-	+
6	loosening	+	-	+	-	+	-
7	retracting	+	-	-	+	+	-
8	stretching out	+	-	+	-	-	-
9	clamping	+	-	+	-	+	+
10	retracting	+	-	-	+	-	+
11	downward swing	-	+	-	+	-	+
12	loosening	-	+	-	+	+	-

Control System Design and Simulation

Programmable Logic Controller (PLC) is widely used in different areas [6, 7] including mechanical engineering, electrical engineering and so on because it has high reliability, intuitive programming, good adaptability, strong interface functions. Therefore, we also adopt “FX2N-16MR” mode PLC to control the machine tool manipulator. This type has 16 total numbers of I/O ports, namely, 8 inputs, 8 outputs. The I/O ports allocated in our control system are shown in Table 2. Fig.3 shows the experimental debugging process, the control programs are shown in Table 3, Fig.4 shows the host computer’s monitoring process. The repeated experimental results showed that the correctness of PLC-based control programs.

Table 2 I/O ports allocations

Field devices		Internal relay address	explanation
input device	SB	X0	start button
output device	3YA	Y0	telescopic boom stretching out
	5YA	Y1	fingers clamping
	4YA	Y2	telescopic boom retracting
	1YA	Y3	telescopic boom upward swinging
	2YA	Y4	telescopic boom downward swinging
	6YA	Y5	fingers loosening
	HL	Y6	indicator

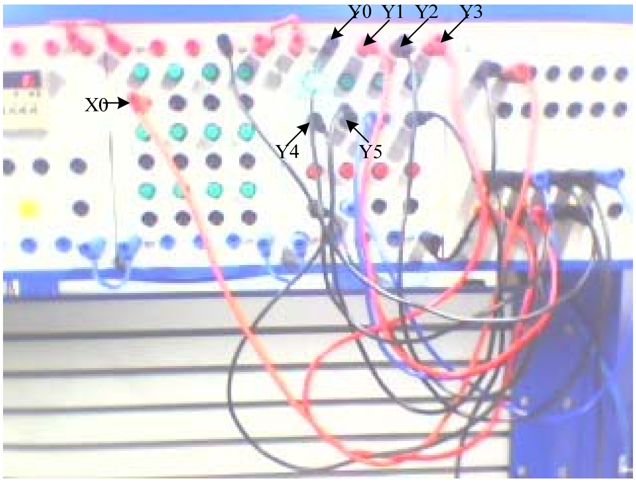

Fig.3 Experimental debugging process

Table 3 Instruction list

0	LD	X001		15	OUT	T10	K25	30	ORB		45	ANI	T5
1	OR	M0		16	OUT	T11	K27	31	OUT	Y001	46	LD	T11
2	ANI	T12		17	OUT	T12	K28	32	LD	T1	47	ANI	T12
3	OUT	M0		18	LD	T6		33	ANI	T2	48	ORB	
4	LD	M0		19	AND	T7		34	LD	T5	49	OUT	Y004
5	OUT	T0	K1	20	ANI	T8		35	ANI	T6	50	LD	T10
6	OUT	T1	K2	21	LD	T3		36	ORB		51	ANI	T11
7	OUT	T2	K3	22	ANI	T4		37	LD	T9	52	OUT	Y005
8	OUT	T3	K5	23	ORB			38	ANI	T10	53	END	
9	OUT	T4	K6	24	OR	T0		39	ORB		54		
10	OUT	T5	K7	25	OUT	Y000		40	OUT	Y002	55		
11	OUT	T6	K8	26	LD	T0		41	LD	T2	56		
12	OUT	T7	K22	27	ANI	T1		42	ANI	T3	57		
13	OUT	T8	K23	28	LD	T8		43	OUT	Y003	58		
14	OUT	T9	K24	29	ANI	T9		44	LD	T4	59		

Fig.4 Host computer's monitoring process

Conclusions and Future Work

A kind of hydraulic-driven manipulator for machine tool is presented in this paper. Firstly, the manipulator's structure is designed and 3D models are built by using solidworks software. Secondly, the hydraulic system diagram for implementing the manipulator's sequences is established. Finally, control system of the machine tool manipulator is implemented based on PLC, and the experimental results show the correctness and feasibility of our design and control programs. Therefore, the results of the paper are very useful for the practical design and control of the device. The future work is how to use some good control algorithms to control the accuracy of movement of the machine tool manipulator.

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