Development of Prosthetic Knee Joint with Combination of Stance Control by Hydraulic Damper and Swing Control by Microcomputer Control of Pneumatic Pressure

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1. General

This is a prosthetic knee joint with a combination of stance control by hydraulic damper and swing control by microcomputer-controlled pneumatic cylinder. In this joint, the unique link mechanism detects the position of ground reaction force and turns on and off the hydraulic pressure according to the user's gait cycle. In addition, there is a rotary type hydraulic damper which enables the user to slowly bend the knee while placing the body weight on the leg. This prosthetic knee joint reduces the anxiety about falling and enables the user to descend slopes and stairs swinging alternately the prosthesis and the normal leg. The microcomputer-controlled pneumatic cylinder enables the user to freely change the walking speed while walking. This development through a combination of hydraulic and pneumatic techniques and microcomputer techniques enables the use of prostheses in life situations in which conventional prostheses could not be used and dramatically improves the QOL of the users.

2. Details of technology

The prosthetic knee joint is a component of above-knee prosthesis used in the case of amputation above knee and compensates for loss of the function of human knee.

As shown in Fig. 1, the developed prosthetic knee joint is controlled by the rotary type hydraulic damper in the stance phase and by the microcomputer-controlled pneumatic cylinder in the swing phase. When this prosthetic knee joint is used, the body weight is supported by the hydraulic power, and the anxiety about falling can be reduced. Since the user can slowly bend the knee while placing the body weight on the leg, he/she can descend slopes and stairs swinging alternately the prosthesis and the normal leg. In addition, the user can go over obstacles, such as uneven surfaces and ditches, and sit down and lift a baggage with the body weight on the prosthesis. In the swing phase, the microcomputer control of pneumatic pressure adjusts the period of pendulum motion of the prosthesis according to the change in walking speed. Therefore, the user can walk comfortably with reduced fatigue at a slow to brisk pace.

To realize these functions, as shown in Fig. 2, the hydraulic damper which brakes the knee axis rotation is connected with the frame which forms the lower leg through the forward link and slide bearing, and the instantaneous center of the mechanism is located near the toe-break on the foot. The forward link is in contact with the hydraulic pressure switching valve. When the ground reaction force moves from the heel to the toe during walking, the positive and negative moment around the instantaneous center changes, and the direction of the movement of the forward link changes. As the result of this, the hydraulic pressure is naturally switched from on to off. To assist the motion to place the body weight on the toe of the prosthesis keeping the knee bent on a downslope, we added a mechanism which keeps the switching valve in the closed state with the aid of the generated pressure even after the ground reaction force passes through the instantaneous center. When commercializing the knee joint, we placed importance on reduction of weight (1.3 kg) and design (Fig. 3). Particularly, we took much time to determine the location of the mechanism and design the structure because prosthetists prefer smaller size of knee. To reduce the weight, carbon fiber composite resin is used for the frame, and high-strength lightweight metallic materials, such as duralumin aluminum alloy and titanium alloy, are used for the components.

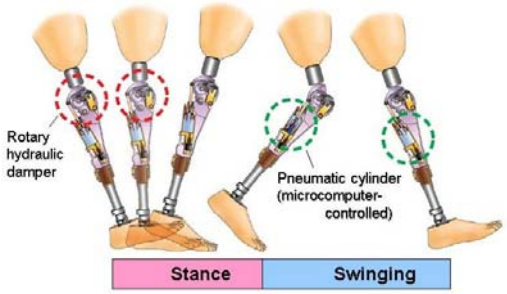

Fig. 1 Functions of hydraulic pressure and pneumatic pressure

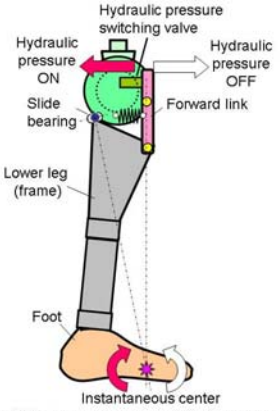

Fig. 2 Hydraulic pressure switching mechanism

Fig. 3 Commercialized prosthetic knee joint

Fig. 4 Descending stairs using developed product

3. Summary

The prosthetic knee joint developed this time was designated as a component for completion of prostheses and orthoses by the Ministry of Health, Labour and Welfare and went on sale as "Hybrid Knee" in 2006. Since then it has sold 1,200 units or more and exported through agents in 20 countries.