Advances in Technology Innovation, vol. 4, no. 2, 2019, pp. 116 - 124

The Innovative Design of the Massage Mechanisms for Massage Chair

Tzu-Hsia Chen[1*], Long-Chang Hsieh[2]

[1]Department of Mechanical Engineering, Minghsin University of Science and Technology, Taiwan, ROC

[2]Department of Power Mechanical Engineering, National Formosa University, Yunlin, Taiwan, ROC

Received 05 June 2017; received in revised form 09 July 2017; accepted 29 July 2017

Abstract

The purpose of this paper is to synthesize all the feasible designs of massage mechanisms (including DOF=2 and 3) for the massage chair, based on the modified Yan's creative design methodology. First, the topological structure and motion characteristics of existing massage mechanisms are analyzed and its design requirements and constraints are specified mechanisms with beating and kneading functions are mechanisms with 2 degrees of freedom (DOF). Then, 14 design concepts are generated. One of the design concepts is curried cut, including kinematic design, engineering drawing, and the prototype manufacture. The simulation result showed that new design can produce a wider range of non-uniform output motion than the extiting design.

Keywords: beating massage, innovative design, kneading massage, massage-mechanism, Yan's creative design methodology

1. Introduction

Due to busy lifestyles in modern days, insufficient time for sports leads to physical illness. Recently, because of the rising economic level and health awareness, the concept of "Health Protection" is well-known. The massage chair is one of the most popular health products. The action of the massage chair is to mimic the massage therapist. With the progress of the society, the demands of the massage chair became more diversified. When people lie on the massage chair, they can enjoy the massage pressure to eliminate muscle fatigue, relieve pressure, and relax.

In general, there are two different modes of the massage chairs, like beating massage and kneading massage, and both of them promote the body health. The massage mechanism can be a planar mechanism [1-2] or spatial mechanism [3-5]. This paper focuses on the systematic design of spatial massage mechanism which provides beating massage and kneading massage, including the concept design, the kinematic analysis, the engineering drawing, engineering design and manufacture of a prototype. First, we analyze the topological structure and motion characteristics of the existing massage mechanisms and conclude its design requirements and constraints. All existing massage mechanisms with beating and kneading functions are mechanisms with 2 degrees of freedom (DOF). The purpose of this paper is to synthesize all the feasible designs of massage mechanisms (including DOF =2 and DOF =3). Then, based on the design requirements and constraints also modified Yan's creative design methodology [6-11], we can synthesize all feasible design concepts of massage-mechanisms for the massage chair. Therefore, one design concept is chosen for the engineering design and prototype manufacture. The beating and kneading massage traces of this new design is simulated by "Cosmos" software to verify the new feasibility of design.

2. Existing Designs

Before implementing an innovative design, the structure of the massage mechanism must be collected and analyzed from academic papers, catalogues, and technical reports. Based on the analysis results, the massage mechanism can be

* Corresponding author. E-mail address: summer34134@gmail.com
Tel.: +886-3-559-3142 ext. 3023; Fax: +886-3-557-3797

classified as the planar mechanism or spatial mechanism. Fig. 1 shows the patent [1] which is the planar mechanism and provides the kneading massage.

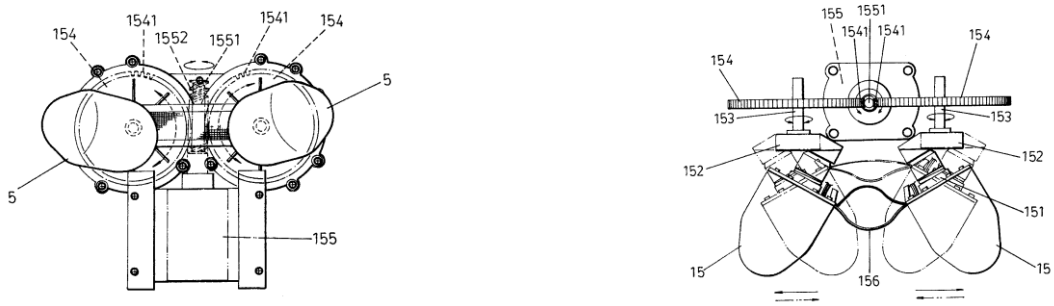
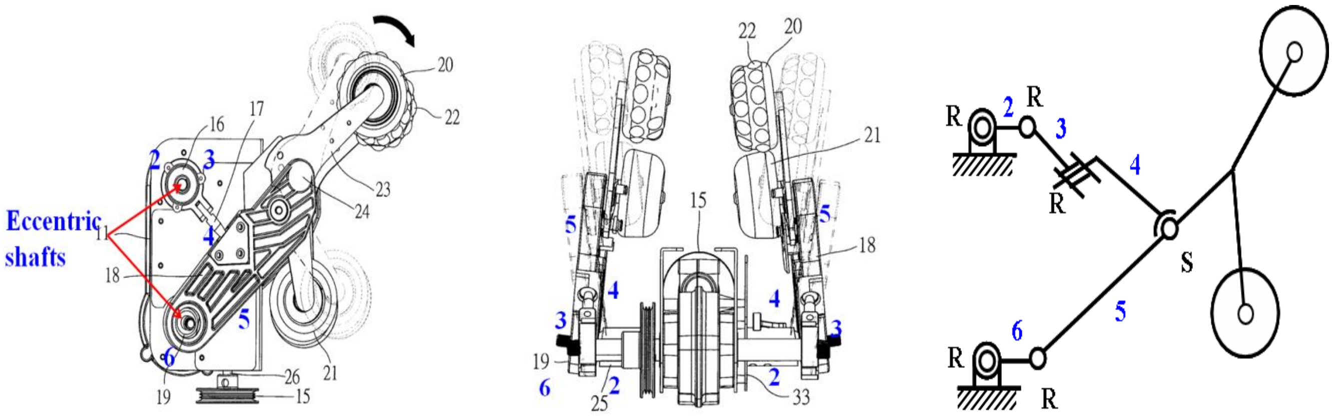


Fig. 1 Improvement structure of massage chair [1]

Fig. 2 shows the patent [3] which is a spatial mechanism and provides the beating and kneading massages. Fig. 2(c) shows its corresponding kinematic skeleton. According to Fig. 2, the mechanism has 6 links and 6 joints (5 revolute pairs and 1 spherical pair) and belongs to the spatial mechanism. In the 1st input motion, link 2 provides a beating function and in the 2nd input motion, link 6 provides a kneading function.



(a) Beating massage (b) kneading massage (c) kinematic skeleton

Fig. 2 Improved Double Drive System of Massage chair [3]

The mobility of the spatial mechanism can be obtained by following Eq. (1).

$$F = 6(N - J - I) + \sum f_i \tag{1}$$

where N is the number of links, J is number of joints, and f_i is the degrees of freedom of joint i. The mechanism shown in Fig. 2 has 6 links, 6 joints (5 revolute pairs and 1 spherical pair), according to the equation of mobility, we get:

$$F = 6(N - J - I) + \sum f_i = 6(6 - 6 - 1) + 8 = +2 \tag{2}$$

3. Creative Mechanism Design Methodology

The design concept is the initial stage of the engineering design process and also the most difficult part. All existing massage mechanisms with beating and kneading functions are mechanisms with 2 degrees of freedoms (DOF). The purpose of this paper is to synthesize all the feasible designs of the massage mechanism (including DOF =2 and DOF =3). For the mechanisms with 3 DOF, there must be 1 redundant degree of freedom. There is no existing mechanism DOF =3) which can provide beating massage and kneading massage, therefore, Yan's creative design methodology [6-10] must be modified. Fig. 3 shows the modification of Yan's creative design methodology, and the steps are as follows:

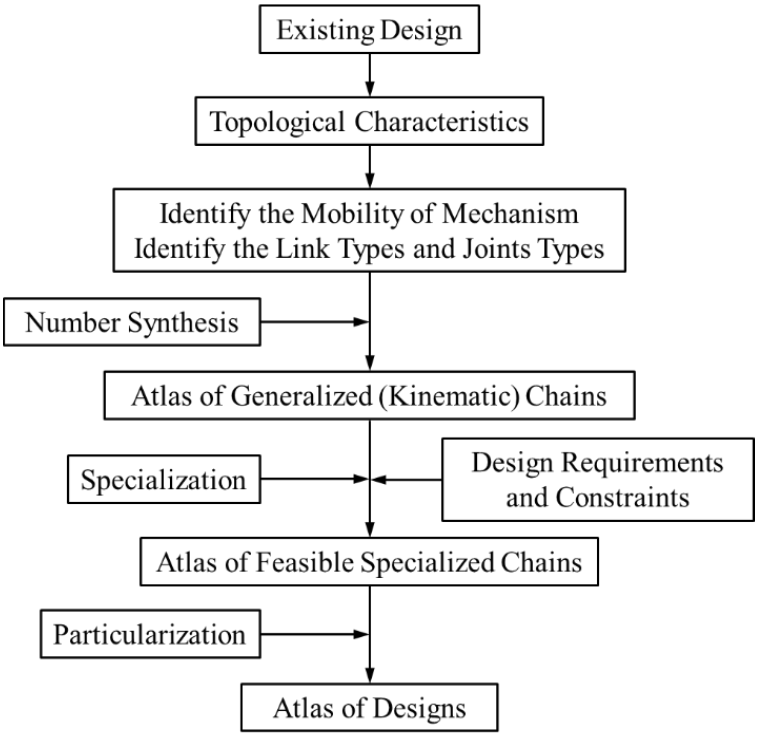


Fig. 3 Modified Yan's creative design methodology [7]

(1) Identify the existing designs (DOF =2) with required design specifications that designers would like to have, and conclude the topological characteristics of these designs.

(2) According to the topological characteristics, identify the mobility of the mechanism and its corresponding link and joint types.

(3) Synthesize the atlas of generalized chains that can be used to design massage mechanism with beating and kneading massages for the massage chair.

(4) Assign types of members and joints to each generalized chain obtained in Step 3, to have the atlas of feasible specialized chains based on the algorithm of specialization to meet needed design requirements and constraints.

(5) Particularize each feasible specialized chain obtained from Step 4 to its corresponding kinematic skeleton, to have the atlas of massage mechanism with beating and kneading massages for the massage chair.

3.1. Topological characteristics

The first step of the modified creative design methodology is to define the design specifications of mechanical devices that design engineers would like to generate. If there is no special consideration, the degree of freedom of a mechanism is equal to the number of independent inputs for the constraint motion. If the degree of freedom is larger than the number of independent inputs, in general, the mechanism will have unconstraint motion. Nevertheless, if the excess degree of freedom is the redundant degree of freedom, it will not affect the moving of other links, the mechanism will still have constraint motion and will still be useful.

The purpose of this paper is to invent the massage mechanism with 2 and 3 degrees of freedoms (*DOF*) to provide beating and kneading functions. In this paper, we only concern the mechanism with revolute and spherical pairs. According to Eq. (1), if N=6, J=6, J_R=5, and J_S=1, the corresponding generalized chain (6, 6) has 2 degrees of freedom. And, according to Eq. (1), if N=5, J=5, J_R =3, and J_S =2, the corresponding generalized chain (5, 5) has 3 degrees of freedom. The results are shown in Table 1.

Table 1 Taxonomy of Swarm-based routing protocols

Degrees of freedom (F)	Number of links (N)	Number of joints (J)	Number of revolute pairs (J_R)	Number of spherical pairs (J_S)
2	6	6	5	1
3	5	5	3	2

Next, the massage mechanisms with beating and kneading functions should have the following topological characteristics:

(1) It must be a spatial mechanism (l = 6).

(2) It must have 2 input links and 1 output link (massage link).

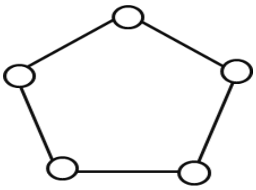
(3) It has a ground link to support or constrain other links.

(4) The joints are constrained to be revolute and spherical pairs.

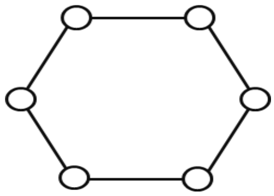
(5) For the mechanism with 2 DOF, it will have at least 1 spherical pair.

(6) For the mechanism with 3 DOF, it will have at least 2 spherical pairs.

3.2. Atlas of generalized chain



(a) (5, 5) generalized chain



(b) (6, 6) generalized chain

Fig. 4 Generalized chains for massage mechanism

The second step of the modified creative design methodology is to synthesize all possible generalized chains which can be used to synthesize the desired mechanism. There is only 1 generalized chain with 5 links and 5 joints and only 1 generalized chain with 6 links and 6 joints. Fig. 4 shows the generalized chains for massage mechanisms.

3.3. Design requirements and design constraints

Design requirements and constraints are determined based on the concluded topological structures. The design requirements and constraints of massage mechanisms for massage chair are:

(1) There must be a ground link (G_R), first input link for kneading function (I1), second input link for beating function (I2), output link (massage link) (O_M).

(2) The ground link (G_R) must be adjacent to 2 input links (I1 and I2) with revolute pairs.

(3) The ground link (G_R) cannot be incident to spherical pair.

(4) The output link (O_M) can’t be incident to 2 spherical pairs at the same time.

(5) For the mechanism with 2 DOF, (6, 6) generalized chain must have 5 joints (J_R) and 1 spherical pair (J_S).

(6) For the mechanism with 2 DOF, (5, 5) generalized chain must have 3 joints (J_R) and 2 spherical pairs (J_R).

(7) For the mechanism with 3 DOF, 2 spherical pairs must be adjacent and cause 1 redundant degree of freedom.

3.4. Specialization

The third step of the modified creative design methodology is to assign specific types of members and joints to each available kinematic chain, subject to certain design requirements to have specialized chains. The specializing steps for massage mechanism are:

(1) For each generalized chain, identify the ground link (G_R) for all possible cases. There are 2 possible identifications as shown in Figs. 5(a) and 5(b).

(2) For each case obtained in step 1, identify the first input link (kneading function) (I1) and the second input link (beating function) (I2). For the specialized chains as shown in Figs. 5(a) and 5(b), based on the design requirements, there are 2 possible identifications show in Figs. 6(a) and 6(b).

(3) For each case obtained in Step 2, identify the output link (massage link O_M). For the specialized chains shown in Figs. 5 (a) and 5(b), based on the design requirements, there are 5 possible identifications show in Figs. 7(a)-7(e)

(4) For each case obtained in Step 3, identify the corresponding revolute pairs (denoted by ○) and spherical pairs (denoted by ●). For (5, 5) generalized chain, there are 2 feasible specialized chains shown in Figs. 8(a) and 8(b). For (6, 6) generalized chain, there are 12 feasible specialized chains shown in Figs. 9(a)-9(e).

Fig. 5 Identify ground link (G_R)

Fig. 6 Identify first input link (kneading function) (I1) and second input link (beating function) (I2)

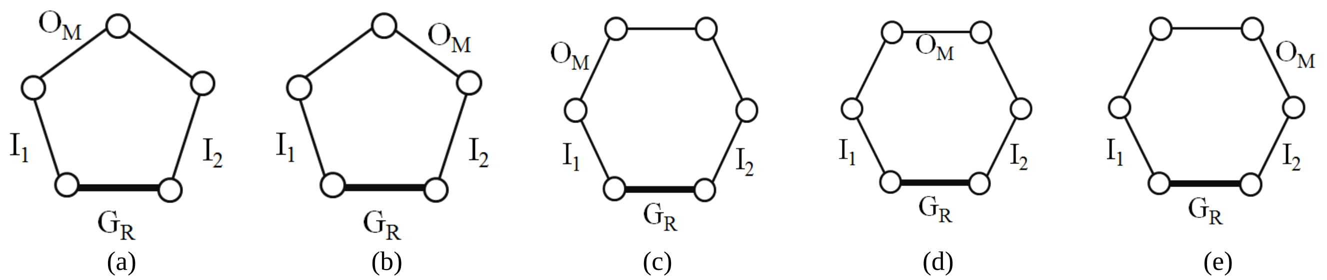


Fig. 7 Identify Output link (massage link) (O_M)

Fig. 8 Atlas of feasible specialized chain of (5, 5) generalized chain

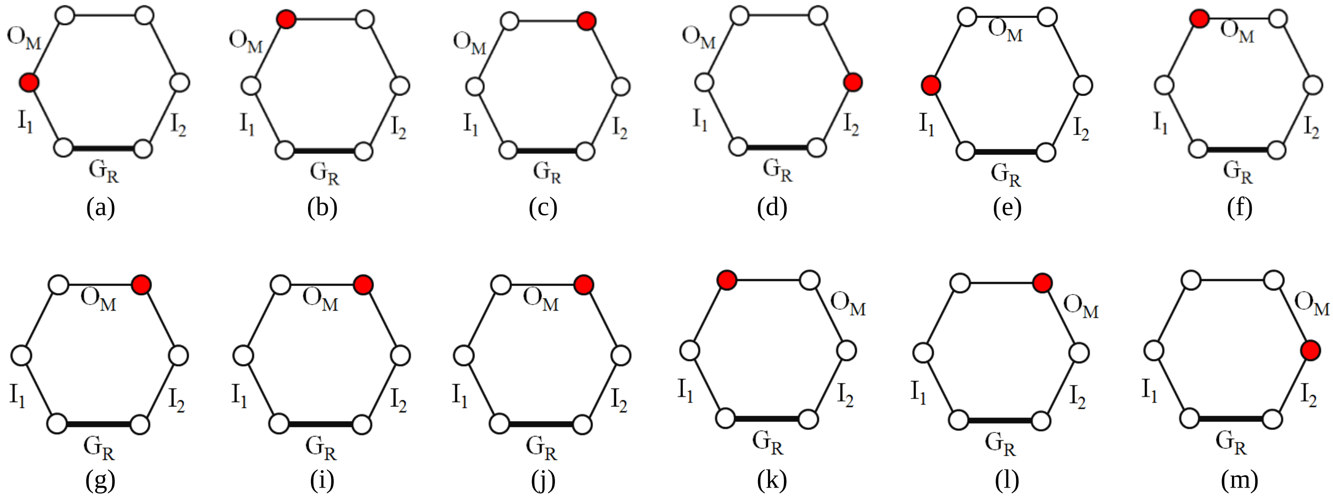


Fig. 9 Atlas of feasible specialized chain of (6, 6) generalized chain

3.5. Particularization

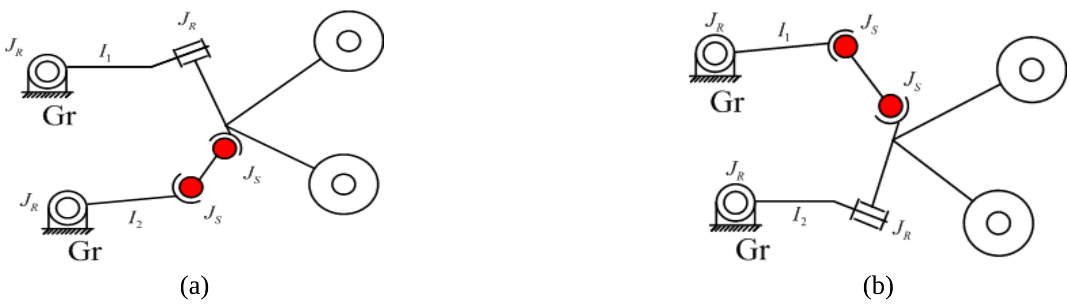


Fig. 10 Atlas of feasible massage mechanisms of (5, 5) generalized chain

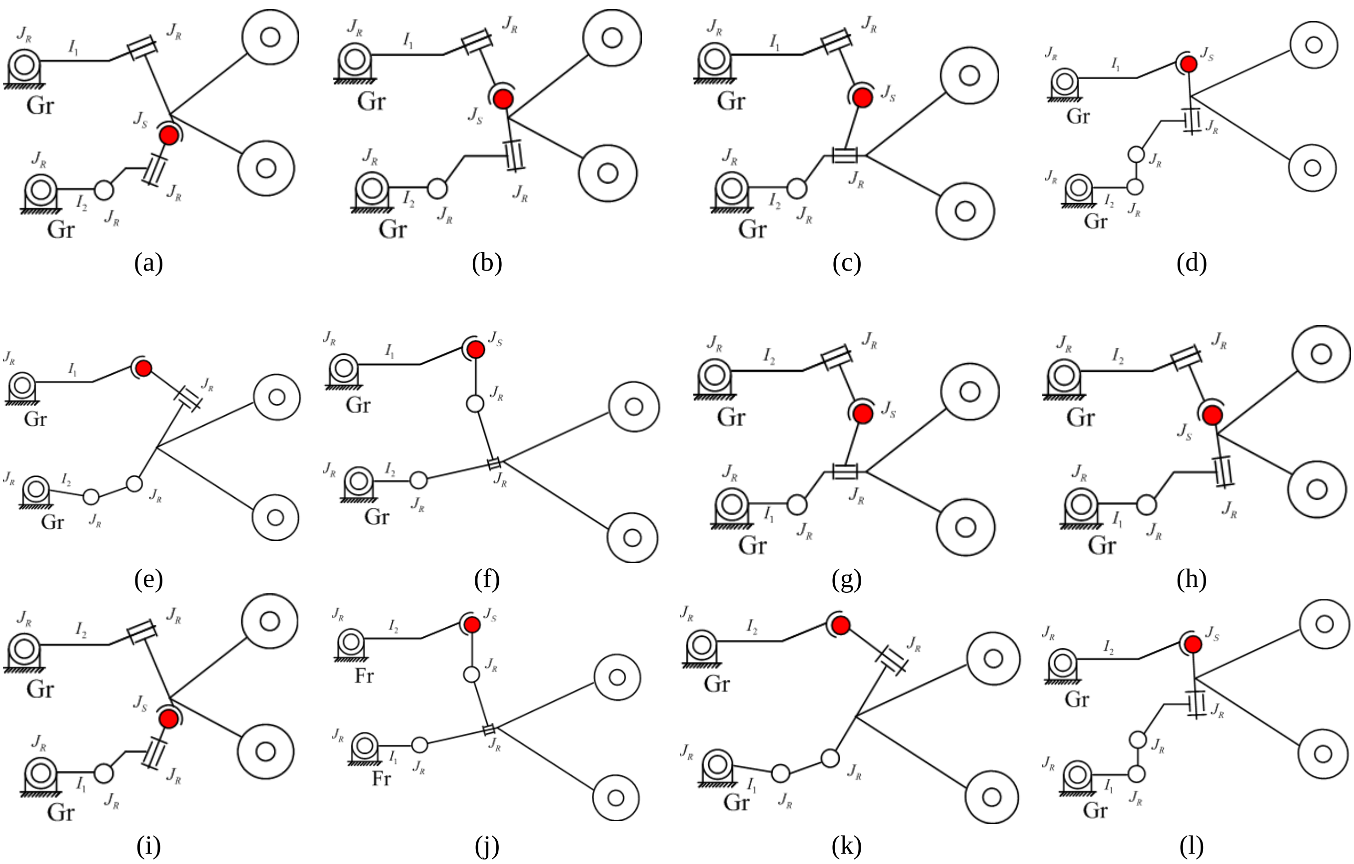


Fig. 11 Atlas of feasible designs for massage mechanism of (6, 6) generalized chain

For each feasible specialized chain, it can be particularized into its corresponding kinematic skeleton. Particularization is the reverse process of generalization and can be done by applying the generalizing rules in reverse order. Figs. 10(a) and 10(b) show 2 feasible massage mechanisms of (5, 5) generalized chain and Figs. 11(a)-11(*l*) show 12 feasible massage mechanisms of (6, 6) generalized chain. The design concept, shown Fig. 11(a), is the same as the existing design in Fig. 2. Therefore, only 11 new designs are synthesized from (6, 6) generalized chain and 2 new designs are synthesized from (5, 5) generalized chain. In this paper, we synthesize 13 new designs of massage mechanisms for the massage chair.

4. Engineering Design and Dynamic Simulation

After an innovative design, the next step is engineering design. Due to the reason of manufacture cost, Fig.10 (a) is selected as a design example to carry out, and its solid model is drawn and shown in Fig. 12. Fig. 13 shows its trace which is simulated by “Cosmos”. Table 2 shows the comparisons of existing design and new design. According to Table 2, we get that new design has larger massage trace than the existing design. If we adjust the initial phase of the kneading input, the range of massage trace will become smaller. Table 2 also shows that if the initial phase of the kneading input is increased 7^{o}, the corresponding kneading trace is almost close to the existing design. Fig. 14 ~16 shows the traces of the new design, respectly.

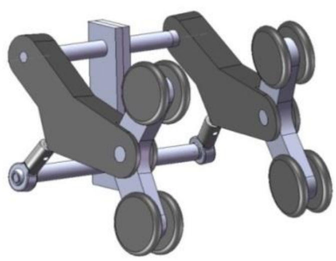
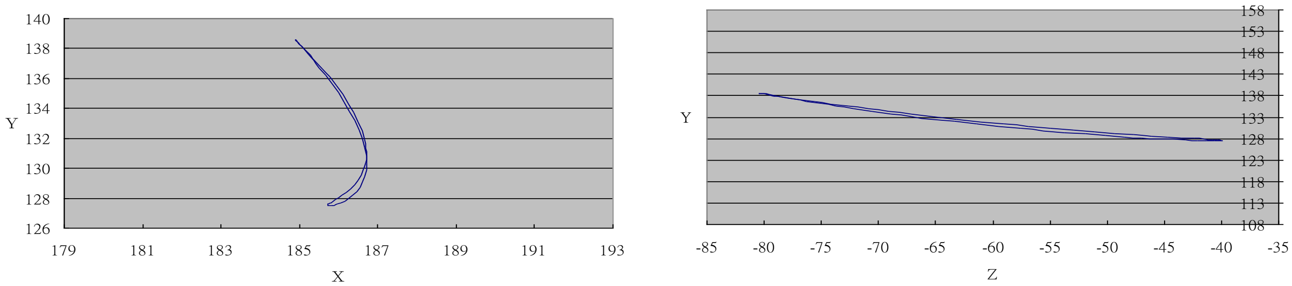


Fig. 12 Engineering drawing of the design concept shown in Fig. 10(a)



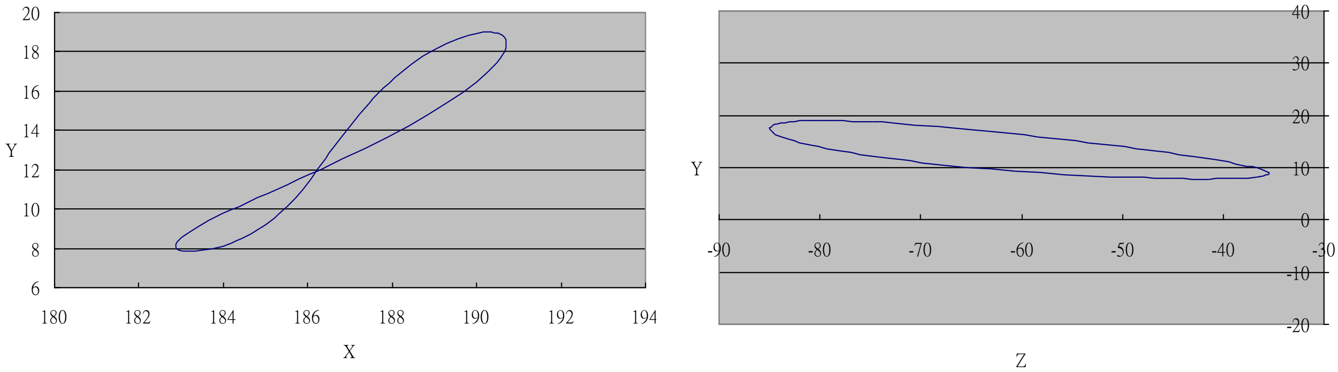
(a) Projection on XY plane

(b) Projection on XZ plane

Fig. 13 Kneading trace of upper roller

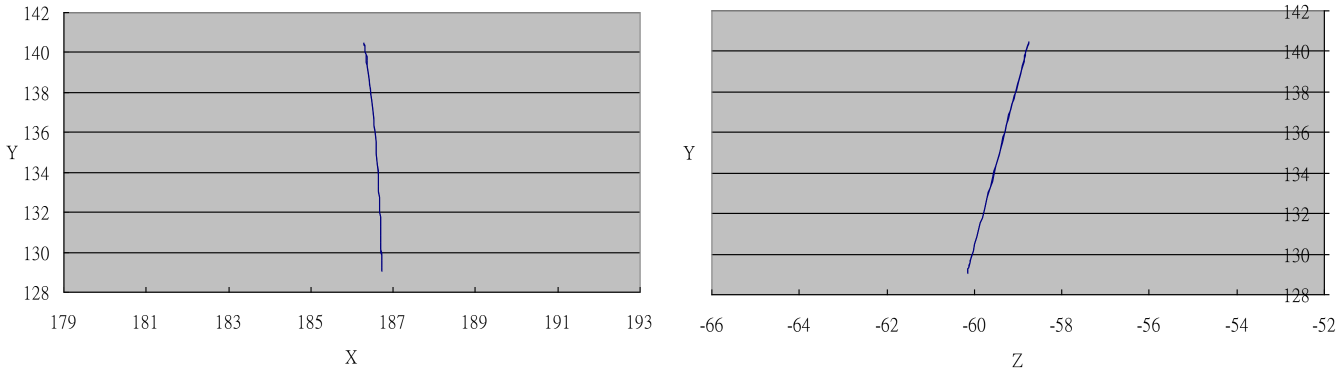
Table 2 The comparisons of existing design and new design

	Dispalcement	Location	Existing Design (Initial phase 0)	New design (Initial phase 0)	New design (Initial phase 7 of kneading input)
Kneading massage	X	Upper roller	2(mm)	2(mm)	2(mm)
		Lower roller	2(mm)	8(mm)	2(mm)
	Y	Upper roller	7(mm)	11(mm)	7(mm)
		Lower roller	7(mm)	11(mm)	7(mm)
	Z	Upper roller	21(mm)	41(mm)	22(mm)
		Lower roller	33(mm)	50(mm)	33(mm)
Beating massage	X	Upper roller	2(mm)	2(mm)	
		Lower roller	2(mm)	8(mm)	
	Y	Upper roller	10(mm)	11(mm)	
		Lower roller	10(mm)	11(mm)	
	Z	Upper roller	1(mm)	1(mm)	
		Lower roller	1(mm)	1(mm)	



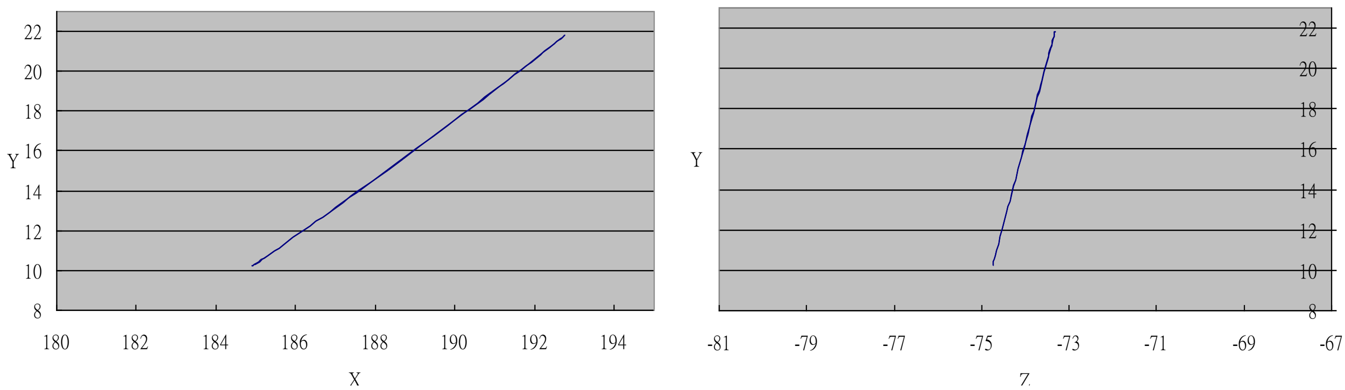
(a) Projection on XY plane (b) Projection on XZ plane

Fig. 14 Kneading trace of lower roller



(a) Projection on XY plane (b) Projection on XZ plane

Fig. 15 Beating trace of upper roller



(a) Projection on XY plane (b) Projection on XZ plane

Fig. 16 Beating trace of lower roller

5. Conclusions

In this paper, the new designs of massage mechanisms have been generated by the systematic design methodology. First, the design requirements and design constraints are summarized based on existing designs. Then, according to modified Yan's design methodology, 13 new design concepts synthesized. One of the new design concepts is selected as a design example and verified by kinematic simulation. The simulation result showed that the new design can produced a wider range of non-uniform output motion than the existing design.

Conflicts of Interest

The authors declare no conflict of interest.

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