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Parameter Optimization of an Inner Bracket Grasp Fragile Workpieces Manipulator Based on Improving Impact Force

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Abstract. When a manipulator to grasp fragile workpieces, the contact impact force between the finger of manipulator and fragile workpieces has an important influence on the grasping stability. In this paper, based on introducing the structure model of the manipulator to grasp fragile workpieces, we present a structural form and parameter optimization of manipulator based on improving contact impact force. In order to find the appropriate operation parameters of manipulator's finger, the finite element model is constructed for the finger of the manipulator by integrating HyperMesh and LS-PrePost to model. After the corresponding loads, constraints and contact types are applied to the finite element model, the stress and strain cloud images for the finger and the fragile parts on the contact collision process are calculated. By analyzing the calculated results, we can obtain the optimized structural parameters of the manipulator.

Keywords. Manipulator, Grasp fragile workpieces, Contact impact force, Optimization design

1. **Introduction**

For the manipulators, the end-effector is a key on the manipulator system to realize the specific grasping function component [1]. For the workpiece, there may be many grasping ways. Using fingertips to achieve accurately grasping objects is a possible solution [2]. Many researchers have carried out grasping analysis and research on different finger design schemes [3]. For instance, Vincent Babin et al, improved the gripping device of robot, enabling it able to grasp thin objects on smooth surfaces [4].Aiming at workpiece feeding and transferring for producing the fragile pyrophyllite block, we designed a kind of grasping and pressing assembly manipulator with internal bracing mode [5].The manipulator adopts a slider driven by cylinder movement, and grippers are installed on the slider block. Through the contact between the grippers and the workpiece, grasping workpiece is completed. In view of the fragile characteristics

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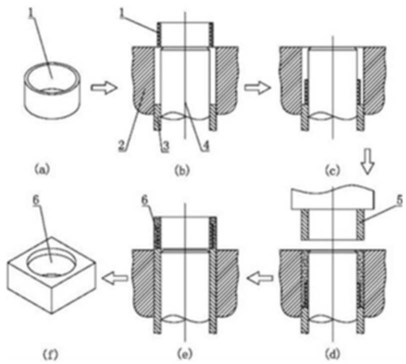
of the cylindrical inner wall workpiece, this paper researches on improving the contact performance between the gripper and the workpiece by optimizing the parameters of the transmission mechanism [6, 7].

2. The structure model of the manipulator to grasp fragile workpieces

Taking the synthetic process of synthetic diamond as an example, the fabrication of pyrophyllite block as artificial diamond raw material is shown in Fig.1, and the raw materials and finished products are all fragile pieces.



1. fragile ring 2. Outer die 3. Bottom die 4. Terrace die5. Press head 6. fragile black

(a)A fragile ring; (b) Transferring fragile piece above to the punch;

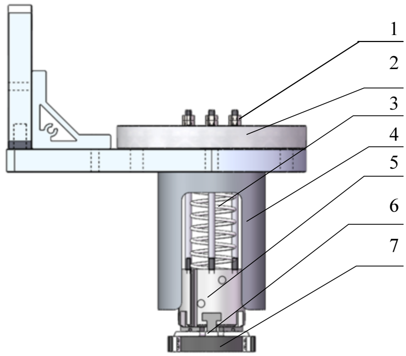
(c) Assemble fragile piece to punch; (d) Pressing into fragile black;

(e) Ejecting the fragile black; (f) Transferring fragile black

Figure 1. Producing process of the fragile block

The fragile piece production process of this topic is shown in Fig.1. Firstly, a special fragile ring, as shown in Fig.1(a), is transported to the top of the terrace die (as shown in Fig.1(b)); and placed in the mold cavity, as shown in Fig.1(c) ;Then, some powders are filled and pressed into fragile black by hydraulic press (shown in Fig.1(d)); the fragile black is shown as in Fig.1(f); next, the compressed fragile black is pushed out , as shown in Fig.1(e). In order to be able to use a manipulator to carry out all the fragile piece, the inner support grasping and pressing assembly manipulator system is designed.

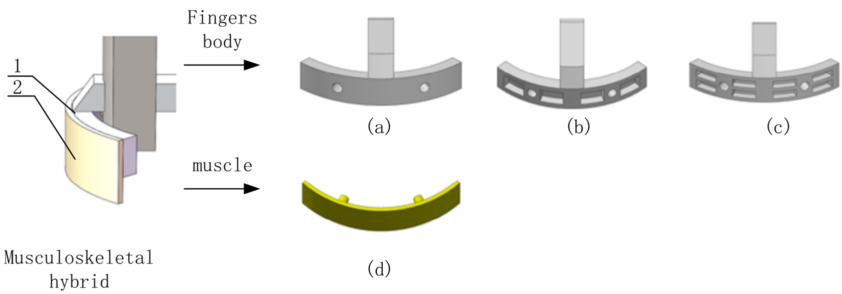
On the basis of overall scheme design for the manipulator system, the structural design of the inner brace grasping manipulator shown in Fig 2. The outside surface of arc three jaw covered with rubber simulates the finger pad skin, tubular palm simulates a special palm. Elastic connection is adopted between the palm and finger to produce the relative movement. The internal brace arc three-claw finger is driven by air pressure.



1.Guide rod 2. Connecting plate 3. Spring 4. Cylinder 5. Tubular palm 6. Finger body 7. Fingerpad

Figure 2. Hand structure of internally supported gripping manipulator

In the case of the three paws releasing the object and holding it still, under the movement of the arm, the cylindrical palm can complete a pressing action to press the circular object onto a fixed fitting. The three paws can eject from the cylindrical palm by using the spring after pressing action. In the process of device design, In search of a finger structure capable of grasping different fragile parts, By using the "associative tree method" and other methods, the skeletal model cluster is constructed, which is the construction of three-dimensional solid muscle mixed with rigid finger body and soft finger muscle, and the structure of the finger body and muscle is different, and different components are combined. A partial models of the rigid finger bodies and finger muscle are shown in Fig. 3.



1. Finger body: (a)surface with round hole; (b)surface with round holes and 4 large square holes; (c) surface with round holes and 8 small square holes. 2. Finger muscle

Figure 3. Muscle and bone construction model of the finger.

3. Contact impact force model and parameter selection

Here, the finite element analysis model of the different combinations for rigid finger body and soft fingers is established, and the dynamic characteristics of flexible fingers with different muscles and bones in the process of operation.

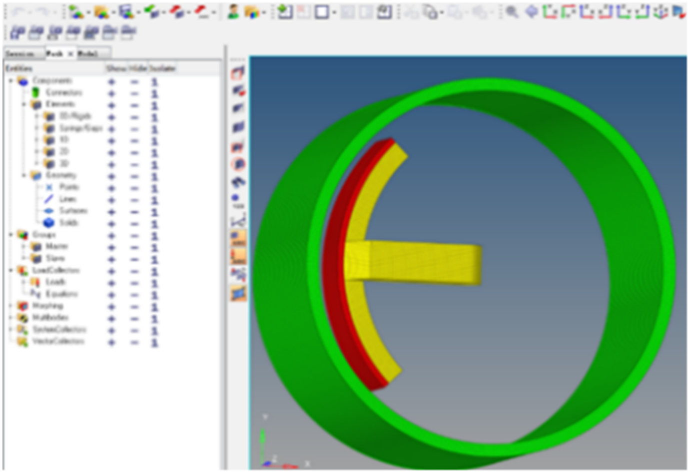


Figure 4. The finite element model of the finger impacting fragile parts

Integrated modeling based on LS-DYNA、SolidWorks and HyperMesh, the finite element model that internal support grasping finger impacts parts that are easily damaged are built, as shown in Fig 4. The inner support manipulator adopts the geometric structure integrating rigid finger body and soft fingers pad, and forms a rigid - soft - brittle medium transmission mode to the fragile parts. The finger body is made of aluminum, and the finger is covered with rubber, the rubber and aluminum alloy is glued. In order to research on the law of force transmission between fingers and workpiece in the contact and collision process, a common friable material --glass is selected as the research object instead of pyrophyllite ring material.

In the research process, fragile parts to be grasped take glass ring as an example, whose outer diameter is 30.75mm, inner diameter is 27.75mm, depth of the ring is 35mm, and mass is 3.19916234E-3 kg. The finger is placed at the horizontal position of the fragile ring, the mechanical finger is 3 mm away from the friable ring, the impact speed of manipulator is 1mm/ms.

In LS-DYNA, when two objects collide, the contact model needs to be defined; otherwise, surface penetration will occur after contact. Here, the AUTOMATIC_SURFACE_TO_SURFACE contact model is selected and the contact algorithm adopts penalty function method.

4. An example for a manipulator optimization

When the manipulator grasps fragile parts, The influence of different structural and parameter combinations on the output goal is investigated by means of the impact contact force fluctuation.

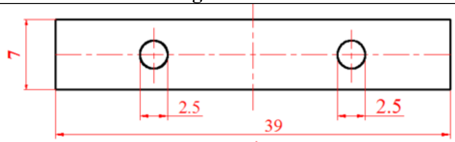
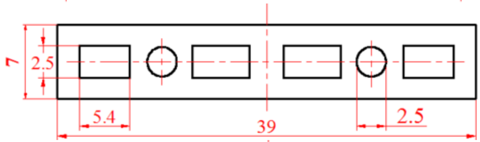
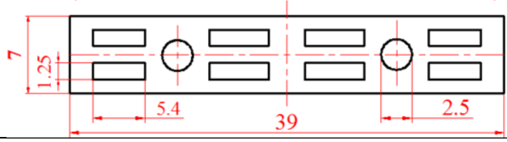
4.1 Designing structure form and parameters

Both the finger structure form and parameters, including the different finger bone combinations, soft finger pad thicknesses, impact speeds, relatively position between manipulator and fragile parts, are design structure form and parameters.

4.2 Designing factors levels and inner/outer arrays

Table 1 shows the different bone lattice structures and the parameters:

Table 1. Table of dimensions of lattice structure

Finger bone type	Schematic diagram of structure size
Surface with round holes	
Surface with round holes and 4 large square holes	
Surface with round holes and 8 small square holes	

For grasping work position, flush position means that the upper surface of the fragile part is in the same plane as the upper surface of the rubber pad and finger, falling position means that the finger drops 10mm.The original structure form and parameters for the manipulator are as follows, the bone lattice structure is the surface with round holes and 4 large square holes, finger pad thickness is 1.5mm, relative position is the falling position, shown as Tables 1. These are the structure form and parameter before optimization, which are expressed as Level 2 in Table 2. We change the structure form and parameter for obtaining structure form and parameter optimization in two directions, i.e., Level 1 and Level 3 shown in Table 2. These structure form and parameters are suitable for the manipulator.

For bone lattice structure, finger pad thickness and relative position, different levels are shown in Table 2.

Table 2. The select-able the structure form and parameters for the manipulator

structure form and parameters	bone lattice structure	finger pad thickness	relative position
Level 1	Surface with round holes	1mm	Flush position
Level2	Surface with round holes and 4 large square holes	1.5mm	Falling position
Level 3	Surface with round holes and 8 small square holes	2mm	

4.3 Calculation process of stress

Here, SolidWorks, Hyperworks and LS-prepost are used for integrated modeling. we use LS-DYNA software to simulate and analyze the finite element model of the manipulator, The specific process is ignored here.

The output parameters such as stress and strain is shown in Fig. 5.

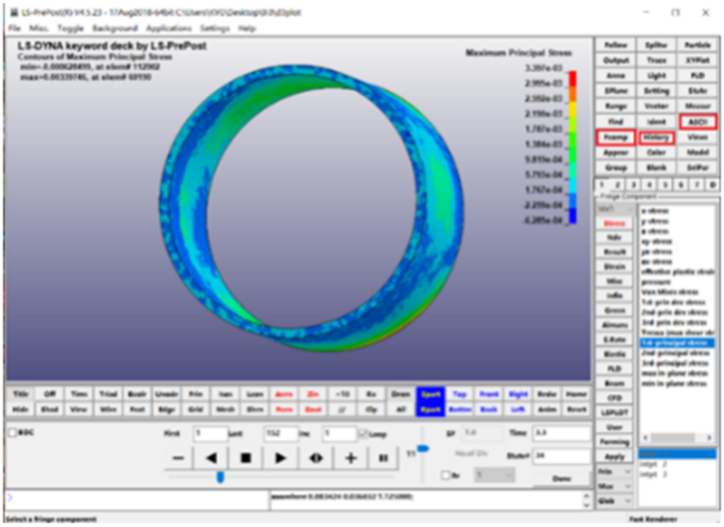


Figure 5. LS-PrePost software simulation results

4.4 Designing inner-outer array for an orthogonal experiment

Considering the various level combinations of multiple factors, to select the best combination of multiple factors at different levels in a larger range, the complex factor experiment was used to design the table head of internal and external factors.

Determine the approximate structure and parameter combination, shown as Table 3: 3 kinds of rigid finger body with different bone lattice structure (structure 1, 2 and 3 correspond to Level 1, 2 and 3 of bone lattice structure in Table 2), 3 types of finger pad thickness (1,2, and 3correspond to Level 1, 2 and 3 of finger pad thickness in Table 2), 2 types of relative position (1 and 2 correspond to Level 1 and 2 of relative position in Table 2). There are 3*3*2=18 schemes.

The maximum contact impact stress under various combinations is listed in Table 3. where, i=1-3, j=1-6 of Sij. The unit of stress is MPa.

Table 3. Stress of different structure and parameter combinations

Array number				Parameter types	**1**	**2**	**3**	**4**	**5**	**6**	
				Finger thickness	1	1	2	2	3	3	
Structure types				Relative position	1	2	1	2	1	2	
	1	2	3	Sij	-	-	-	-	-	-	Saverage
1	1	0	0	-	7.89	5.06	6.47	4.79	5.93	4.33	5.75
2	0	1	0	-	7.11	4.35	6.02	4.28	5.72	3.85	5.22
3	0	0	1	-	7.05	3.3	5.94	3.21	4.95	3.13	4.6

Furthermore, the change of maximum contact stress with the parameter is expressed as Fig. 6.

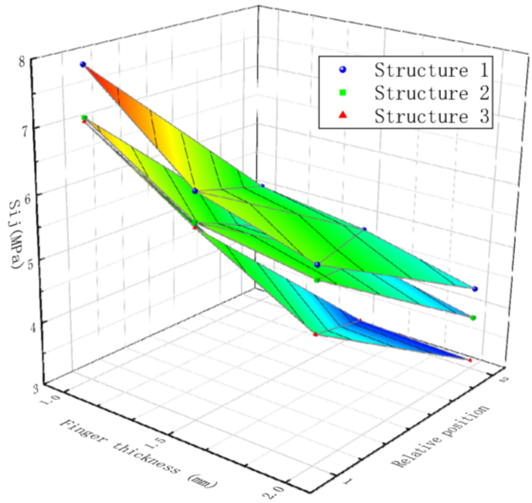


Figure 6. The relationship between finger structure and parameter to the maximum contact stress in grasping contact collision

4.5 Result analysis

By analyzing Table 3, we find that the maximum impact stress is minimum when the manipulator structure form adopts Level 3, finger thickness adopts Level 3, the relative position adopts Level 2, the manipulator adopts the same grasping speed,.In other words, this kind of manipulator finger bone structure and related parameters is a better design scheme.

Through further analysis, we found that the influencing factor of the contact stress force, grasping position ⩾ finger pad thickness ⩾ manipulator structure. The exact process is omitted here.

5. Conclusion

In this paper, the model for the collision of the manipulator on the fragile parts of thin wall is established, and the maximum stress value of the fragile parts of thin wall under the collision is obtained. Based on a large number of simulations, the following conclusions are obtained according to a large number of analyses: The optimal parameter combination is Structure 3(Structures=2 round holes and 8 small square bone lattice), pad thickness 3 (finger thickness=2 mm) and position 2 Relative position = (falling 10 mm), the corresponding stress value is 3.13Mpa.

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