DESIGN AND VERIFICATION OF A CLAMPING SYSTEM FOR MICRO-INJECTION MOLDING MACHINE

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ABSTRACT

Precision injection molding technology can be applied for the computer, communication, electric appliance and medical components industries. This paper presents a new design of a tiebarless clamping system for micro-injection molding machine. The tiebarless clamping system can provide lots of convenience, such as more mold space for automation etc., for a micro-injection molding machine. Good parallel precision between stationary platen and movable platen of a clamping system is an important feature for high precision injection molding. With special mechanism of this tiebarless clamping system, the movable platen will deform with the stationary platen synchronously under high clamping force to maintain the parallelism. Via tests and verifications, the parallel precision is controlled at good condition under 6 tons of clamping force.

LE DESIGN ET LA VÉRIFICATION D'UN SYSTÈME DE SERRAGE POUR LA MACHINE À MOULURE DE MICRO-INJECTION

RESUME

La technologie de moulure d'injection précisée peut être exercé sur l'ordinateur, la communication, l'appareil électrique et les industries de composants médicales. Ce papier présente un nouveau design d'un système de serrage sans tiebar pour la machine à moulure de micro-injection. Le système de serrage sans tiebar peut avoir beaucoup d'avantage, comme plus d'espace telle que l'espace de moule pour l'automation etc., pour une machine à moulure de micro-injection. La bonne précision parallèle entre le rouleau fixe et celui mobile d'un système de serrage est une caractéristique importante pour l'injection moulant avec la precision haute. Avec le mécanisme spécial de ce système de serrage sans tiebar, le rouleau mobile déformera synchroniquement avec le rouleau fixe sous la force forte de serrage pour maintenir le parallélisme. Par les essais et les vérifications, la précision parallèle est bien contrôlée sous 6 tonnes de force de serrage.

1. INTRODUCTION

The clamping system of an injection molding machine accommodates the injection mold. It provides the motion needed for closing, clamping, opening, and generates the forces that are necessary to close, open and clamp the mold. The main components for the clamping system in a traditional injection molding machine are the tie bars, the stationary and movable platens, and the mechanism for opening, closing, clamping and ejecting. The clamping unit together with the mold forms a closed system of forces. The clamping system is the mechanism that keeps the mold effectively closed during the injection and holding-pressure (packing) stages.

In order to develop micro-injection molding machine, some conditions for the clamping unit must be satisfied. First, when a mold is closed under high pressure, the parallel precision between it's stationary and movable platens should be small. Second, for optional clamp compression stage, the motion accuracy of the movable platen must be less than 0.01mm and the motion respond time should be as small as possible.

The general structures of clamping systems can be classified into two types, with tie bars and tiebarless. When a high clamping force is applied by hydraulic or servo motor, the structure of clamping system will be deformed conspicuously. Thus, in order to prevent the spill of molten plastic and maintain good quality of the injection molding parts, aligning stationary platen and movable platen accurately and keeping high parallel precision is important. The main functions of tie bars are to supply clamping strength and maintain parallel precision.

For micro-injection molding machines, only a small amount of clamping force is needed and the size of a clamping unit is not large. If a tie bar type clamping system is used in a micro-injection molding machine, the four tie bars will seriously limit the flexible usage of mold space between the stationary platen and the movable platen. It means that more convenient mold changing methods and most automatic robots may not be applied. Therefore, a tiebarless type clamping unit was developed to solve these problems.

However, there are still some problems with the tiebarless clamping system. The deformation of the clamping unit is large when a high clamping force is loaded. In this situation, good parallel precision between the stationary platen and the movable platen can't be achieved. Therefore, special mechanism designs are required to solve this problem. In recent years, most designs [2-6] are to reduce the structural deformation of clamping unit in order to keep good parallel precision during repetitive clamping stage. Regardless of U-type or L-type stationary platens, outward deformation of a tiebarless clamping system is hard to avoid. But, the tiebarless clamping system in this study is not to reduce the deformation of the stationary platen. The mechanisms of the movable and tail platens are rotatable to improve the parallel precision between stationary and movable platens.

This paper presents an improved tiebarless clamping system, which has several special features, for a micro-injection molding machine. The following are the main objectives and characteristics of the tiebarless clamping system in this paper:

1. Good parallel precision can be achieved during repetitive clamping stage under 6 tons of force.
2. Clamping force can be held by Belleville springs under tail stock platen to prevent the spill of molten plastic.
3. The parting surface of mold can be held tightly and clamping force can be applied uniformly.
4. Mold replacement mechanisms can be more flexible.
5. More support systems can be used for the ejection of the molded parts, for examples, robot suckers, vacuum system and variable mold temperature system etc.

2. DESIGN OF TIEBARLESS CLAMPING SYSTEM

The main design target of this tiebarless clamping system is to keep good parallel precision between the stationary and movable platens during injection molding processes. In order to maintain parallel precision, the main mechanisms of the tiebarless clamping system are redesigned in the following ways. A detailed design drawing of the tiebarless clamping unit was shown in Fig.1.

1. The movable and stationary platens are constructed with a combination of a linear slide rail and a L-type base (Fig.2). The movable platen can deform with the stationary platen synchronously under it's high pressure clamping process. The L-type base is fixed on the undercarriage by screws and nuts.
2. The clamping force is transmitted by a special connector (Fig.3), which connects the movable platen by three points at one end and connects to the ballscrew at another end. The purpose of three point contact between the movable platen and the special connector is to make the resultant of clamping force located at the upper part instead of the center of movable platen. With this design, the parting surface of mold will be held tightly and the clamping force will be applied uniformly.
3. A spherical roller bearing is used in the tail stock platen and a ball screw is connected to it. The spherical roller bearing and the pin connection (Fig.3) of special connector provide the ballscrew with rotation capability.
4. The tail stock platen is fixed on the undercarriage by a pin and the tail stock platen can rotate under high clamping force (Fig.4, Fig.5).
5. The clamping force can be held by the Belleville springs which are set under the tail stock platen (Fig.4, Fig.5). This mechanism can maintain the clamping force at an almost constant level.

The full model of the tiebarless clamping unit is shown in Fig.6. Before fabricating the prototype of the tiebarless clamping unit, CAE software (ANSYS) was used to simulate the deformation and stress for the main components. With the results of simulations, the location and magnitude of maximum deformation and stress were carefully examined as shown in Fig.7. The detail calculations of the selected components were carried out according to the criterion of the components. The used criterions in selection were provided by the manufacturers. For example, the standard dynamic loading and standard static loading are the main concerns for guise rail; the average axial loading and normal rated life are the main concerns of the ball screw and bearing.

The prototype of the tiebarless clamping system is shown in Fig.8 and its specification is listed in Table 1. The clamping force is 6 tons and clamping stroke is 300mm. The ejector was pneumatic powered. Since this machine is a prototype, the clamping speed was designed at 26/mm only.

3 MEASUREMENT AND VERIFICATION OF THE PARALLEL PRECISION

Three approaches were used to verify the parallel precision between the stationary and movable platens when 6 tons of clamping force was applied.

3.1 Load Cell

This method used a test mold, which includes load cells and Belleville springs. Four sets of load cells and Belleville springs were used for the test. There four sets of load cells were located at four corners of the mold as shown in Fig.9. In the test mold, four sets of load cells and Belleville springs are fixed as Fig.10. The four load cells used for the test were well calibrated. If the deformation is not uniform, the reading on the four load cells will not be the same and have a large amount of variance. The resolution of the load cells is 1kgf.

3.2 Filler Gauge

This approach used filler gauges to measure the clearance of parting surface of the test mold. There are two perpendicular clearances on the movable mold surface (Fig.11). The clearances were made by grinding, groove AB and groove CD were not fabricated at same time. The depth of the two ground clearances was 0.5mm. If the parting surface is not perfectly contacted compactly under a clamping force, the measurements of opposite ground clearance will not be the same. The resolution of the filler gauge is 0.01mm.

3.3 Dial Indicator

Two dial indicators were used to measure the parallel precision between the stationary platen and the movable platen. The bases of dial indicators were fixed by a magnet at stationary platen and the probes touch movable platen (Fig.12). If the clamping surface is contacted compactly under the clamping force, the displacement readings of the left and right sides of the movable platen will be the same. The resolution of dial indicator is 0.01mm.

4 RESULTS AND DISCUSSION

The following are the results of parallel precision tests:

4.1 Load Cell

The results of this approach were shown in Table 2. The standard deviations of relative forces measured by load cells were small under the combined error of the load cells (5000kgf×0.025% = 1.25kgf). The relative magnitudes of forces on the load cells were based on the deformation of the Belleville springs, so the readings of the four load cells were not 6 tons.

4.2 Filler Gauge

The results of this approach are shown in Table 3. The measurement of the grinded clearance between A and B is the same. The measurement of grinded clearance between C and D is also the same. Because of the characteristic and resolution of the filler gauge, the standard deviations of this test could not be provided.

4.3 Dial Indicator

When the mold is closed under 6 tons of clamping force, both of the dial indicator show the same value –0.04mm (Fig.13). Because the resolution of the dial indicator is only 0.01mm, the standard deviations of this test could not be provided either but the result of the test was stable.

4.4 Discussion

Although parallel precision can't be identified by the test of load cell, it can check whether the variation of the four relative forces is small or not. Since the variation of the measurement readings is small, the parallel precision between the platens is well maintained. The standard deviations of the measurement readings may be caused by the non-uniform elastic deformation of test mold, quality deviation of Belleville springs, the inaccuracy of load cell and plane machining accuracy of test mold.

With the test method of filler gauges, it can be found that the ground clearances on the movable platen are equal under clamping force. Because of grinding processes, the clearance depths of groove AB and groove CD are 0.51mm and 0.48mm (Table 3). Besides, a Renishaw laser interferometer was used to measure the parallel precision between stationary and movable platens under high clamping force. The deformation between stationary and movable platens under high clamping force was about 100μm, which was satisfactory for the design.

By the test method of dial indicators, it can be shown that the movable platen deforms with the stationary platen uniformly. If the movable and stationary platens with bad parallelism are applied under a clamping force, the variation of the measurement reading will be large.

3. CONCLUSIONS

In this paper, a tiebarless clamping system was successfully designed and fabricated for an all-electric micro-injection molding machine. The parallel precision between stationary and movable platens under 6 tons of clamping force was verified by several alternative methods. But, this machine presents a new concept of flexible design of the tiebarless clamping system. With proper design a tiebarless clamping system can perform well and with high precision. In the future, the tiebarless clamping system will be applied in the injection molding machine to test the molding experiment. It will be more flexible to adopt some mold replacement mechanisms and more support systems can be used for the ejection of the molded parts, for examples, robot suckers, vacuum system and variable mold temperature system etc.

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Table 1 Specifications of tiebarless clamping system

Specifications	Unit	Value
Clamping Force	kN	60
Clamping Stroke	mm	300
Min. Mould Space	mm	70
Overall Size of Platens	mm×mm	250×170
Pressure Ejector Force	kN	1~2
Ejector Stroke	mm	60
Clamping Speed	mm/s	26
Clamping Unit Size	mm^3	370×417×1173

Table 2 Measured result of load cell

unit : kgf

	A	B	C	D
1	358	366	366	364
2	360	365	365	363
3	360	365	365	364
4	359	364	365	364
5	359	364	366	362
6	359	364	366	363
7	359	364	366	363
8	359	364	366	362
9	359	364	366	362
10	359	364	365	362
11	359	363	366	362
12	359	363	366	362
13	359	363	366	362
14	359	363	366	362
15	359	363	366	361
16	358	366	366	361
17	359	363	366	361
18	359	363	366	361
19	359	363	366	361
20	359	362	366	361
Ave.	358.95	363.8	365.8	362.15
Standard Deviation	0.459	1.056	0.410	1.039

Table 3 Clearance of parting surface under 6 tons of clamping force

Clearance (×0.01mm)			
A	B	C	D
51	51	48	48

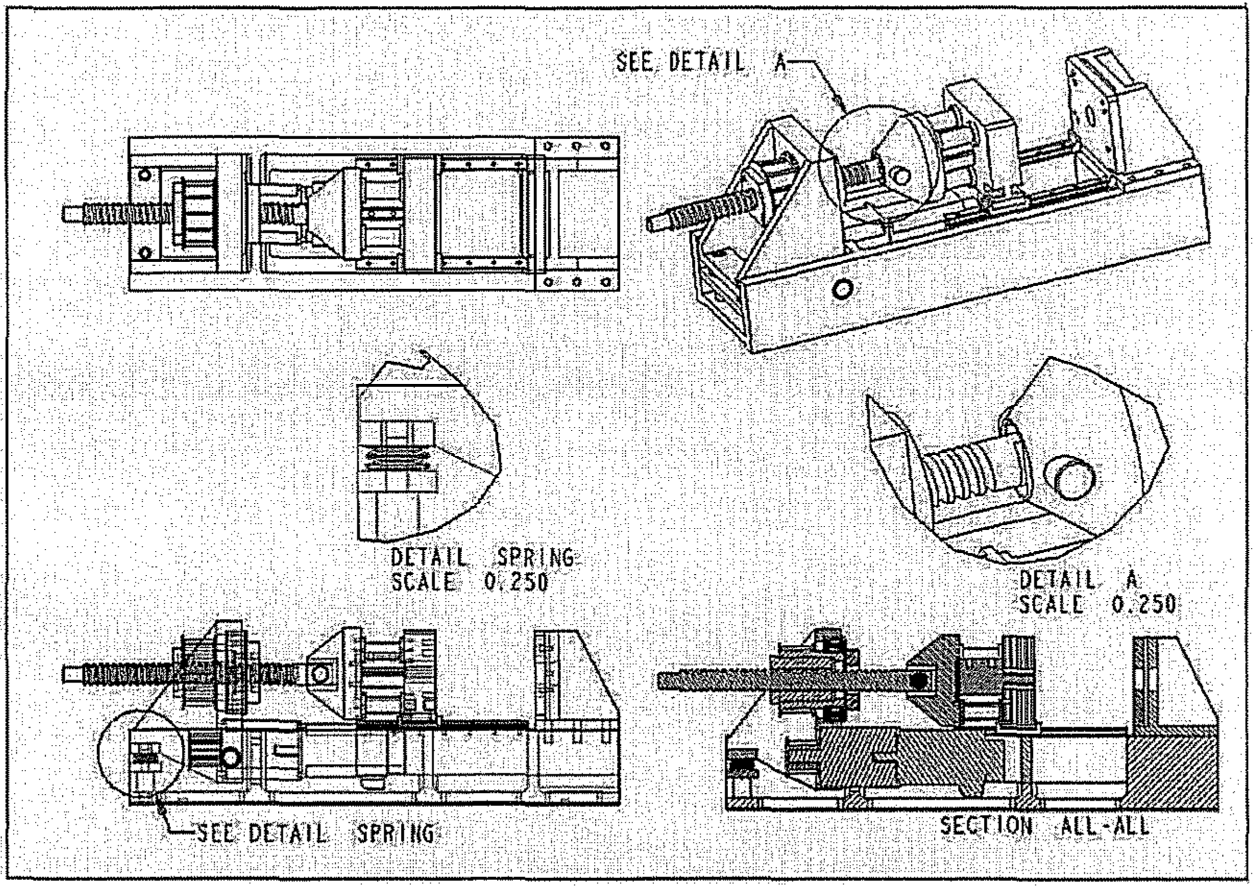

Fig. 1 Detail design drawing of tiebarless clamping unit

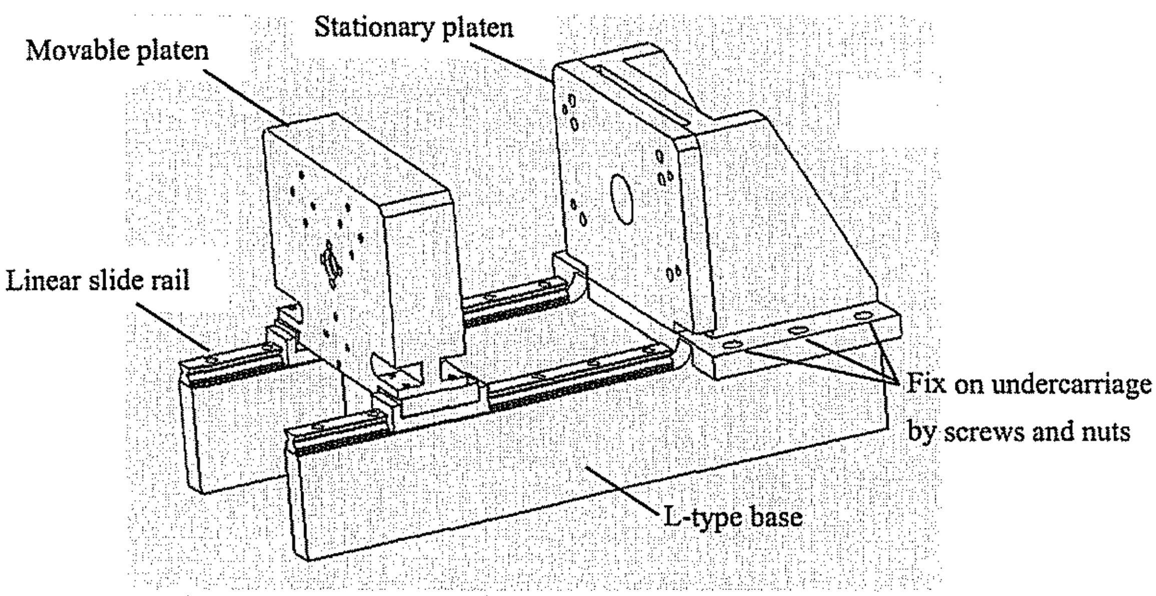

Fig. 2 Stationary platen, movable platen and linear slide rail

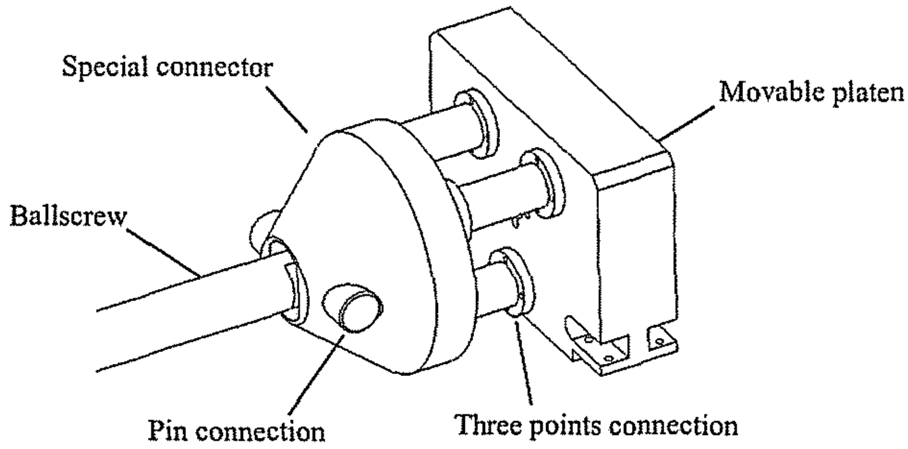

Fig. 3 Connector between ballscrew and movable platen

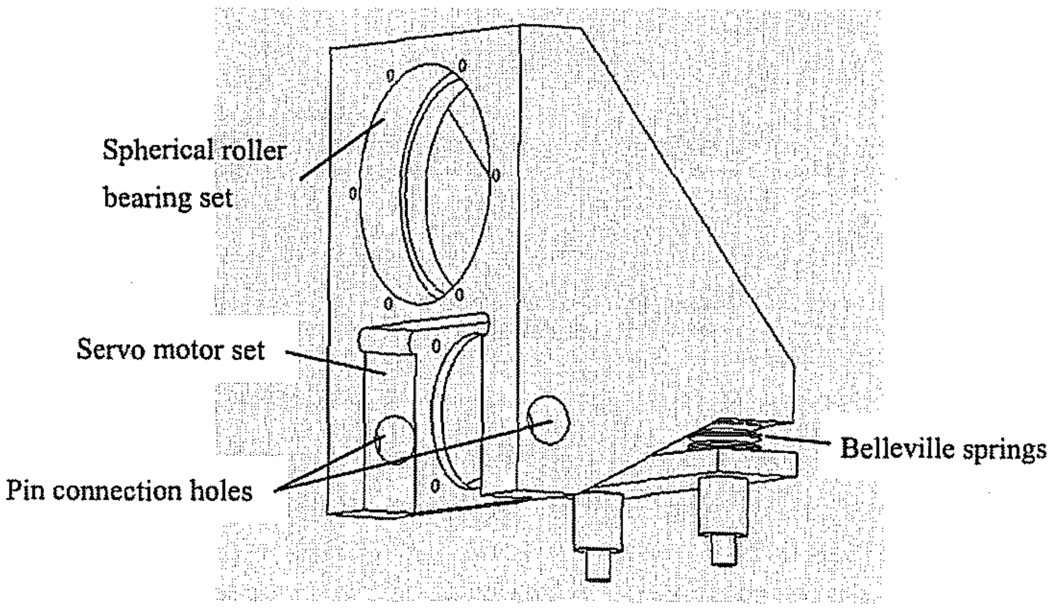

Fig. 4 Tail stock platen

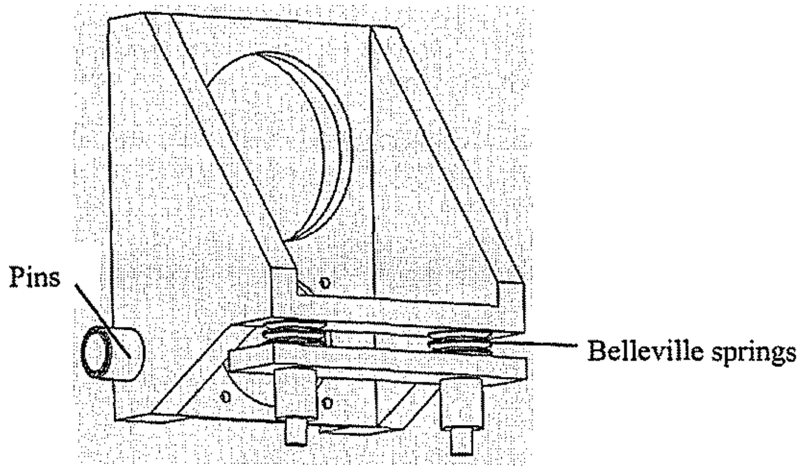

Fig. 5 Tail stock platen

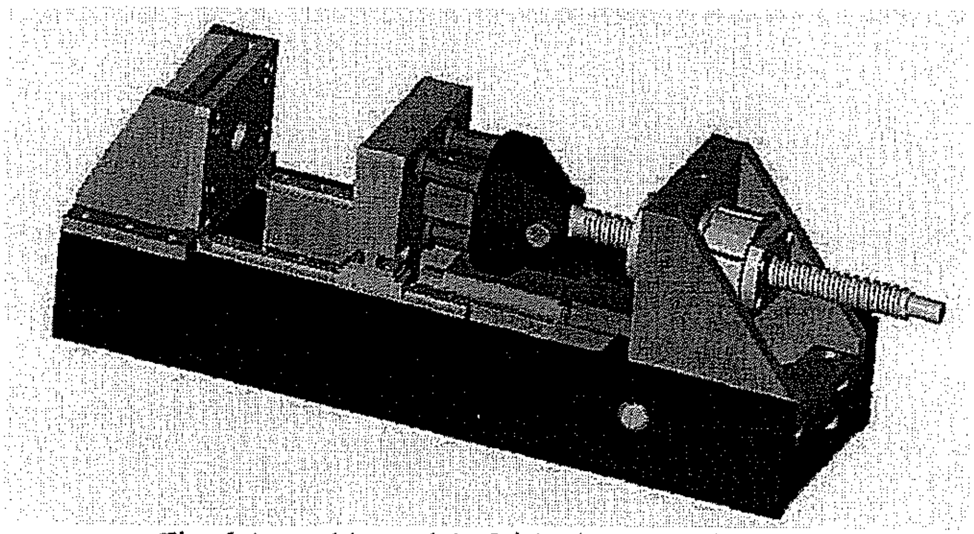

Fig. 6 Assembly model of tiebarless clamping unit

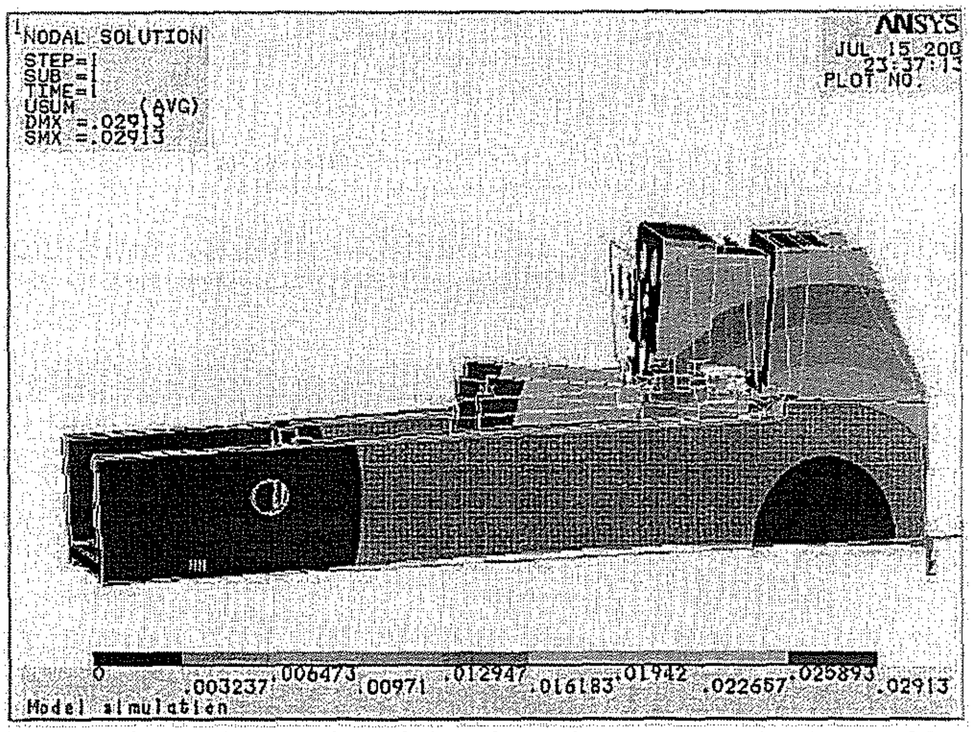

Fig. 7 Maximum deformation of clamping unit structure under 6 tons of force

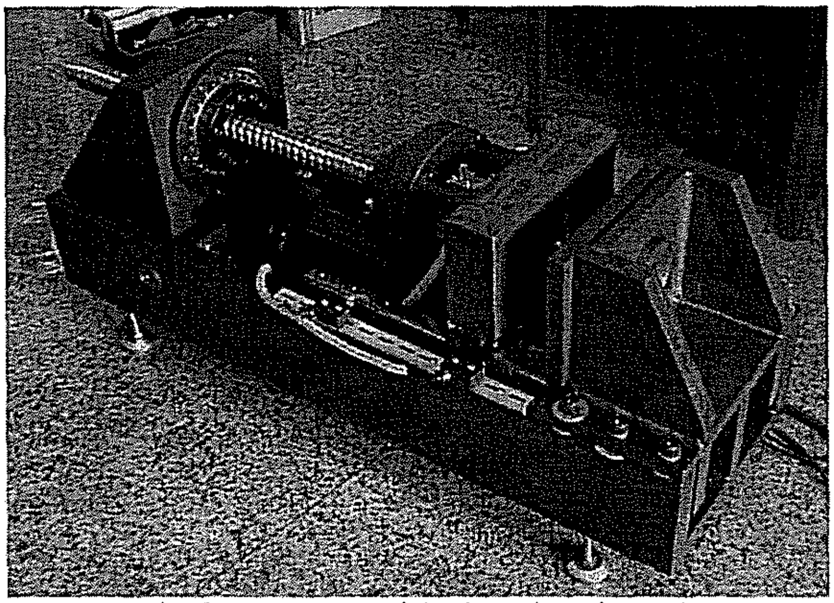
Fig. 8 Prototype of tiebarless clamping unit

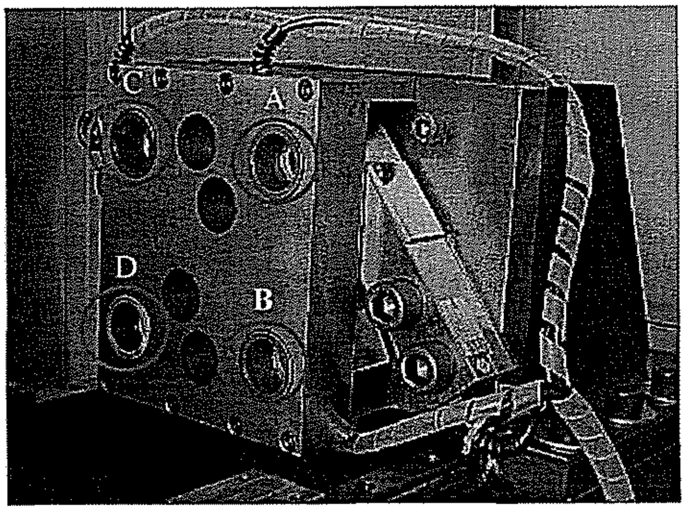

Fig.9 Load cells and location of test mold

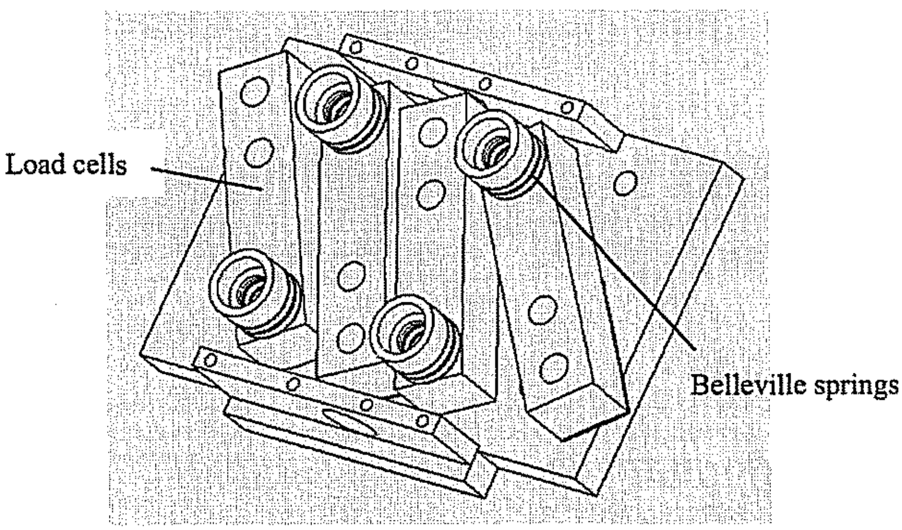

Fig.10 Internal structure of load cells

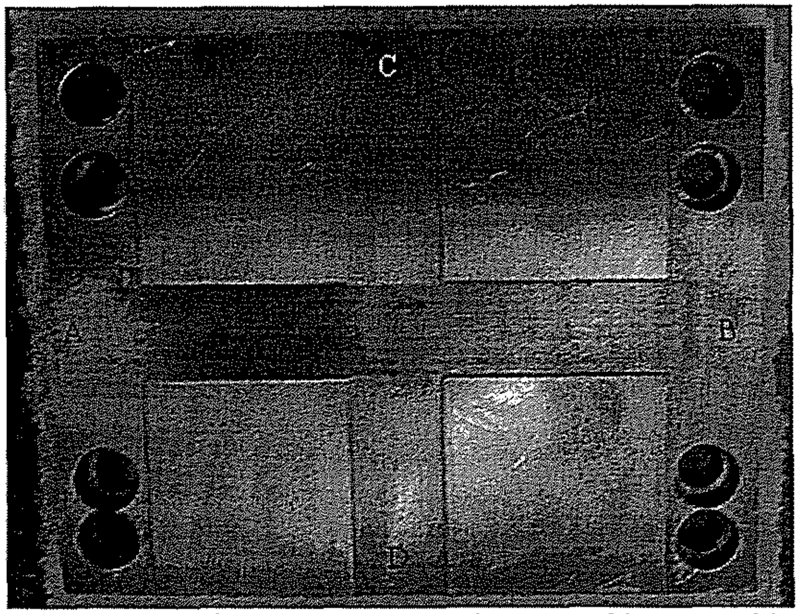

Fig.11 Measured location of clearance on the test mold on movable platen

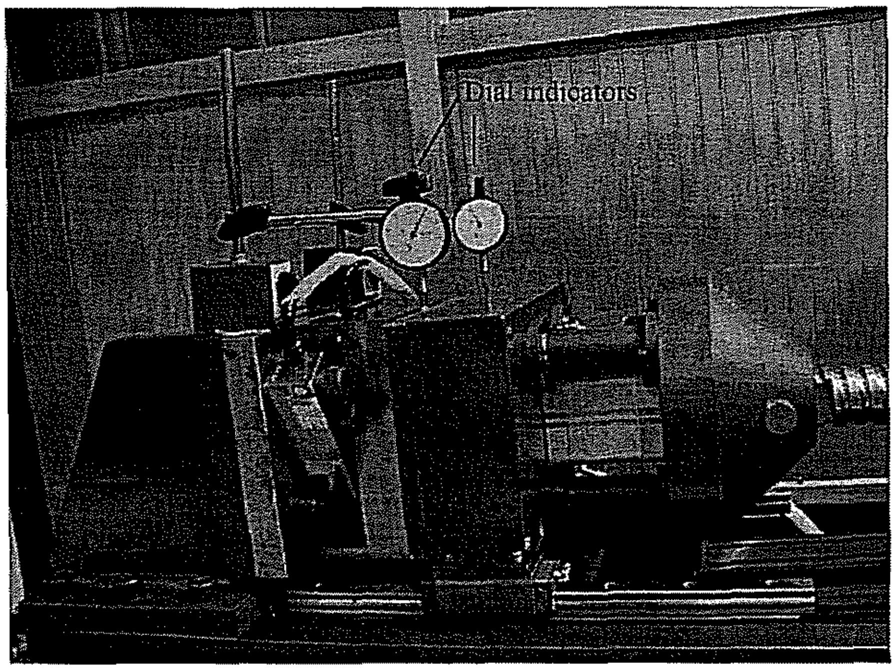

Fig.12 Dial indicators

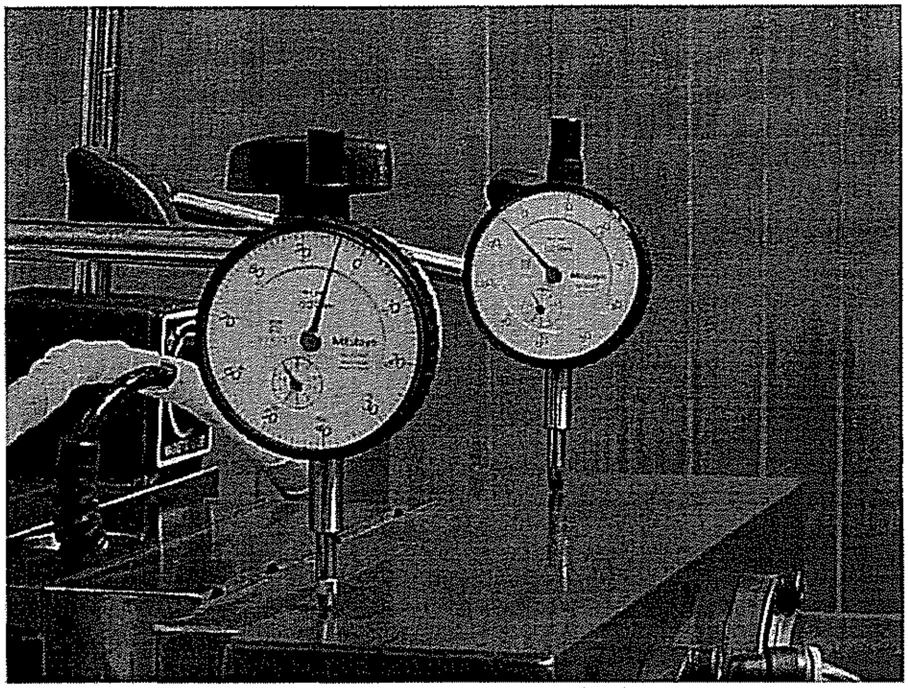

Fig.13 Measurements of dial indicators