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Optimal Structure Design of Multi-functional Folding Drawing Board based on TRIZ Theory

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Abstract

In drawing area, aiming at the problems of drawing breadth and angle cannot be adjusted individually and not convenient to carry, a kind of multi-functional folding drawing board is designed by us. The appearance of the multi-functional folding drawing board is kind of drawing board, some light materials like basswood and rigid plastics are used in main structure of the drawing board to make it light and convenient to carry. The main structure can be folded and it is suitable for A1 and A2 drawings. In the designing procedure, dip angle adjusted mechanism by worm wheel and gear, magnetic pull-in mechanism, leading rail, slide-way, drawer, tool library, paper bag and horn locks are applied based on modularity designing theory. Finite element analysis of key components of drawing board is analyzed.

Keywords: *folding drawing board, structure design, multi- functional, TRIZ theory*

1. Introduction

The drawing board is used to place the drawing and provide the user with a tidy drawing area. It is born with the need of the human beings' manual drawing. According to the statistics, about 37 million work on drawing work or study, and the amount of the drawing workers is rising by years. With the development of science and technology, the request of improvement of the quality of manual drawing and the conveniences, security and reliability of the auxiliary tools is prominent. The quality of manual drawing is closely related to the conveniences, security and reliability of the auxiliary tools. At present, there are many innovative products on the market. The mainstream products can be divided into two types, multi-boards combination and single-board. The function of present drawing board on the market is too simple to satisfy the individuation needs of different designers. Disadvantages of present structure are as follows:

(1) Not convenient to carry with plenty of drawing instruments, easy to omit, even lose, not only brings financial loss but also influence the following drawing works.

(2) Core drawing function of the drawing board is simple. And the dip angle is fixed or limited adjustment.

(3) Volume of present drawing desk is big and inefficiency of using. At the same time, ordinary drawing board has to be used with drawing desk, the dip angle cannot be adjusted when single used.

(4) Drawing instruments have to be carried alone.

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So, how to improve the function of the drawing board to satisfy the diversification need of the consumers is the hotspot which the auxiliary drawing tools designers focus on and has a great real value.

2. TRIZ Theory

TRIZ theory originates from the former Soviet Union. In 1946, G. S. Altshuller and his colleagues on the basis of researching in more than 250 million copies of the patent documentations around the world, and found the law behind these inventions. TRIZ is an abbreviation of Russia "Theoria Resheneyva Isobretatelskehuh Zadach", which means Theory of Innovative Problem Solving (TIPS). It is a methodology to create systematic innovation and improve the thinking process of designer [1, 2]. Research and application of TRIZ in China has just started, after 2000, a lot of domestic scientific research institutions, enterprises and experts began to pay attention to TRIZ. Heilongjiang is the first province in China to TRIZ methods popularization and application promotion. In 2007 Heilongjiang province and Russia's TRIZ research institutions have worked together to trained chief executive leaders of science and company technology, those leader come from various places of Heilongjiang province, and popularized the theory of TRIZ, and in the patent application and technological innovation have made remarkable achievements [3-5]. TRIZ theory is a solution to the method of the invention issues and ultimately achieve innovation, also a kind of sharing numerous inventor's knowledge and experience to increase the project personnel innovation ability method [6-7].

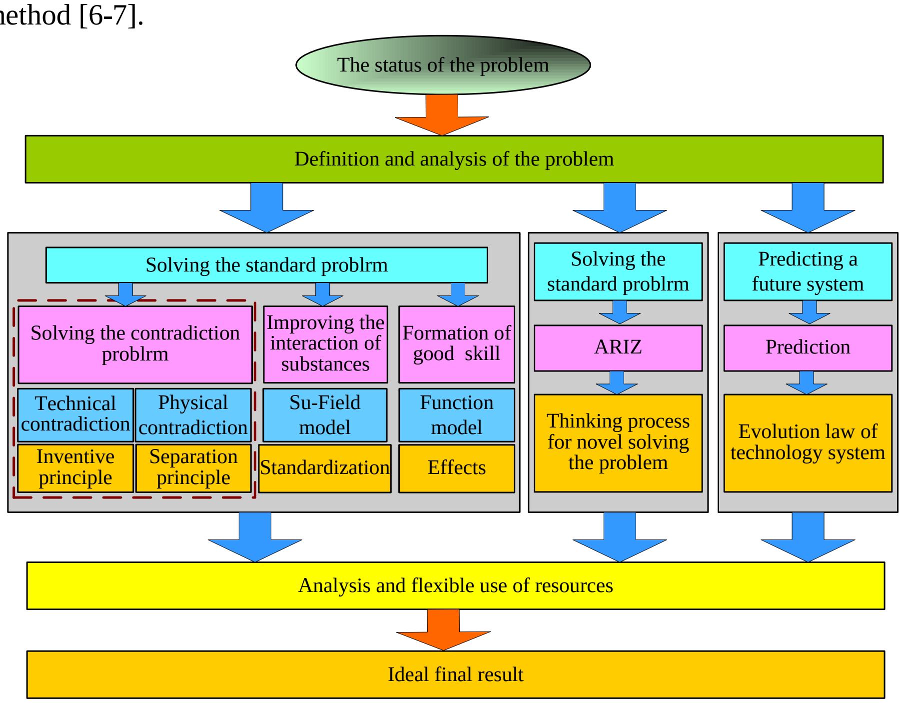

Figure 1. Method of Solving the Problem using TRIZ

TRIZ theory is a problem resolution system on the basis of evolution law of technology system. The theory and method architecture of TRIZ is consist of eight evolution law of technology system, thirty-nine general engineering parameters, forty inventive principles, thirty-nine multiple thirty-nine contradiction matrix, seventy-six standard solutions, algorithm for inventive-problem solving (ARIZ) and engineering effect database [4]. TRIZ theory system achieve a highly condensed summary of the innovation process, through studying human innovation instance, the innovation system is based on that the establishment of the excitation environment of innovative thinking, set conversion condition for innovative thinking, the specification activities of the process, combined with the principle of engineering and technical innovation, control and prediction to achieve a certain degree of innovative thinking. Method of solving the problem using TRIZ is shown in Figure 1.

3. TRIZ Theory Application on Structural Design of Assisted Washing-hand Device

3.1. Area Adjustment of Drawing Board using Physical Contradiction

At present, the biggest size of the drawing board used at the university is 420mm×297mm. In the drawing, the size of the drawing board sometimes need big, sometimes need to small. This forms a physical contradiction. Physical contradiction is as follows:

(1) Big drawing board can realize the drawing of big mechanical drawing sheet.

(2) Small drawing board is easier to carry.

The core concept of the solving of physical contradiction is the separation of physical contradiction.

Separate principle of physical contradiction is as shown in Figure 2.

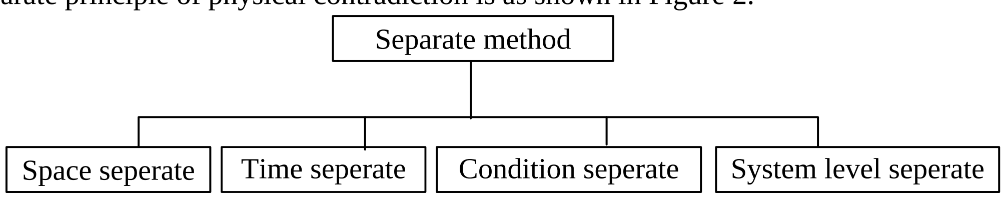

Figure 2. Separate Principle of Physical Contradiction

Space separate principle is used to solve this problem.

Step 1: the definition of physical contradiction

Parameter: area of drawing board

Requirement 1: big area can realize the drawing of big drawing sheet.

Requirement 2: small area is easier to carry.

Step 2: If we want to realize the ideal condition of technology system, which spaces can realize the different requirement of the parameter?

Space 1: the upper spaces

Space 2: the lower spaces

Srep 3: analyze these two space region, and judge these two space region whether intersect or not?

Through the analysis, these two space region don't intersect, so we select the space separate principle to solve this problem.

The relation between separate principle and 40 invention principle is as shown in Table 1.

1#inventive principle: Segmentation method

2#inventive principle: Taking out method

3#inventive principle: Local quality method

4#inventive principle: Asymmetry method

7#inventive principle: "Nested doll" method

13#inventive principle: "Do it in reverse" method

17#inventive principle: Another dimension method

24#inventive principle: "Intermediary" method

26#inventive principle: Copying method
30#inventive principle: Flexible shells and thin films method

Table 1. The Relation between Separate Principle and 40 Invention Principle

Separate principle	Invention principle
Space separate principle	1, 2, 3, 4, 7, 13, 17, 24, 26, 30

Compare with these invention principles, invention principles of 1#, 7#, the integration of 1# and 5# are adopted to solve the contradiction of area and length of stationary object.

Scheme 1: Segmentation method

Split type drawing board is as shown in Figure 3.

Figure 3. Split Type Drawing Board

Scheme 2: "Nested doll" method

Three layers of draw out the drawing board with extensible mapping space is as shown in Figure 4.

Figure 4. Three Layers of Draw Out the Drawing Board with Extensible Mapping Space

Scheme 3: the integration of invention principle 1# and 5#

Expanded structure of multi-functional folding drawing board is as shown in Figure 5.

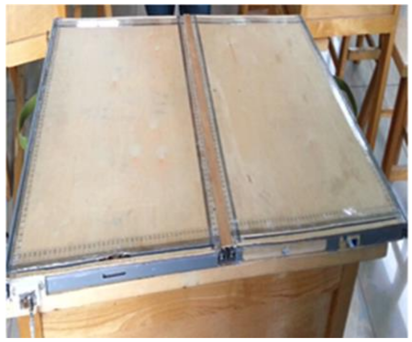

Figure 5. Expanded Structure of Multi-functional Folding Drawing Board

Through the analysis and comparison, we select the scheme 3 to solve this problem.

3.2 Angle Adjustment of Drawing Board using Technical Contradiction

Aiming to the problem of angle adjustment of drawing board, utilization conveniency and aesthetics of drawing board form a contradiction. Through the contradiction table, we select the inventive 7# and 17# to solve this problem. The angle adjustment structure adopts the ratchet mechanism or worm and gear mechanism. The angle adjustment structure is embedded the inside of drawing board. When we use it, the angle adjustment structure is come put in order to realize the adjustment.

4. Strength Evaluation

4.1. Strength Check for the Supporting Pole on the Upper Board

As shown in Figure 6, for load-bearing, the supporting pole linked with worm wheel can be simplified into a 200mm long straight tube, the loading on the bearing face of the tube can be counted as uniformly distributed load.

Figure 6. Load-bearing of the Supporting Pole

Bearing force on the supporting pole can be simplified into simply supported beam as shown in Figure 6, *L*=200mm.

It is known: material of the supporting pole is aluminum alloy 6070, yield strength $\delta_s = 276\text{Mpa}$, modulus of elasticity $E = 70\text{Gpa}$, take the safety factor $s = 1.2$, external diameter of the supporting pole is $\phi 8\text{mm}$, inner diameter is $\phi 6\text{mm}$, the maximum load-bearing is designed at 30Kg, force situation is shown in Figure 7.

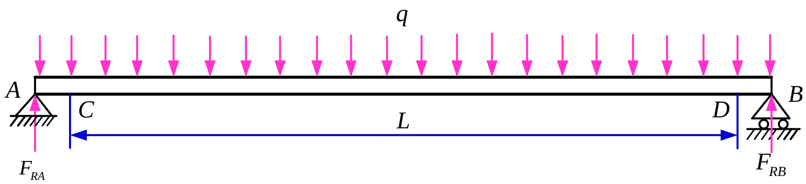

Figure 7. Force of the Supporting Pole

(1) evaluate the maximum working load

Maximum load of the supporting pole is:

$$F = G = mg = 30 \times 10\text{N} = 300\text{N} \tag{1}$$

Uniformly distributed load is:

$$q = \frac{F}{L} = \frac{300}{0.2}\,{}^{\text{N}}\!/_{\text{m}} = 1500\,{}^{\text{N}}\!/_{\text{m}} \tag{2}$$

(2) evaluate the bearing reaction

From the symmetry of load,

$$F_{RA} = F_{RB} = \frac{F}{2} = \frac{1500}{2}\text{N} = 750\text{N} \tag{3}$$

(3) evaluate shearing force $F_s(x)$ and bending moment $M_s(x)$

Shearing force,

$$F_s(x) = F_{RA} - qx \tag{4}$$

Bending moment:

$$M_s(x) = F_{RA}x - \frac{1}{2}qx^2 \tag{5}$$

(4) Draw the diagrams of the shearing force and bending moment, as shown in Figure 8.

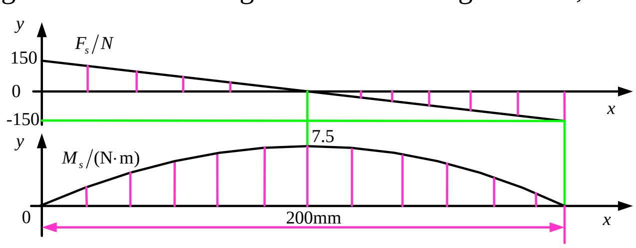

Figure 8. Shearing Force and Bending Moment of the Supporting Pole

(5) evaluate maximum bending normal stress

Moment of inertia on Z axis,

$$I_z = \frac{\pi D^4}{64}\left[1 - \left(\frac{d}{D}\right)^4\right] = \frac{\pi 8^4}{64}\left[1 - \left(\frac{6}{8}\right)^4\right] = 138.67\text{mm}^4 \tag{6}$$

Section modulus in bending,

$$W = \frac{I_z}{y_{\max}} = \frac{138.67}{4}\text{mm}^3 = 34.67\text{mm}^3 \tag{7}$$

Maximum bending normal stress,

$$\sigma_{\max} = \frac{M_{\max}}{W} = \frac{7.5}{34.67\times10^{-9}}\text{pa} = 216.3\text{Mpa} \quad (8)$$

(6) strength check on the supporting pole

Permissible bending stress,

$$[\sigma] = \frac{\sigma_s}{s} = \frac{276}{1.2}\text{Mpa} = 230\text{Mpa} \quad (9)$$

It is obviously that $\sigma_{\max} < [\sigma]$, satisfies the strength requirement.

4.2. Evaluate Rigidity of the Supporting Pole

From the simplified model, the maximum deformation (deflection) when maximum load is loaded on the supporting pole is,

$$\omega_{\max} = -\frac{5qL^4}{384EI_z} = -\frac{5\times1200\times0.2^4}{384\times70\times10^3\times1.39\times10^{-2}}\text{m} = -0.0032\text{m} = -3.2\text{mm} \quad (10)$$

From this, the maximum bending deformation of the supporting pole is 3.2mm and it appears at the middle position, satisfies the using requirement.

5. Finite Element Analysis of Key Components

After 3D modeling of the multifunctional foldable drawing board, it is necessary to carry out static analysis for the loaded key parts, to detect corresponding mechanical properties of the multifunctional foldable drawing board structure. In the condition of sketchpad loaded, sketchpad deformation will affects the quality of the drawing. This work applied ANSYS/Workbench software to 1mm thickness, 2mm thickness on upper sketchpad and the upper board surface perpendicular to supporting frame for the statics analysis.

5.1 Statics Analysis of Upper Sketchpad with Thickness of 1mm

Statics analysis were conducted respectively on upper board when thickness of 1mm, thickness of 1mm with additional stiffeners on surface. The analysis results are as shown in Figures 7-9. It can be seen from the results of analysis that the maximum deformation of the upper board is 3.3268mm，the maximum deformation of the upper board with additional stiffeners on surface is 1.3831mm when loading 300N force on board with thickness of 1mm.

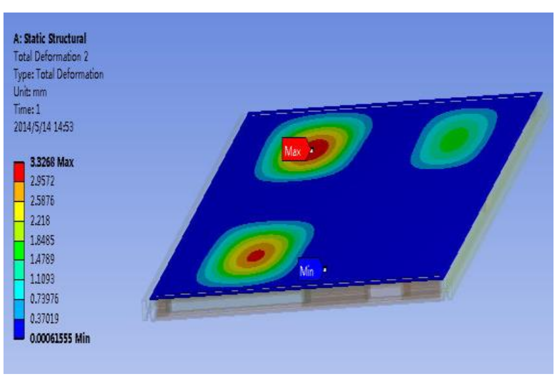

Figure 7. The Deformation of Upper Board with Thickness of 1mm

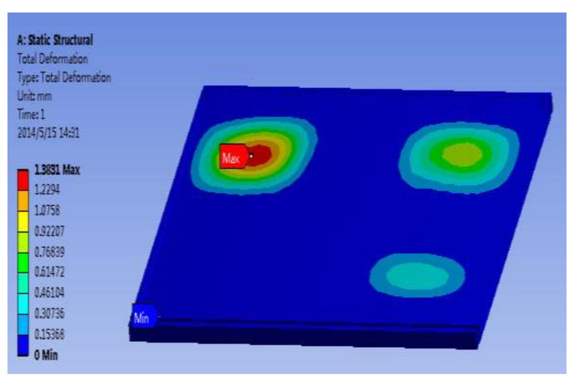

Figure 8. The Deformation of Upper Board with Additional Stiffeners

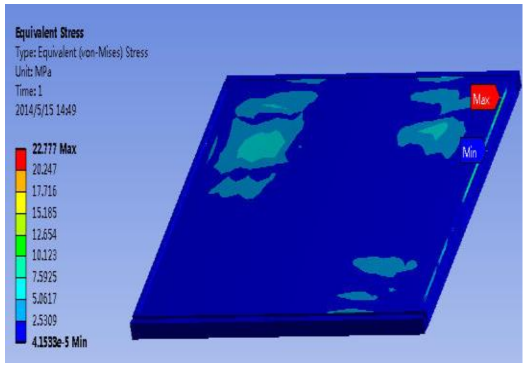

Figure 9. The Equivalent Stress of Upper Board with Additional Stiffeners

5.2. Statics Analysis of Upper Sketchpad with Thickness of 2mm

Statics analysis were conducted respectively on upper board when thickness of 2mm, thickness of 2mm with additional stiffeners on surface. The analysis results are as shown in Figures 10-12. It can be seen from the results of analysis that the maximum deformation of the upper board is 0.41469mm. The maximum deformation of the upper board with additional stiffeners on surface is 0.3152mm when loading 300N force on board thickness of 2mm.

5.3. Statics Analysis of Upper Sketchpad with Thickness of 2mm

Statics analysis were conducted respectively on supporting frame and the overall when upper board thickness of 2mm, the upper board surface perpendicular to supporting frame. The analysis results as shown in Figures 13-15. It can be seen from the results of analysis that the maximum deformation of supporting frame is 1.2267mm when the upper board surface perpendicular to supporting frame and the maximum deformation of the overall is 1.3915mm when loading 300N force on board.

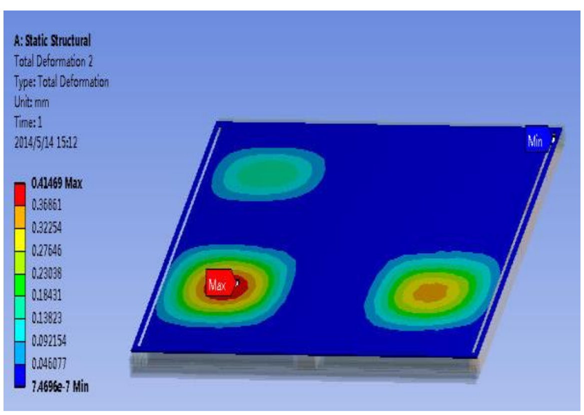

Figure 10. The Deformation of Upper Board with Thickness of 2mm

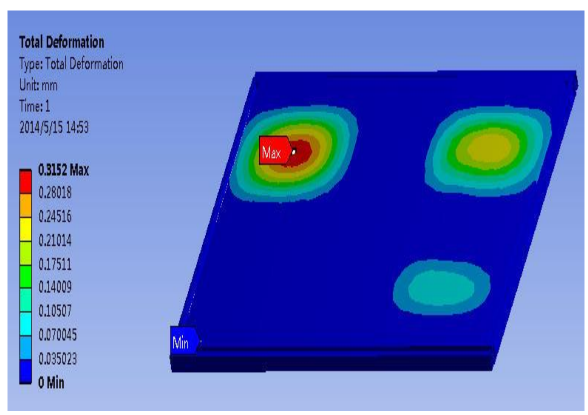

Figure 11. The Deformation of Upper Board with Additional Stiffeners

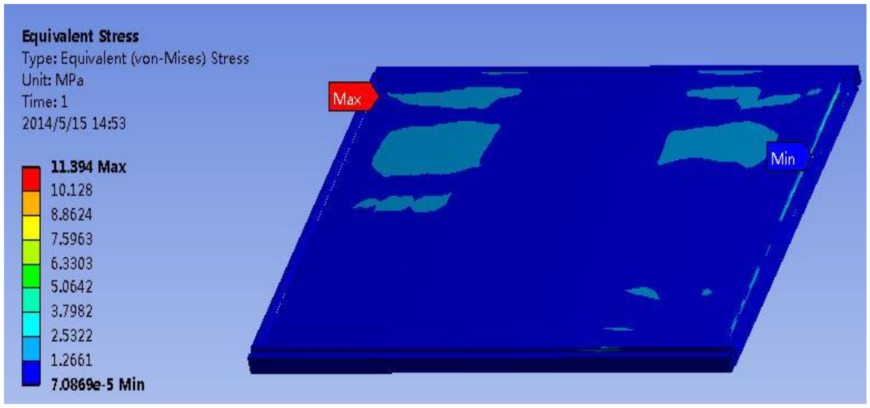

Figure 12. The Equivalent Stress of Upper Board with Additional Stiffeners

Through the above simulation results shows that the maximum stress and deformation of upper board thickness of 2mm and upper board with additional stiffeners on surface meet the requirements of drawing board deformation when precise drawing . The results of the largest stress deformation of supporting frame show that the design of support frame is reasonable.

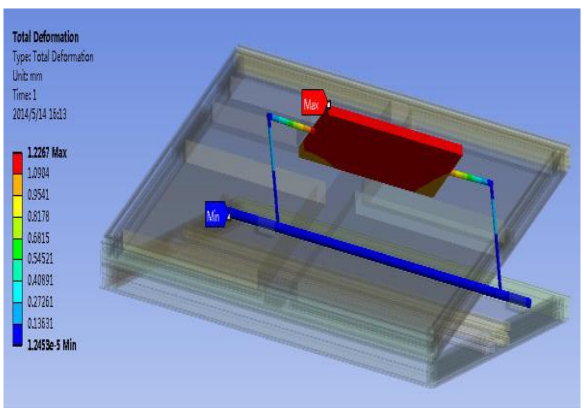

Figure 13. The Deformation of Supporting Frame when the Upper Board Surface Perpendicular to Supporting Frame

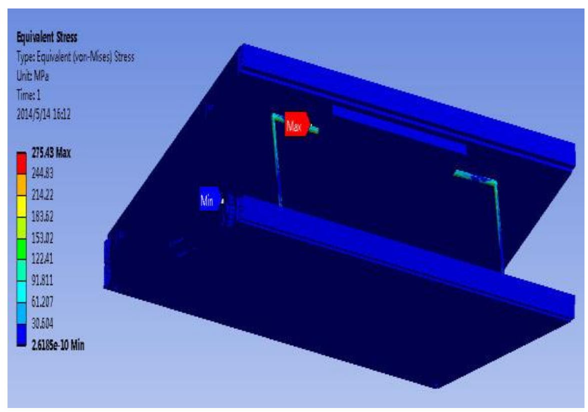

Figure 14. The Equivalent Stress of Supporting Frame when the Upper Board Surface Perpendicular to Supporting Frame

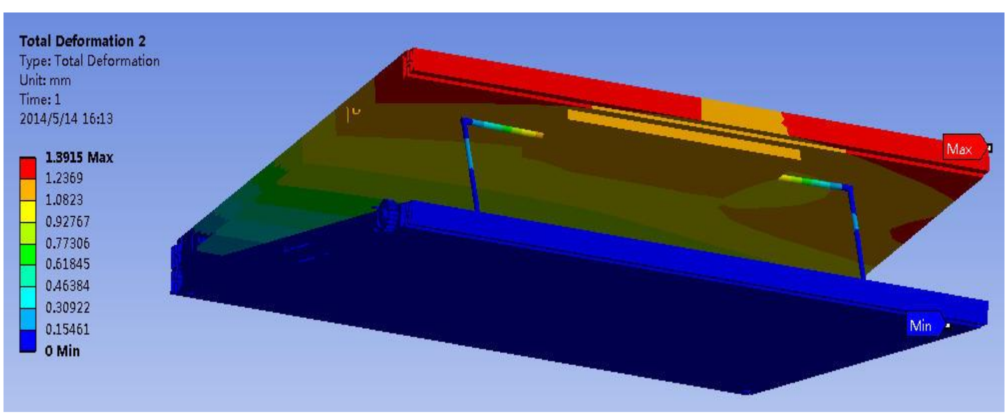

Figure 15. The Deformation of the Overall when the Upper Board Surface Perpendicular to Supporting Frame

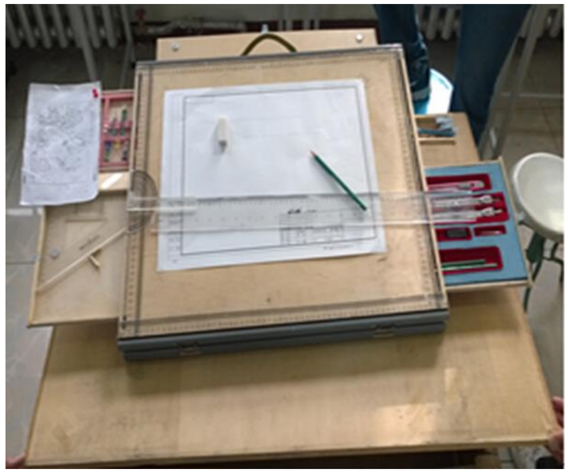

Figure 16. The Unfolding Status of the Multi-functional Folding Drawing Board

6. Conclusions

(1) Aiming at the problems of drawing breadth and angle cannot be adjusted individually and not convenient to carry, a kind of multi-functional folding drawing board is designed by us. The appearance of the multi-functional folding drawing board is kind of drawing board, some light materials like basswood and rigid plastics are used in main structure of the drawing board to make it light and convenient to carry.

(2) Based on the contradiction analysis of TRIZ theory, the main structure can be folded and it is suitable for A1 and A2 drawings. In the designing procedure, dip angle adjusted mechanism by worm wheel and gear, magnetic pull-in mechanism, leading rail, slide-way, drawer, tool library, paper bag and horn locks are applied based on modularity designing theory. Finite element analysis of key components of drawing board is analyzed.

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References

[1] F. Jiang, H. Sun and Y. J. Wang, "Application of TRIZ theory in mechanical principle experiment teaching and management [J]", Experiment Science & Technology, vol. 8, (**2010**), pp. 140–143.
[2] X.-t. Liu, C.-y. Zhao and P. Xu, "TRIZ theory and students innovative ability cultivation [J]", Higher Education Forum, vol. 3, (**2011**), pp. 29-31.
[3] F. Jiang, J. Yu and Z. W. Liang, "The plan research on the mechanical foundation experiment system combined with TRIZ theory [C]", 2010 International Conference on Education and Sports Education, (**2010**), pp. 61–64.

[4] J.-g. Jiang, Y.-d. Zhang, J.-y. Zhang and H.-y. Du, “Training pattern of undergraduate’s innovative ability based on TRIZ theory [C]”, The 8th International Conference on Computer Science & Education, (**2013**), pp. 1102–1106.
[5] S. Y. Liu, “The design and application of the mechanical parts based on the TRIZ theory [J]”, Applied Mechanics and Materials, (**2014**), pp. 556-562, pp. 1241-1244.
[6] T. Wu, W. Li and Y. Li, “Innovative design of an automatic train picking hook device based on TRIZ [J]”, Advanced Materials Research, (**2011**), pp. 328-330: 309-313.
[7] R. Zhang, M. Zhang, X. Wang, L. Han and M. Li, “The innovative design on the scheme of the vertical turn stereo garage based on TRIZ and AD [C]”, International Technology and Innovation Conference 2009, (**2009**), pp. 1-6.
[8] M. Ilevbare Imoh, P. David and P. Robert, “A review of TRIZ, and its benefits and challenges in practice [J]. Technovation, vol. 33, nos. 2-3, (**2013**), pp. 30-37.