Newly Designed High-Speed and Fully Automated Mechanical System for Assembling of Self-Centering Clutch Release Bearing

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Abstract

The purpose of this article is to present a design and analysis of a fully automated and high speed assembling system. This system will continuously assemble a self-centering clutch release bearing and bearing hub without any mismatch. To accomplish the required task at high speed, the center matching tool and the self-centering gripper have been designed. The movements of these automated tools are done by the rod less pneumatic cylinders. The assembled part will then be sent to the inspection station by using the precision indexing conveyors. To design this system, the Creo parametric 2.0 software was used. Whereas, the analysis was performed by ANSYS Workbench 16.0

Keywords: Automated high-speed assembly system, Center matching tool, Self-centering gripper, Rodless pneumatic cylinder, Creo parametric 2.0, Finite element analysis (ANSYS Workbench 16.0).

Introduction

"Science is the engine of prosperity. All the prosperity we see around us is the byproduct of scientific invention"- Michio Kaku [1]. To refer to the above quote, we can say that an automation and high speed technology are the needs of an advance science. Automation is the key for industrialization. The competitive world insists to the industries to develop an innovative and cost effective automated system to be sustained in the competitive market. The word automation is defined as; a tool and innovative strategy that can boost production rate efficiently and reduce human involvement. Nowadays it is used in almost all the small and large scale industries. Automation helps to perform a given task without any error, and reduce the repetition or redundant task [2].

To develop a design, which is easy for visualization, the Computer Aided Engineering Design softwares are especially used, in most of the industries, moreover we can say that nowadays a Computer Aided Engineering Design (CAD) and the Computer Aided Engineering Analysis are the most effective and time saving tools used in automated and high speed industries [3].

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Once the design gets ready, the above mentioned tools help to analyze the design; however, the special analysis tools like ANSYS are available in market. This article proposes an automated and high speed technique for assembling self-centering clutch release bearing. A self-centering clutch release bearing is used to prevent noise caused by uneven pressure acting upon diaphragm spring. It fixes on to transaxles and aligns itself with the centerline of the diaphragm spring, which helps to prevent noise associated with clutch disengagement [4]. As most of the industries are still using a manual assembly technique, which takes time, extra cost, and causes mismatching errors, also ultimately results in damage of parts. To overcome such problems, this article introduces newly designed automated tools and system. The system has been designed by using the Creo parametric 2.0 whereas; the analysis is done with ANSYS workbench 16.0. To match the exact centers of bearing hub and self-centering bearing, a self-centering gripper and a center matching tool is designed and also been tested for required loading conditions.

Assembly System for Self-Centering Clutch Release Bearing

The system is designed for automatic assembly, with high precision and without mismatching errors by detecting the exact centers. Figure 1 shows the picture of self-centering clutch release bearing and bearing hub [4].

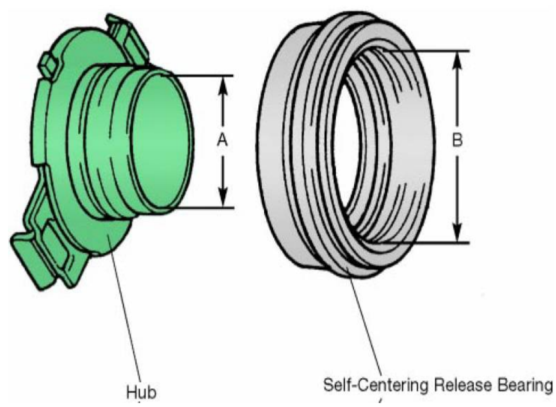

Figure 1.Components of Self-Centering Clutch Release Bearing

Operations performed during the whole process:

1. Picking and placing the components on the respective conveyors using a rodless pneumatic cylinder.
2. The bearing hub will then be passed through a mechanical flipper mechanism, where the bearing hub will get flipped upside down by using a mechanical flipper.
3. Both components will then be sent to the assembly station, where the center matching, followed by the assembling takes place by using a center matching tool, a self-centering gripper, and a rodless pneumatic cylinder
4. Then the assembled component will be sent to the 90^0 rotation station
5. The last station is the inspection station, where the actual alignment will be tested.

Among these operations, this article is specifically focused on the third operation that is assembling of self-centering clutch release bearing and bearing hub. To explain all the functions and the stations clearly, Fig. 2 shows the 3D CAD model of the full system.

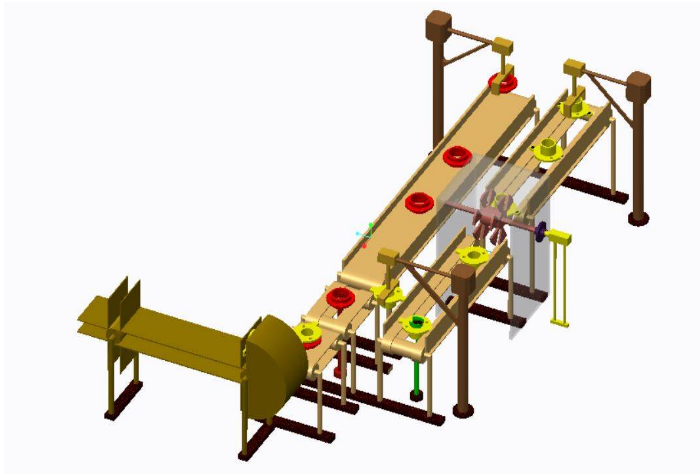

Figure 2.3D Model of a Complete Assembly

To perform the operations, various tools have been designed and used in these systems which are:

1. Rodless pneumatic cylinder
2. Self-centering gripper
3. Center matching tool

Rodless Pneumatic Cylinder

Rodless pneumatic cylinders are the effective and reliable replacement for the industrial mechanical robots. The structure and mechanism is very simple and easy to maintain. The tool is generally preferable in high speed and fully automated industries. In this article, it is used for the movements of self-centering gripper, as well as center matching tool to pick and place the bearing parts and matching the centers respectively.

The advantages of the rodless pneumatic cylinders over the industrial robotic arms are:

1. Less complexity
2. Easy to maintain
3. Can be used, where the space is limited
4. Less cost

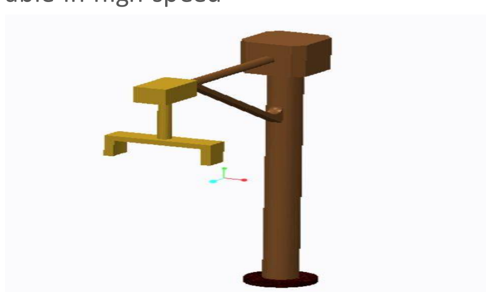

Figure 3.3D Model of Rodless Pneumatic Cylinder

Self-Centering Gripper

To make sure that the assembly of the components has been done perfectly, the mating axes of the components should be perfectly matched. Thus, to match the axes of a bearing hub and a bearing, a two finger self-centering gripper is used. To achieve the proper grip, extra rubber padding is provided. The material used for this gripper is A36 steel. The gripper can apply the holding force in the range of 5N to 650N (1.12 lb to 146 lb).

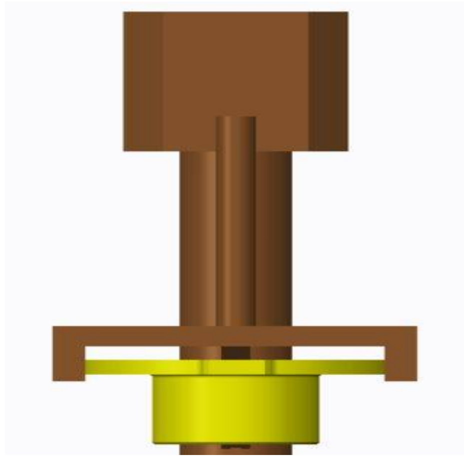

Figure 4.3D Model of Self-Centering Gripper

Center Matching Tool

In some industries, the assembling of self-centering clutch release bearing is still being done manually, which causes the mismatching errors and eventually damage of mating edges. To prevent such mismatching and make the assembling process fully automatic and quick, a center matching tool has been designed. It works with the help of pneumatic rodless cylinders, it has X and Z direction movement. As we know, not a single machine can produce exactly the same parts every time thus, we provide tolerances. The same concepts have been taken into the consideration while designing this tool. To match the assembly, we should rely on the inner surface of the actual mating parts regardless of the outer geometry. Once the actual mating surfaces get assembled, the whole parts will assemble automatically. To match the exact centers, the side moving grippers of the center matching tool detects the holes of the parts and get fixed on the inside surface of the hole.

Figure 5.3D Model of Center Matching Tool

Assembly Station

The actual assembling process will be done at this station with the help of rodless pneumatic cylinder, self-centering gripper, center matching tool and precision indexing conveyor. First, bearing and bearing hub will be placed on precision indexing conveyor, by using pneumatic rodless cylinder. Then, the centers of the parts will be matched by using center matching tool. Once the center of the two meting parts has matched, the self-centering gripper will hold the bearing hub and put it onto the bearing. To make this assembly accurately, the centers of the self-centering gripper and center matching tool have been matched. Once the assembling is done, the assembled parts will be sent to the next station by using the precision indexing conveyor. Precision indexing conveyors are particularly used for automated and high-speed assembling of small components, in which high part count or assembling process complexity is involved [5].

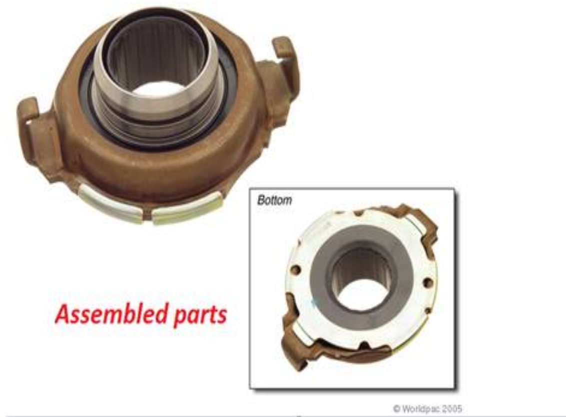

Figure 6.Assembly of Self Centering Clutch Release Bearing

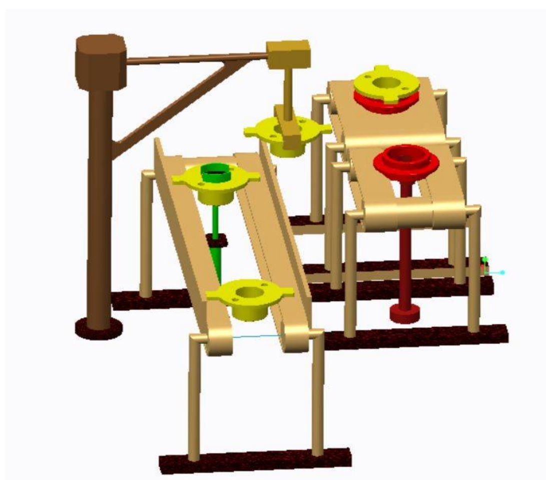

Figure 7.3D Model of Assembly Station

Analytical Calculations

To verify the results of computer aided analysis, some necessary analytical calculation was done by using the following formulas.

Equation 1 gives the value of gripping force and factor of safety [6].

$$\eta = \frac{2 \times \mu \times F}{m \times (g+a)} \quad \dots (1)$$

Where,

□ is factor of safety

μ is coefficient of friction

F is allowable gripper force

m is mass

g is acceleration due to gravity

a is acceleration of handling

To calculate the deformation and stress generated equation 2 and equation 3 was used [7].

$$y = \frac{W \times L^3}{3 \times E \times I} \quad \dots (2)$$

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$$\sigma = \frac{W}{A} \quad (3)$$

Where,

y is maximum deflection

W is point load at free end

L is overhanging length of pneumatic cylinder-gripper unit

E is Young's modulus

I is moment of inertia

σ is stress

A is surface area

To calculate the factor of safety, yield strength and maximum stress are taking into consideration and calculated by the following formula: [7]

$$FS = \frac{Yield\ Strength}{Maximum\ Stress} \quad (4)$$

Computer-aided Analysis of Rodless Pneumatic Cylinder with Gripper

The structure of rodless pneumatic cylinder is cantilever in nature, which may cause failure while using it. Thus, to avoid future problems, a computer aided structural analysis of rodless pneumatic cylinder has been done.

To perform the structural analysis, an ANSYS Workbench 16.0 was used. To check the reliability, maximum loads were applied. Moreover, for the cost effectiveness and the sustainability, two materials have been tested, which are Structural Steel and Aluminum Alloy. Tables 1 and 2 show the results obtained with two different materials.

Table 1.FEA Results for A-36 Structural Steel

Force (Lbf)	Deformation (mm)	Stress (MPa)	F.O.S
80	0.45	51.76	4.8296
90	0.5	58.235	4.293
100	0.56	64.705	3.8637
110	0.62	71.117	3.5124

Table 2.FEA Results for Aluminum Alloy

Force (Lbf)	Deformation (mm)	Stress (MPa)	F.O.S
80	1.268	51.22	5.4105
90	1.4275	58.22	4.8093
100	1.5861	64.689	4.3284
110	1.7447	71.158	3.9349

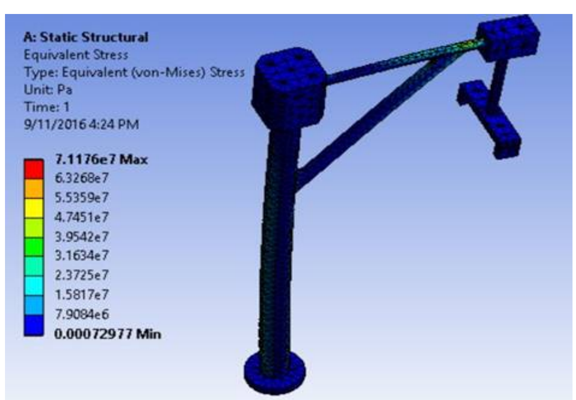

Figure 8.Stress Profile of Rod-Less Pneumatic Cylinder with Gripper for A36 Structural Steel

Figure 8 shows maximum stress generated as 71.17 MPa, when a maximum force of 110 Lbf was applied. As the yield strength of A36 steel is 250Mpa (36000 psi), we get a 3.5124 safety factor, which is well above the required value of 2 [8].

Figure 9 shows the displacement profile for A36 Steel, which shows that the deformation caused by maximum load is within the limit.

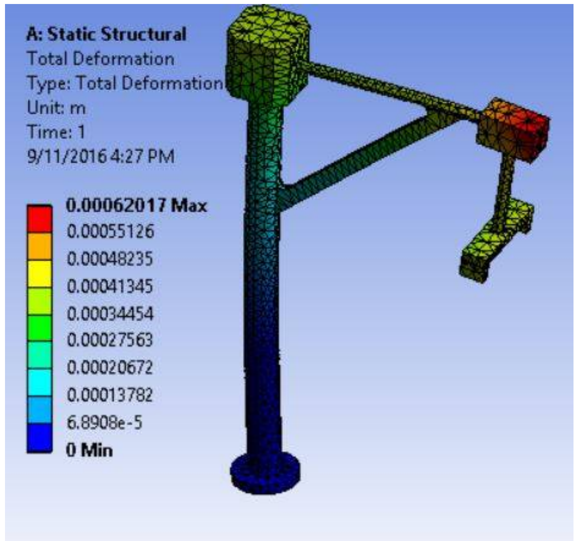

Figure 9.Displacement Profile of Rod-Less Pneumatic Cylinder with Gripper for A36 Structural Steel

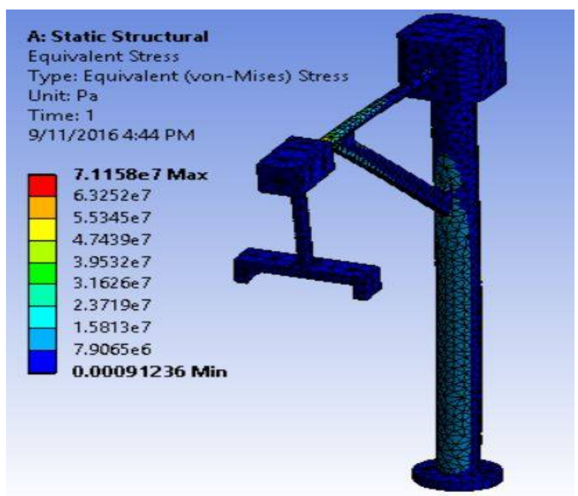

Figure 10.Stress Profile of Rod-Less Pneumatic Cylinder-Gripper Unit for Aluminum Alloy

Figure 10 shows maximum stress generated with the Aluminum alloy as 71.158 MPa, when a maximum force of 110 Lbf was applied. As the yield strength of Aluminum Alloy is 280Mpa (40610 psi), we get a 3.9349 safety factor which is well above the required value of 2.

Figure 11 shows the displacement profile for Aluminum alloy, which shows that for the maximum load, this material deforms more than that of the steel material.

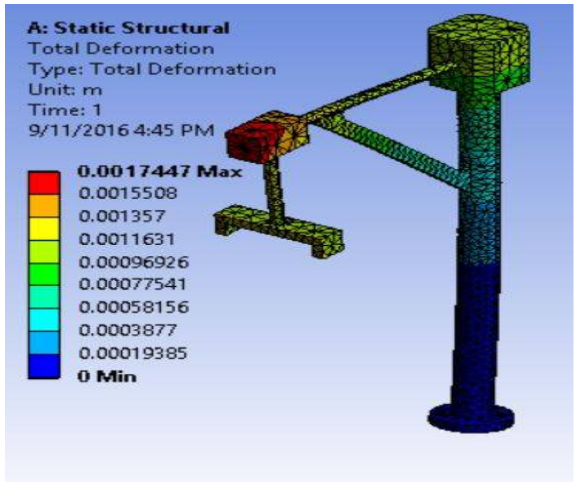

Figure 11.Displacement Profile of Rod-Less Pneumatic Cylinder-Gripper Unit for Aluminum Alloy

Computer-aided Analysis of Bearing Hub

Similarly, to make sure that the bearing hub will not cause any deformation because of the gripper holding force, a static structural analysis of the bearing hub was done by applying different loading conditions.

Table 3 shows the deformation and stress induced, due to the maximum applied loads.

Table 3.FEA Results for Bearing Hub

Force (Lbf)	Deformation (mm)	Stress (MPa)
10	1.08e-5	0.20065
20	2.160e-5	0.40129
30	3.240e-5	0.60194
40	4.3206e-5	0.80259

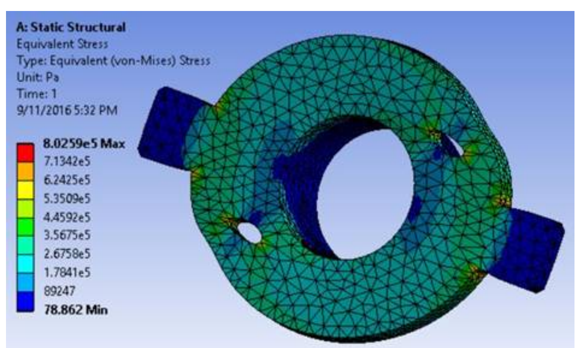

Figure 12.Maximum Shear Stress Profile of Bearing Hub

Figure 12 shows maximum shear stress generated in the Bearing hub as 0.80259MPa for the maximum holding force of 40 Lbf. The material used for bearing hub is pressed steel which has the yield strength near about 250Mpa (36000 psi) [8]. From Table 3, it shows that the maximum stress generated due to the maximum holding force is 0.80259 MPa, which is negligible for the required loading condition whereas, deformation pattern shows the highly negligible amount.

Figure 13 shows the color banded view of deformation pattern for bearing hub.

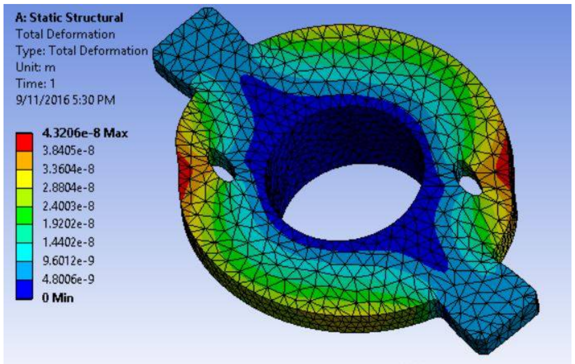

Figure 13.Displacement Profile of Bearing Hub

Taking a look at all the results obtained from computer aided analysis; it confirms that the proposed design system is safe and feasible for automated industries.

Conclusion

This system is specifically designed to improve production rate, quality of product and eventually to increase productivity by reducing excess cost. The intension of designing this system is to provide an advanced technology to the manufacturing industries. To prove the reliability of this system, the structural analysis of pneumatic rodless cylinder and bearing hub was performed in ANSYS, and the results were validated with the analytical results, which proves that the newly designed assembling system works satisfactorily. Before selecting the materials for the system, the analysis was performed for both the materials i.e. A36 steel and Aluminum alloy, and the results obtained show that the deformation caused with aluminum alloy was greater than that of the A36 steel, whereas, the steel is cheaper than that of aluminum. Moreover, the factor of safety obtained with the steel material is greater than the acceptable limit. So, by considering all the results, A36 steel has been selected for the given design. For the future improvements, as the factor of safety is greater than the required one i.e. 2 and also, if anyone wants to make this system even more cost effective, a lower grade materials available in the market can be used, whereas, some modifications in dimension can also be done to minimize the cost of the system [9].

References

1. Kaku M. Science Is The Engine of Prosperity. Triangulation Episode 145 Uploaded by Kaku M Videos. Dec 24, 2014. Available from: https://www.youtube.com/watch?v=08vgySZvljo.
2. Automated Testing Advantages, Disadvantages and Guidelines. Available from: http://www.exforsys.com/tutorials/testing/automated-testing-advantages-disadvantages-and-guidelines.html.
3. Li JZ. CAD, 3-D Modeling, Engineering Analysis and Prototype Experimentation. *Springer International Publishing,* 2015.
4. Manual Transmission and Transaxles. Available from: http://stuff.jaygroh.com/prius/Prius%20Info/Official%20Toyota%20Info/References/Technical%20Training/Introduction%20to%20Manual%20Transmissions%20&%20Transaxles.pdf.
5. Li JZ. A New Automated and High-speed Machinery System for High Viscous Liquids. *Journal of Applied Mechanics and Materials* 2011; 66-68: 140-45.
6. Engineering Design Assistance, Gripper Force Formula. Available from: http://

www.emicorp.com/eoat/forms-pdfs/gripper_formulas.pdf.

7. Bhandari VB. Design of Machine Elements. 3rd Edn. *Tata McGraw Hill*, 2010.
8. Li JZ. Study and Analysis of a New Automated and High-speed Mechanical System for Computer Mouse Assembly. *Journal of Mechatronics* 2014; 2(2): 109-12.
9. Saeki E, Sugisawa M, Yamaguchi T et al. Mechanical Properties of Low Yield Point Steels. *Journal of Materials in Civil Engineering* 1998: 143-52.