Orclever Proceedings of Research and Development
https://doi.org/10.56038/oprd.v3i1.415
OR CLEVER Science & Research Group

Dinamik Deformasyon Yoluyla Konnektör Pimlerinin Kalibrasyonu

Feza Gökışık[1], Emre Akca[2], Şeref Naci Engin[3], Cihan Demir[4], Sezer Yetkin Payaz[5]

[1]Aksan Kalıp San. ve Tic. A.S., 0009-0005-3471-4380, feza.gokisik@aksan-co.com
[2]Aksan Kalıp San. ve Tic. A.S., 0009-0001-6004-7447, emre.akca@aksan-co.com
[3]Yıldız Teknik Üniversitesi, Kontrol ve Otomasyon Müh. Bl., 0000-0003-2514-9250, nengin@yildiz.edu.tr
[4]Yıldız Teknik Üniversitesi, Makine Müh. Bl., 0000-0001-8412-0787, cdemir@yildiz.edu.tr
[5]Aksan Kalıp San. ve Tic. A.S., 0000-0002-8093-8669, sezer.payaz@aksan-co.com

(First received October 21, 2023 and in final form December 20, 2023)

3rd International Conference on Design, Research and Development
(RDCONF 2023)
December 13 - 15, 2023

Reference: Gökışık, F., Akca, E., Engin, Ş., N., Demir, C., Payaz, S., Y. Dinamik Deformasyon Yoluyla Konnektör Pimlerinin Kalibrasyonu. Orclever Proceedings of Research and Development,3(1), 720-732.

Özet

Otomotivde kullanılan konektörlerin ilgili baskı devre kartlarına bağlanan kısımlarının tolerans aralıkları günden güne daralmaktadır. Otomotiv üreticileri kendi kendine sürüş yapan ya da sürücü desteği sağlayan parçalarda daha çok güvenilirliğe ihtiyaç duymaktadır. Kesip kıvırıp üzerine plastik malzeme enjekte etmekten oluşan alışılagelmiş imalat yöntemleri ile dar toleransları sağlamak mümkün olmamaktadır. Bu durumda soket üreticileri iletkenlerin uç pozisyonlarını kalibre edecek yöntemlerin arayışına girmişlerdir. Bunlardan bir tanesi pimlere kalıcı deformasyon vererek düzeltmektir. Bu yöntem değişik pim şekillerinin değişik vektörel deformasyonu ve geri yaylanma kontrolüne bağlı olarak daha karmaşık süreçler ve daha pahalı yatırımlar gerektirmektedir. Aynı zamanda bu yöntem kullanıldığında konektör başı kalibrasyon zamanı da uzamaktadır. Sonuç olarak üreticiler iletkenlerin ataletini kullanarak dinamik deformasyon sağlayan yöntemler geliştirmeye başlamışlardır. Uygulanabilir bir yöntem olarak, teorik pim şeklini çevreleyen kısıtlı genlikli titreşimlerin çözüm olabileceği görülmüştür. Pimlerin etrafında teorik olarak belirlenen şekle kadar titreşen duvarlar pimleri düzeltmeye zorlayacaktır.

Aksan Kalıp ve YTU (Yıldız Teknik Üniversitesi) işbirliği ile kurgulanan projede de benzer bir pim düzeltme yöntemi geliştirme üzerine odaklanılmıştır. Bu amaçla üretimdeki mevcut konektörlerden biri seçilip üzerinde çalışmalar yapılmıştır. Üniversite işbirliğinde yürütülen çalışmalarda, sonlu elemanlar

https://doi.org/10.56038/oprd.v3i1.415

yöntemi ile konektör plastik gövdesi sabit tutularak pimlerin doğal frekans ve titreşim biçimleri belirlenmiş yapısal zayıflıkları üzerinden eğilmeye maruz kalabilecekleri doğrultular tespit edilmiştir. Doğal frekans ve harmoniklerinde uygulanan kısıtlı titreşimlerin etkisiyle pozisyon düzelmesi sağlandığı saptanmıştır. Titreşim hareketini pimlere vektörel uygulayan geometriler optimize edilmiştir. Hesaplamalı olarak tespit edilen frekanstaki titreşimi sağlamak için bir kam mekanizması tasarlamıştır.

Makalede projenin bu ilk aşamasında yürütülen tüm faaliyetler ve elde edilen sonuçlar çeşitli şekil ve grafiklerle ayrıntılarıyla sunulmuştur. Geliştirilen dinamik deformasyon tabanlı yöntemin başarılı sonuçlar vermesi üzerine çalışmalarda tespit edilen gerekli yüksek titreşim frekanslarının, yaygınlıkla kullanılan kam mekanizması ile sağlanmasının sağlıklı olmayacağı anlaşılmıştır. Bunun üzerine, projenin ikinci aşaması için istenen yüksek frekanslı titreşimleri üretebilen bir ultrasonik titreşim eyleyicisinin tasarımı ve imalatı planlanmıştır.

Anahtar Kelimeler: Pim, Pozisyonlama, Titreşim, Kalibrasyon

Orclever Proceedings of Research and Development
https://doi.org/10.56038/oprd.v3i1.415
OR CLEVER Science & Research Group

Calibration of Connector Pins via Dynamic Deformation

Abstract

The demand for increased reliability in automotive connector pin-end positions, which are press-fit to printed circuit boards, crucial for self-driving and driver assistance functionalities, has led to progressively tighter tolerance zones. Traditional manufacturing methods, such as cutting, bending and plastic injection, inherit limitations in achieving these tight tolerances. Connector suppliers have thus searched for innovative pin calibration methods, one of which involves correcting pins by means of permanent deformation. However, this approach exhibits challenges, including complicated processes and substantial investments due to vectorial deformation variations among different pin shapes and the necessity for spring-back control, leading to extended calibration times for individual connectors. In response to these challenges, manufacturers have explored methods utilizing the dynamic deformation properties of conductors exploiting the inertia of the components. As a viable method, it was found that vibrations with restricted amplitudes encompassing the theoretically determined pin shape could be the solution. In other words, walls around the pins vibrating up to the theoretically determined shape would force the pins to straighten.

The current project initiated as a collaboration between Aksan Kalıp and Yildiz Technical University (YTU), focuses on developing a similar pin correction method. To achieve this, one of the existing connectors in production was selected, and extensive studies were conducted. Through collaborative efforts with the university, the natural frequencies and mode shapes of the pins were determined with the finite element method by keeping the plastic body of the connector constant, and the directions in which they could be subjected to bending over their structural weaknesses were determined. It was found that position correction was achieved with the effect of limited vibrations applied at natural frequencies and harmonics. It was determined, using the finite element method, that by applying limited vibrations at the natural frequency harmonics of the pins while keeping the connector's plastic body fixed, position correction could be achieved. Geometries optimizing the vectoral vibration motion applied to the pins were subsequently identified, and a cam mechanism was designed to facilitate controlled vibration.

The first phase of the project, including all activities and results, has been presented in detail with various figures and graphs. Following the promising outcomes of the dynamic deformation-based method, it was concluded that achieving the required high vibration frequencies, as identified in the study, through the commonly used cam mechanism might not be optimal. Consequently, the design and manufacturing of an ultrasonic vibration actuator, capable of producing required vibrations with high frequencies, are also planned for the second phase of the project.

Keywords: Pins, Positioning, Vibration, Calibration

https://doi.org/10.56038/oprd.v3i1.415

1. Introduction

One of the production methods of connectors used in automotive industry is based on trimming and bending pins from pre-cut band shape and injecting plastic on them via over mould. There are also mechanical and ultrasonic guided insertion of pins on pre molded plastic [1,2]. In case of over mould process, tolerances of tip locations such as the ones shown in Figure 1 are hard to obtain. The difficulties in assembly processes are needed to be solved by precise positioning via robot [3] or by tighter tolerances on metal strips of terminals. These tolerances are needed to ensure an effective electrical conductivity to the respective circuit bord (PCB) when assembled as in Figure 2. This assembly process has been widely studied among automotive industry [4,5].

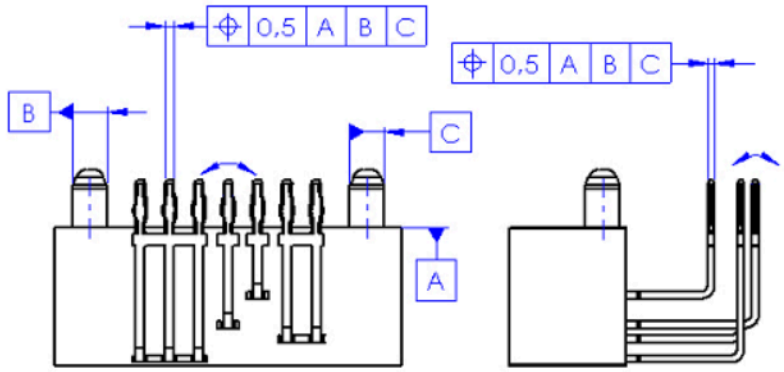


Figure 1. View of a typical connector pins

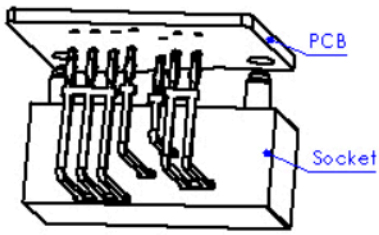


Figure 2. An assembled connector

In order to achieve tight tolerances, pin tips must be moved to the desired tolerance zone by plastically deforming them in two directions shown with curved arrows in Figure 1. Holding the pins one by one and introducing controlled movements followed by position measurements after spring back, is a very cumbersome process. There are a couple of issues with the current approach that need addressing. First, the spaces between the pins are too narrow, making it challenging to introduce individual hold jaws. Second, the measure-move-measure process takes too much time, resulting in a slow production rate of 100 pin connectors and 2500 pieces per day. To address these problems, a novel solution is proposed. Instead of moving each pin individually, all the pins must be exposed to deformation simultaneously for a more efficient and faster production process. In this case, even the correctly sized pins within the tolerance zone undergo unnecessary plastic deformation, leading to strain hardening. Additionally, uncertainties arise in terms of the movement amplitude, end time, and position of the deformation process for all pins, stemming from variations in pin deviations from the nominal and spring-back. These factors collectively contribute to the consideration of a repetitive dynamic deformation process.

https://doi.org/10.56038/oprd.v3i1.415

2. Bounded Vibration Movement

The dynamic deformation process relies on a vibrating guide part encircling the pin tips, moving in the direction indicated in Figure 3 for correction. Such vibratory motion is also utilized in improving mechanical properties of materials [6]. The guide moves until the onset of nominal pin plastic deformation. The advantage is, the vibrating guide does not induce strain hardening on already correctly shaped pins. However, for pins deviating from the nominal shape, the movement extends beyond the plastic deformation boundary towards the nominal shape. The female cavity of the vibrating guide must be so designed that the most deviated pin from its theoretical shape be corrected.

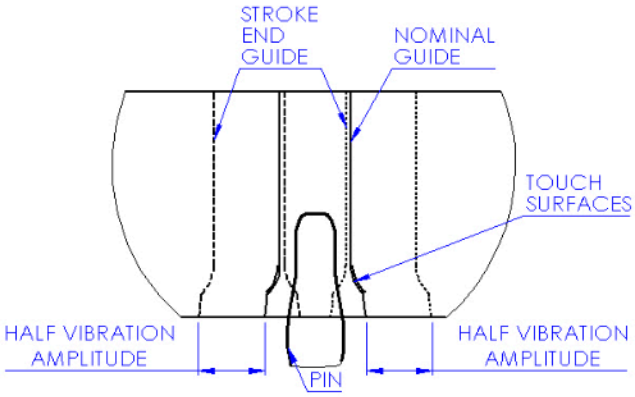


Figure 3: Female cavity guide for pin vibration

Vibration guide female cavity must touch with the pin surfaces that are not used in PCB electrical contact. With that constraint touch surfaces of guide cavity are optimized via finite element analyses.

2.1. Modelling

Pins have different structures as single, double and triple. Mechanical properties of different geometries have already been studied [7]. Their geometrical dimensions are given in Figure 4.

https://doi.org/10.56038/oprd.v3i1.415

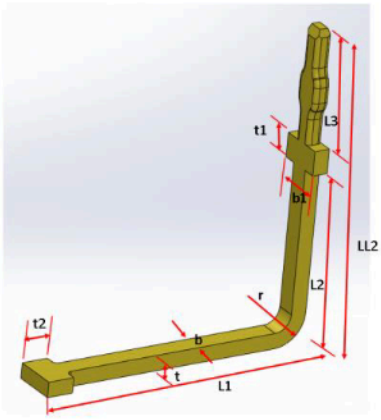
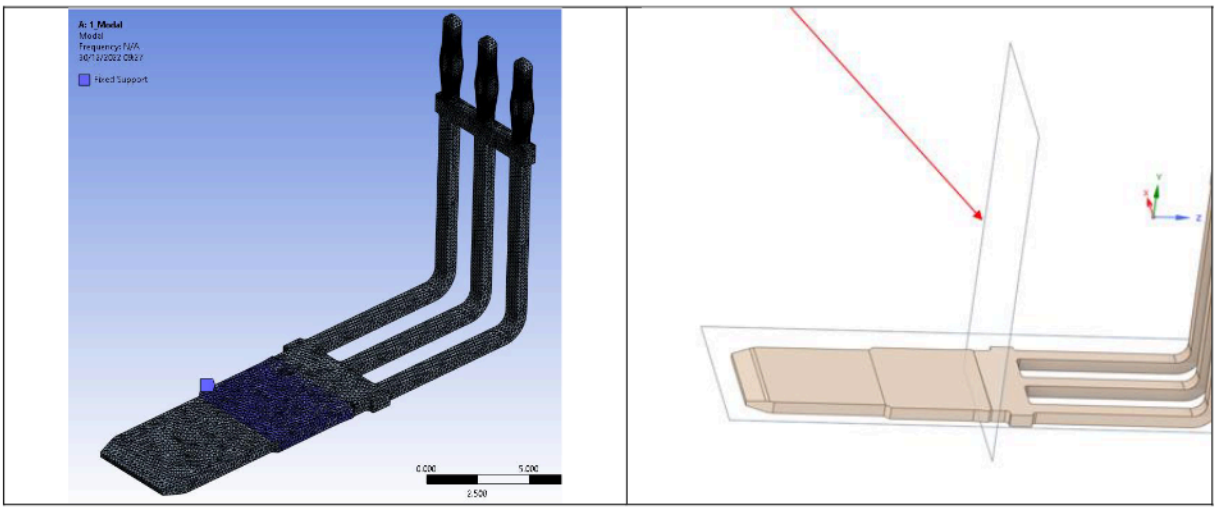
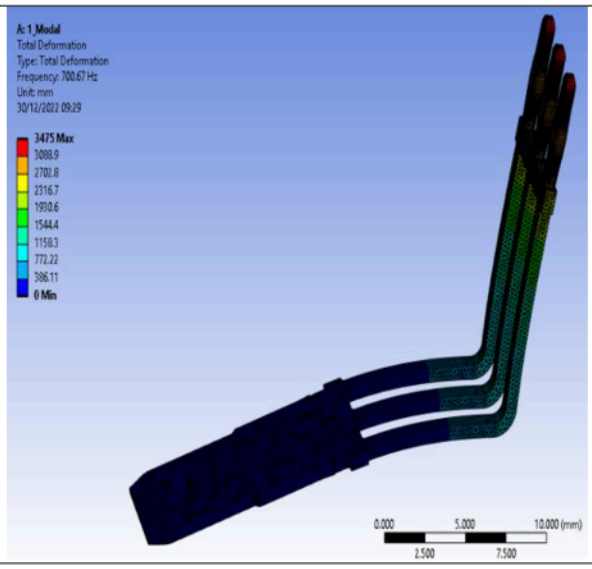


Figure 4: Pin parameters for single structure

The pins are grouped based on their location inside the connector and all types have been examined in order to obtain a common solution.
The analyses were carried out in two ways; by fixing the pin structures from the portion inside the plastic and by fixing them from the portion outside the plastic as the part is connected to the plastic. Since the differences were around 0.7%, the analyses were performed by cutting the pins from the front face of the plastic part.



https://doi.org/10.56038/oprd.v3i1.415



a) Pin full model | b) Pin half model

Figure 5: Models for pin analysis

The first two natural frequency values for each different pin model are given in the table below.

Table 1: First two natural frequencies for every pin structure type

Pin	Structure Type	f1 [Hz]	f2 [Hz]
8 Top	1	2905.6	3066
10 Top	1	2905.6	3065.5
3 Top	1	3045	3281.6
6 Top	1	3044.3	3280.6
2 Top	1	1532.1	1621.6
3 Mid	1	1532.1	1621.1
6 Mid	1	1531.8	1620.3
3 Bottom	1	817.82	845.49
6 Bottom	1	817.74	845.08
2 Bottom	1	830.43	890.87
7 Top	2	2989.2	4154
9 Top	2	2989.2	4154
4 Top	2	3147.8	4155.9
5 Top	2	3147.8	4155.8
4 Bottom	2	827.9	926.53

https://doi.org/10.56038/oprd.v3i1.415

5 Bottom	2	827.9	926.18
7 Bottom	2	827.91	926.21
9 Bottom	2	827.95	926.26
1 Top	3	3442.7	4944
1 Bottom	3	705.43	844.47

In conclusion, when the effect of natural frequency values and mode shapes on structure weakness is evaluated in terms of size;

- The reduction of LL2 (therefore L2) is more effective in increasing the frequency even if L1 increases.
- The package of the pins increases the structural rigidity. In particular, it can lead to a reduction in-plane movement or bending.

2.2. The Correction Process

Since analyses will be performed according to the deformed pin, static analysis was performed and the deformed structure was obtained. The shape of this deformed structure was transferred to the modal analysis part of the project and a prestressed modal analysis was performed. From this point of view, it is possible to restore the bent structure and drive the system at its natural frequencies or subharmonics with the help of a guide.

In the pin correction process, the structure of the guide is particularly important in terms of the tolerance up to which deformed pins can be corrected. In the design studies for the guide structure, it was predicted that the inner surface of the guide should be convex, and the width of the surface on which the shoulder part sits should be the sum of the pin width and tolerance. In addition, it was thought that having an open top would provide ease of application for different sizes.

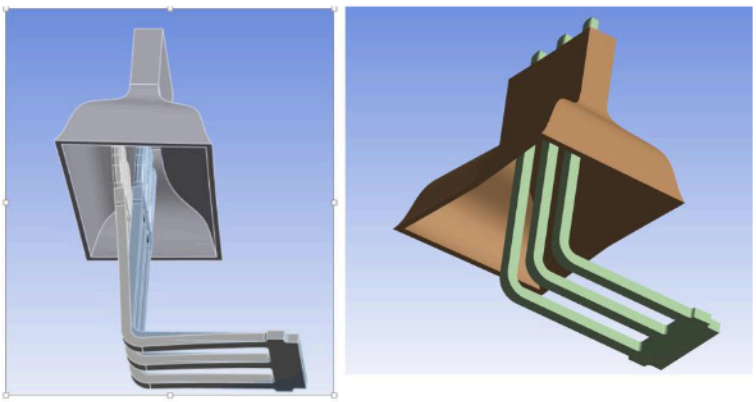


Figure 6: Pin guide design

2.3. The Excitation Process

https://doi.org/10.56038/oprd.v3i1.415

The drive part was performed in the Workbench Ls-Dyna program. The movement consists of two parts.
In the first part, it is aimed to take the guide into the tilted pin, and in the second part, it is aimed to perform the correction process by changing the amplitude and frequency. Although it was predicted that the excitation process would be done from the guide part or the lower part of the pin, as a result of the analyses, it was deemed appropriate to give it from the lower part as shown in Figure 7.

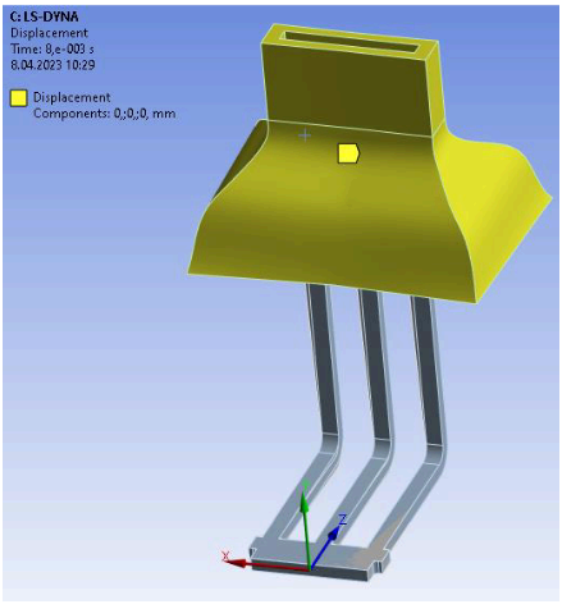
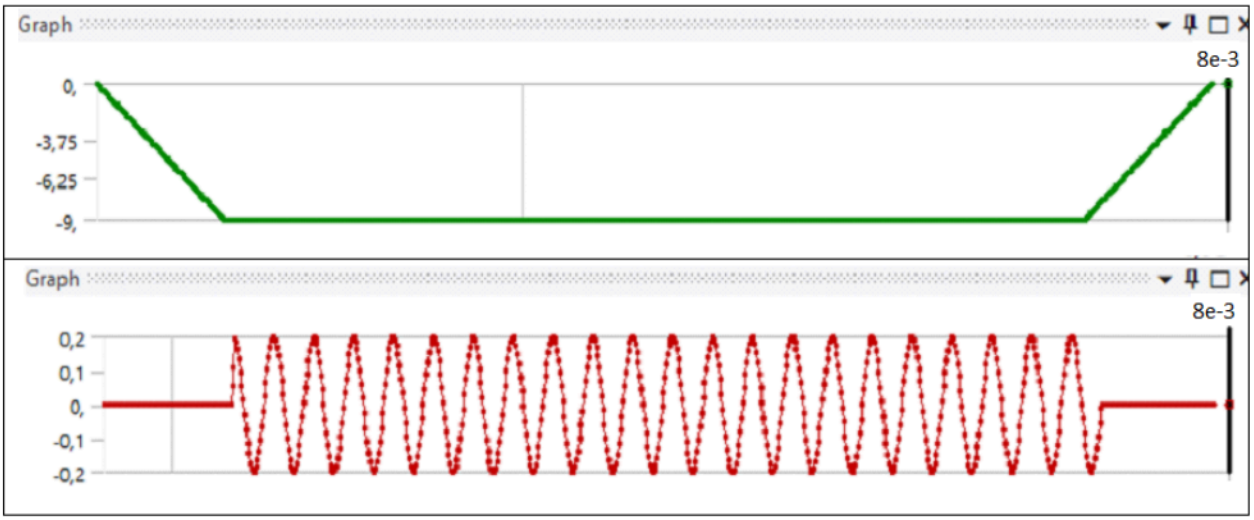


Figure 7: Shaking structure and point for excitation

The actuation frequency and amplitude, depicted in Figure 8, are produced as Excel functions and they are introduced to LsDyna as displacement-time values.



https://doi.org/10.56038/oprd.v3i1.415

Figure 8: Displacement-time graphs

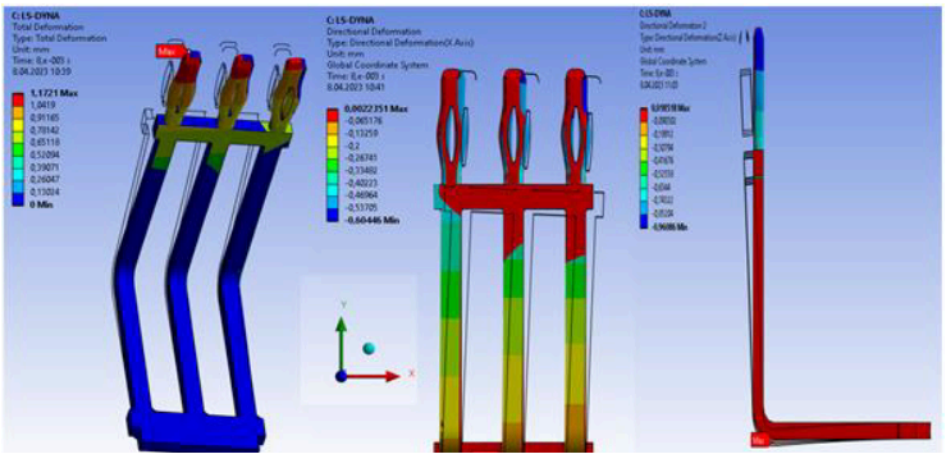


Figure 9: Displacement demonstration after analysis of excitation on the pins

In Figure 9, as a result of 2525 Hz frequency 0,2 mm amplitude vibration plastic deformations can be monitored. In X-direction 0,6553 mm misalignment is calibrated to 0,0509 mm. In Z-direction 0,92602 mm misalignment is calibrated to -0,034 mm.

3. Calibration Machine Construction

The rotational motion generated by the actuation motor needs to be transformed into a reciprocating movement of the guide, which, in turn, conveys motion to the pins. Conventional motors exhibit torque versus rotational speed characteristics, meaning their speed fluctuates as the applied torque on the shaft varies. If a flywheel is introduced, ramp up of machine elapses much of the cycle time of production. Servo speed-controlled motors can be used. As long as the torque applied on them remains certain limit, their rotational speed is constant. A cam mechanism with cycloid profile which gives finite acceleration and jerk at motion ends. Cam mechanism also provides flexibility on vibration amplitude by only changing the cam. Figure 10 illustrates the construction of calibration machine. Low friction slide tables are also introduced to lower the torque on motor. For calibration of pins along transverse direction another machine that reciprocates respectively is required.

https://doi.org/10.56038/oprd.v3i1.415

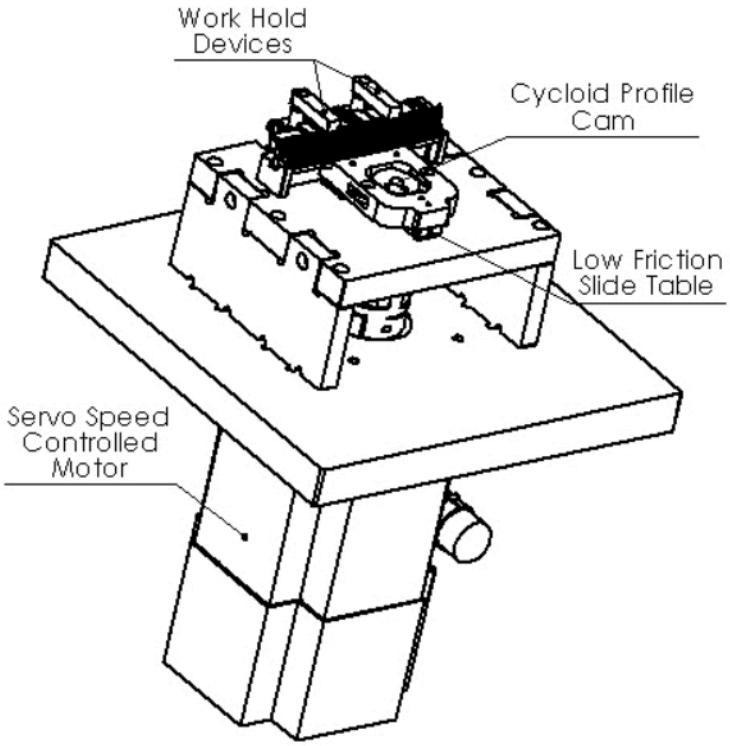


Figure 10: Construction of calibration machine

The graph in Figure 11 shows the torque variation due to inertia, during single reciprocate guide motion that corresponds to 360° motor shaft rotation.

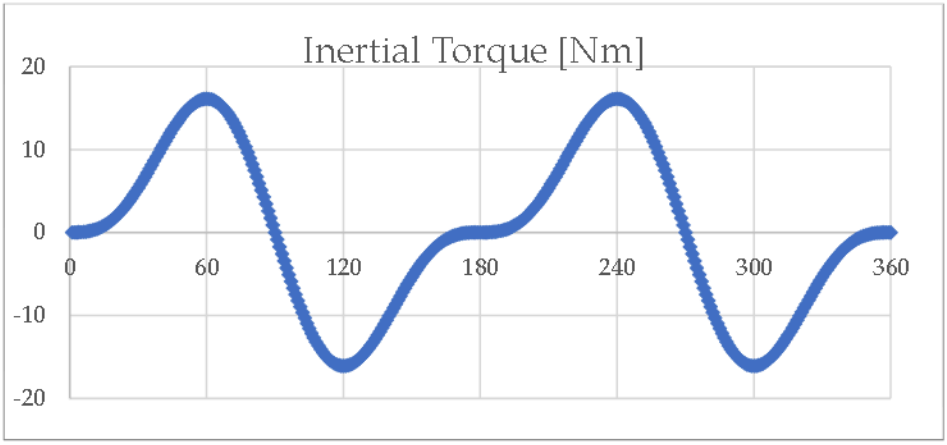


Figure 11: The inertial torque vs. time plot during one full motor shaft rotation.

Since rated motor torque 24 Nm is larger than peak due to inertia variation which is 16 Nm, calibration machine can run up to 100 Hz constant.

https://doi.org/10.56038/oprd.v3i1.415

4. Conclusions

Calibrating socket pins through dynamic deformation proves to be an efficient process. The cam mechanism, while cost-effective and inducing minimal inertial torque variation, falls insufficient when it comes to handling high frequencies, primarily due to its substantial inertia. Conducting the machine's frequency and amplitude assessments is necessary. Among them, the limitations of the cam mechanism in handling high frequencies should be evaluated. The impact of increased frequency on the dynamic deformation process should be examined. Potential issues such as accuracy and precision degradation as the frequency rises should be investigated. Amplitude related issues that should be taken into consideration can be analyzing the relationship between amplitude and the effectiveness of dynamic deformation, exploring how varying amplitudes might influence the calibration quality, and discussing the balance between amplitude and frequency for optimal calibration performance. Methodological a technological alternatives in parallel with the state-of-the-art should be considered. Process optimization and also calibration precision are other issues that need further assessment.

5. Future Work

In order to enhance the calibration process, replacing the motor and cam mechanism with an ultrasonic vibration actuator will be considered. The impact of high frequencies on pin calibration will be explored through this alternative approach.

6. References

[1]. N. J. Cook, G. F. Smith and S. J. Maggs, "A Novel Multipin Positioning System for the Generation of High-Resolution 3-D Profiles by Pin-Arrays," in IEEE Transactions on Automation Science and Engineering, vol. 5, no. 2, pp. 216-222, April 2008.

[2]. Shaohua Fei, Weiwei Wang, Huiming Ding, Haijin Wang, Jiangxiong Li, Yinglin Ke, “Strengthening of composite T-joints using Ø 0.11 mm Z-pins via an ultrasound-guided insertion process”, Compos. Sci. Technol, 213 (2021), Article 108906

[3]. HuL.S. et al. “An Investigation of the Insertability of Connectors in Printed Circuit Boards”, 1987, Annals of the CIRP

[4]. L. S. Hu and P. Dewhurst “An Investigation of the Insertability of Connectors in Printed Circuit Boards” Cirp Annals Volume 36, Issue 1, 1987, Pages 9-12

[5]. X. Jin, X. Ye and Z. -j. Zhang, "Positioning Accuracy Calculation Method of Plane Multi-pin Based on Statistic Characteristics", 2007 International Conference on Mechatronics and Automation, Harbin, China, 2007, pp. 3046-3050.

[6]. M. Ezequiel, I.A. Figueroa, S. Elizalde, J.M. Cabrera, C. Braham, L. Morin, G. Gonzalez, “Numerical and experimental study of a 5754-aluminum alloy processed by

https://doi.org/10.56038/oprd.v3i1.415

heterogeneous repetitive corrugation and straightening",2020, J. Mater. Res. Technol., Volume 9, Issue 2, pp. 1941-1947.

[7]. Antonio Strozzi, Matteo Giacopini, Enrico Bertocchi, Sara Mantovani, Andrea Baldini, "Towards an analytical model of a pin-lug connection", International Journal of Solids and Structures, Volume 253, 2022, 111446, ISSN 0020-7683