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Design of Slip Horizontal Table System for Shaker

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Abstract

Shakers can produce vibration functions at the desired frequencies and amplitudes according to the vibration standards. Also, shakers have the same working principle with devices of hydraulic, mechanical pneumatic, electromagnetic etc. Shakers can produce vibration in the vertical and horizontal direction depending on the type of table. The test sample is fixed on the table with fixture. In this study, the appropriate slip table was designed and manufactured in order to improve test capability of shaker. Therefore shaker had the capability of vibration drive in the horizontal directions for test sample. Finite element method (FEM), modal analysis, harmonic analysis and vibration measurements were applied to assess vibration analysis. After, results of FEM and confirmation experimental were in a good agreement with each other, the design of vibration shaker table system was manufactured.

Keywords: shaker, slip table, modal test, vibration analysis

1. INTRODUCTION

The products using in the different industrial area have been tested to verification design and to achieve vibration standard depend on the international tests standard. The most important and most common of these test have been vibration test. Vibration test has been used under the actual operating conditions to determine weakness of the design and the structural strength [1,2].

The strength of the products and load that can be applied on the products were determined depend on the test standard [3,4] or data that can be gathered under the actual operating conditions. All experiments were carried out under the test standard [5,6] with using data acquisition-processing equipment, control equipment, accelerometers, load meters, shakers, and the heating cabin.

The shaker used in this study, could only be used for limited studies in the vertical direction. This shaker cannot fully answer to the vibration test in the academic word, TSE [8] and international standard. For this reason, as shown in Fig. 1 horizontal table was redesigned and reproduced depending on the literature [9,10] to make two-axis motion and obtain desired vibration tests. In addition, literatures about the plate vibration [11] were analytically investigated. As a result, an original design was created.

Figure 1. Electrodynamic shaker, direction changing system and slip table system [12]

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The designed slip table will also be exposed to vibration. Therefore, the natural frequencies of the table need to be determined. If the system was driven at these frequencies, the test results can be adversely affected. Thus, the design of vibration test fixtures was very important issue [13]. Before the test, products were connected to the vibration table. All test must be applied towards the international standards. The connection must be applied according to the actual operating condition, when the products were connected to the vibration table.

In this study, the appropriate slip table was designed and manufactured for shakers in order to increase shaker's test capability of horizontal direction. The production of the magnesium alloy slip plates with the technical drawings was carried out by special casting method at VIG Metals Inc. facilities in Kütahya. VIG Metals Inc., which produces the first and only magnesium alloy in Turkey, which can handle the business in-house, is an expert and experienced company. The manufactured table assembled to the shaker and vibration tests were carried out. The experimental results shown that the desired material strength properties and vibration parameters were in a good agreement with each other. In addition, this study shown a way about design and production of the shaker slip table.

2. HORIZONTAL SLIP TABLE DESIGN

The most important criterion in the design of the horizontal table is the technical properties of the shaker. Some of these features are; the size, shape, weight, maximum shake capacity and motion direction of the device. The design of the table was made in accordance with shakers that shown in Fig. 2. The technical properties of shaker was given in Table 1.

Figure 2. LDS V450V electromagnetic shaker with 311 N sinus load capacity

Table 1. LDS V450 / 1 Shaker Performance Parameters and Characteristic

Standard LDS Amplifier	PA500L
Sine Force (Peak) – Forced Air Cooled	311 N
Armature Resonance (f_n)	6 kHz
Useful Frequency Range	5 Hz – 7.5 kHz
Effective Mass Of Moving Element	0.426 kg
Velocity (Sine Peak)	1.78 m/s
Maximum Acceleration (Sine Peak) Naturally Cooled	74.5 g
Displacement (pk-pk) - Continuous	19 mm
Shaker Body Mass - Base Mounted	64 kg
Shaker Mody Mass – Trunnion Mounted	82 kg
Cooling Air Flow	0.012 m^3/s
Armature Diameter	63.5mm
Maximum Weight	82 kg
Maximum Dimensions (H x W x D)	395.4x 300.5x 375 mm

Vibration tables working principle can be in hydraulic, pneumatic, mechanical types according to the operating conditions [14]. The working principle of the hydraulic type can be described that the sliding table moves on the hopper filled with hydraulic fluid. For the pneumatic type has similar working principle with hydraulic. However, in this mechanism, the table movement is provided by air pressure instead of a fluid. The table with mechanical design can be in different forms such as rotating bearing, linear bearing, T-bed, V-bed, etc. According to the investigations, mechanical type of the sliding table with bearing are more cost efficient than other types.

The test can take a long time in shaker. Because of the long operation time, slip table materials must have good fatigue life and strength-weight ratio. The slip table materials can be magnesium alloy, aluminum alloy, stainless steel or coated metal. Magnesium alloys are more preferred for shakers in terms of lightness. For this reason, the shaker was produced by using magnesium alloy. Oil-filled cestamid with linear bearing was used for bearing slip table.

2.1. Design of Geometric Solid Model

Magnesium table was desired to be small size. Magnesium table was designed and calculated to test for small piece sample which was maximum 200 Newtons weight. The working system was given in the Fig. 3.

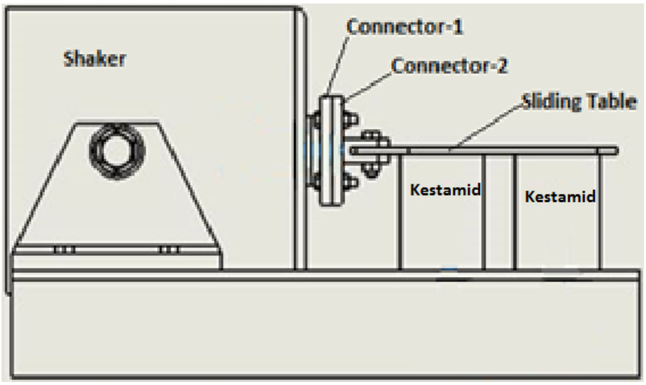

Figure 3. Schematic representation of the shaker system

Shaker solid model was generated based on the shaker actual dimension. For connection of the slip table with the connector-2 piece as shown in Fig. 4, 3 holes with 10 mm diameter were drilled and 3 pieces M10 bolts were used. The test sample assembled on the slip table with M6 bolts. As can be shown in Fig. 5 to increase the fatigue life of the design, we avoided from sharp edges that caused stress accumulation.

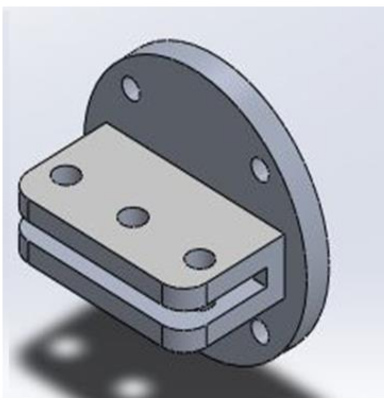

Figure 4. Connector-2 part

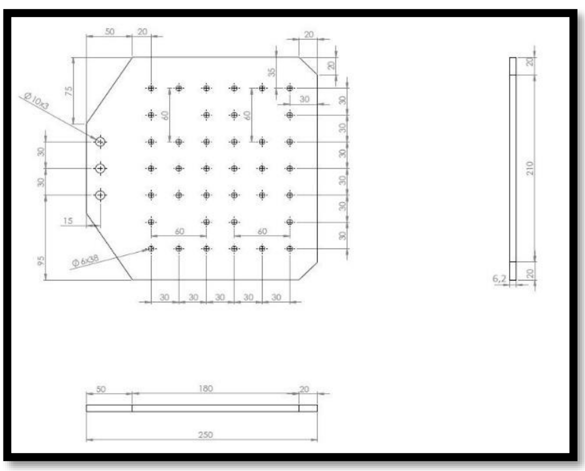

Figure 5. Technical drawing of horizontal table

As can be observed in Fig. 6, chassis components were designed to carry the entire system on which mounted shakers and other parts of the system. The chassis was produced based on system weights, easy assemble, and strength-weight ratio. At the same time, the design of the system allowed to be used vertically direction without disassembling.

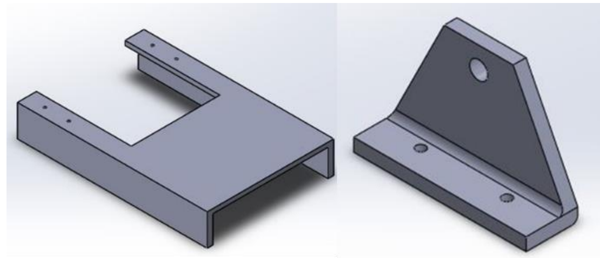

Figure 6. Chassis-shaker holder design

The most important criterion in the design of the ear was able to carry 82 kg and can easily switch from vertical to horizontal direction. The reason of the ear design was joined by the mechanics instead of welding was allowed to disassemble when ear used different chassis. Finally, minimum materials was used to avoid weight and cost.

The following steps have been taken into consideration in designing the connector-2 part,: 1) the behind side of the connector-2 be able to screwed together on the 100 mm diameter side of the connector-1 piece as mentioned in the previous step and as seen in Fig. 7, 2) the other side of connector-2 be able to hold slip table rigidly, 3) it can be able to transfer the force and various vibrational frequencies from the shaker to the table without resonance.

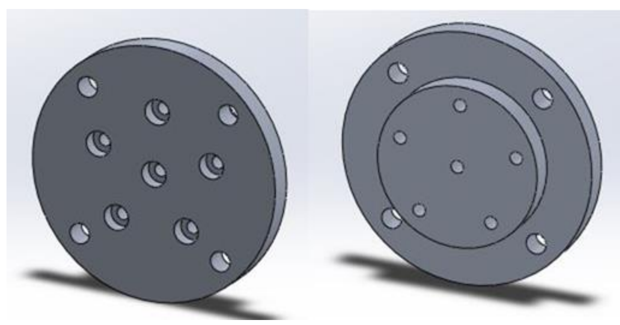

Figure 7. Connector-1 part

Connector-1 part was designed using a solid model design program to undertake the task of connection between a 100 mm diameter side of the connector-2 part and a 64 mm diameter side of the shaker. Cestamid parts were used to support from the bottom of the slip table. In order to minimize the friction, 0.6 mm depth and 40 mm length channels are manufactured on the upper surface of the 43x80x112 mm sized cestamid pieces. Machine oil and bearing balls were placed in the channels to reduce friction. Afterwards, all parts were assembled as seen in Figure 8.

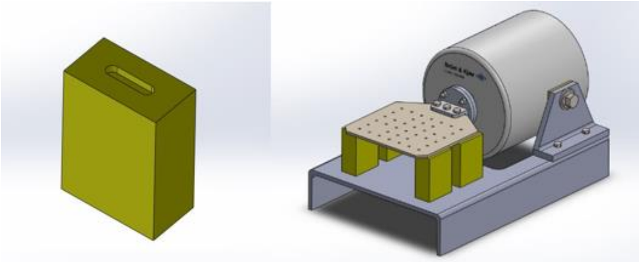

Figure 8. Cestamid oil reservoir and system assembly

3. STRUCTURAL AND VIBRATION ANALYSIS OF PLATES

3.1. Operating Parameters

The maximum load was applied by the shakers to the sliding table was up to 300 Newton. This force was applied as distributed load, from the side to which the shaker was connected to the table. Therefore, the force is defined as distributed load during vibration analyzing. The solid model of the sliding table was generated and then transferred to the ANYSN [16] for vibration analysis.

3.2. Static Analysis

As can be seen Fig. 9, the horizontal table was meshed according to the surface features.

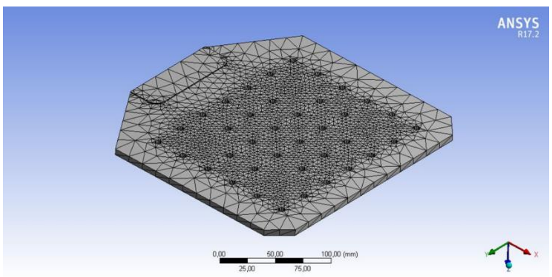

Figure 9. Finite element model of slip table

In the static analysis, the table was modeled as a console and the deformations from the weight of the table were investigated. The horizontal table with static analysis is shown in Figure 10. The fact that the maximum deformation is too small suggests that the tables are sufficiently rigid.

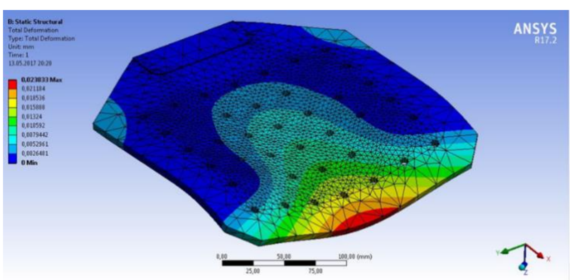

Figure 10. Results of static analysis of slip table

3.3. Modal Analysis

In this study, the modal characteristic of the slip table model was investigated. As a result of analysis 10 natural frequencies were obtained. This natural frequency corresponding to the 10 mode shapes were examined. The results belong to the sliding table can be seen in Table 2.

Table 2. Modal analysis results of slip table

Mode Shape	Natural Frequency (Hz)	Normalized Deformation
1	353	1
2	618	0,96
3	798	0,9
4	**820**	**1,1**
5	1066	1,46
6	1142	0,997
7	1151	1,11
8	1186	0,699
9	1496	0,83
10		

As can be seen in Fig. 11,12,13 and 14, the first 4 mode shapes of the slip table was obtained during the working conditions.

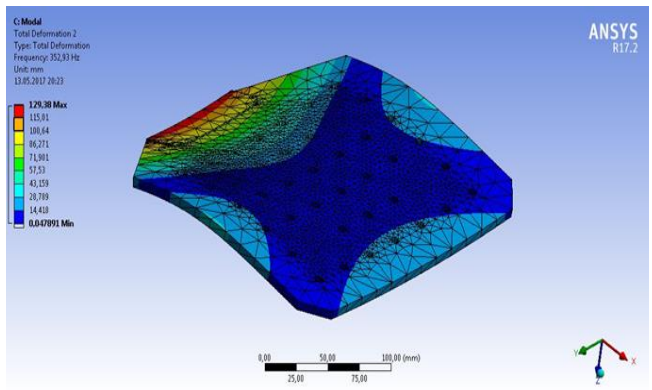

Figure 11. 1st mode shape of slip table

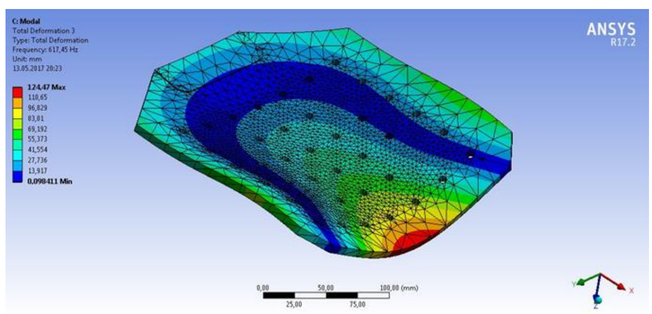

Figure 12. 2nd mode shape of slip table

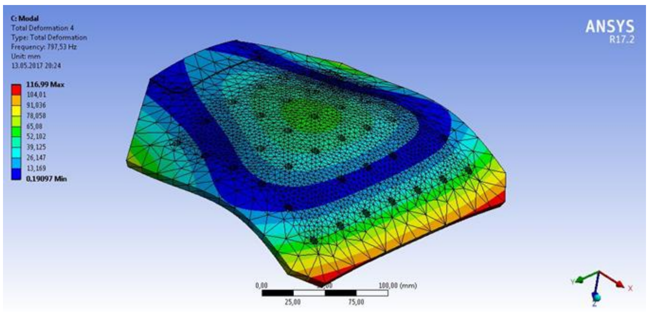

Figure 13. 3rd mode shape of slip table

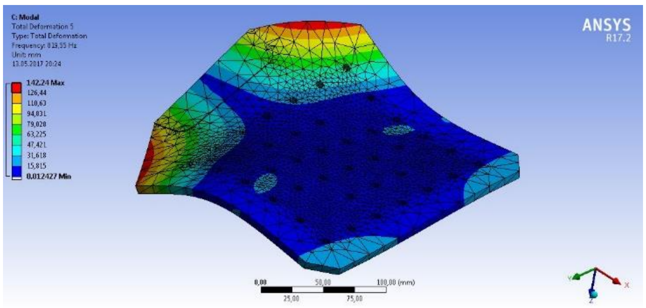

Figure 14. 4th mode shape of slip table

Based on the modal analysis, the results were in a close to each other for sliding table which was made of magnesium even if maximum deformation was applied on the sliding table.

3.4. Harmonic Response Analysis

The results of amplitudes corresponding to the natural frequencies, which was generated by using harmonic drive, were observed. One of the ten model was obtained during the actual operating condition. It was the main mode shape. As can be seen in Fig. 15, the main mode frequency was 820 Hz represented at the fourth mode.

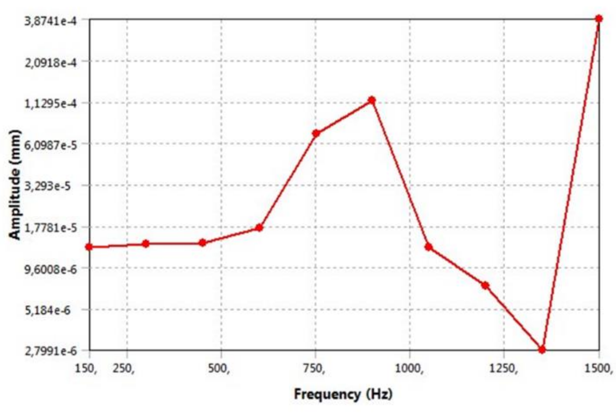

Figure 15. The amplitude-frequency curve obtained in the harmonic analysis for the slip table

4. EXPERIMENTAL STUDIES

To obtain vibration measurements manufactured parts were assembled as shown in Fig. 16.

Figure 16. Assembly of slip table, connection parts shakers

The measurement plan was prepared as shown in Figure 17 to obtain the vibration measurements from the slip table.

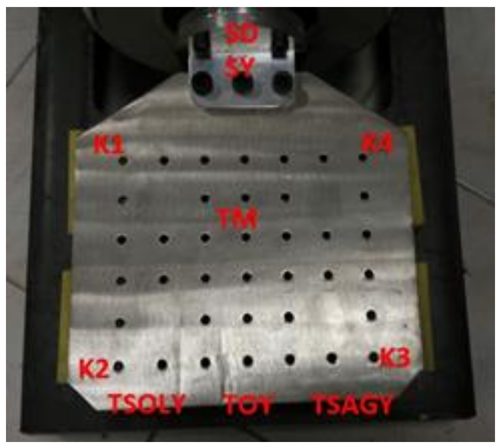

Figure 17. Vibration measurement points of slip table

SD: Vertical axis acceleration measurement point of shaker,

SY: Horizontal axis acceleration measurement point of shaker

TM: Vertical axis acceleration measurement point of table center

K1;K2;K3;K4: Vertical axis acceleration measurements points of the corner points of the slip table.

TSOLY: Horizontal axis acceleration measurements point of the farthest left corner point of the slip table.

TOY: Horizontal axis acceleration measurements point of the farthest middle point of the slip table.

TSAGY: Horizontal axis acceleration measurements point of the farthest right corner point of the slip table.

It was determined that the measurements taken by the harmonic test were in agreement with the modal analysis. The 4th mode corresponds to the high frequency (820 Hz). However, it is measured that the vibration peak values are very low due to the rigidity of the slip tables. So even operating the shaker at 820 Hz is not a risk. However, the stable working frequency of the slip tables is already 50 Hz. The vibration measurements taken at 50 Hz from slip table, are given in Figure 18, Figure 19, Figure 20 and Figure 21.

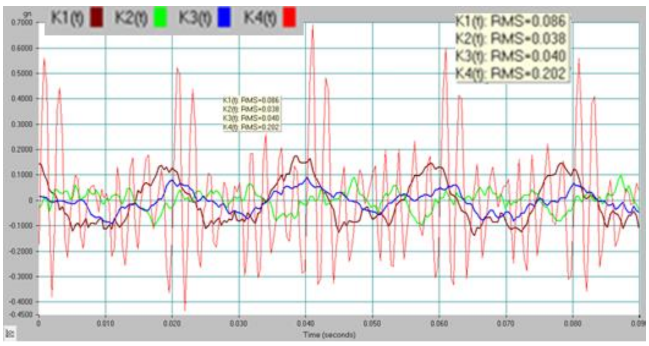

Figure 18. Vertical acceleration measurements (K1, K2, K3, K4 points) of the corner points of the slip table

The RMS values of the points K1, K2 and K3 in the vertical direction are 0.086, 0.038, 0.040 and 0.202, respectively. As shown in Fig. 18, the RMS value of the point K4 is higher than the other three points. When the reason is investigated, it has been found that K1, K2, K3 points are processed in the same thickness during manufacturing and the thickness of K4 point is thicker than the other three points. An error occurs because the thickness of the table is not uniform. After measurements, the plate thickness is uniformed.

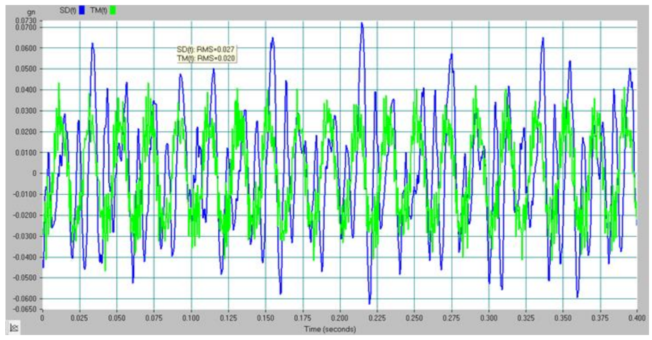

Figure 19. Vertical acceleration measurements of the shaker and slip table center (SD and TM points)

The RMS values taken from points SD and TM are 0.027 and 0.020, respectively, as shown in Figure 19. The acceleration values measured in the horizontal direction are exactly the same. Thus, it can be seen that the force generated from the shaker can be transmitted to the end point of the table without any interruption as shown in Figure 20. The RMS measurements taken from the TOY and SY points are 2,031 and 2,033, respectively as shown in Figure 20.

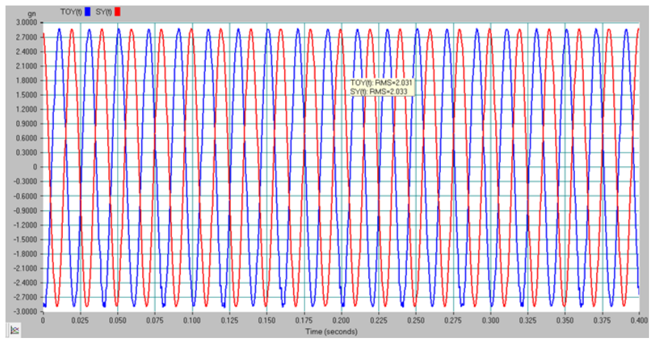

Figure 20. Acceleration measurements in the horizontal direction (TOY and SY points) of shaker and slip table end, center and edge point,

As a result of the measurements taken from the end point of the table at the horizontal axis, the same results were obtained at the three points of the slip table and the results showed the slip table have the same stiffness at every point in the axial direction as seen in Fig. 21. The RMS measurements taken at the TOY, TSAGY and TSOLY points, are 2.031, 2.014 and 2.050, respectively as shown in Fig. 21.

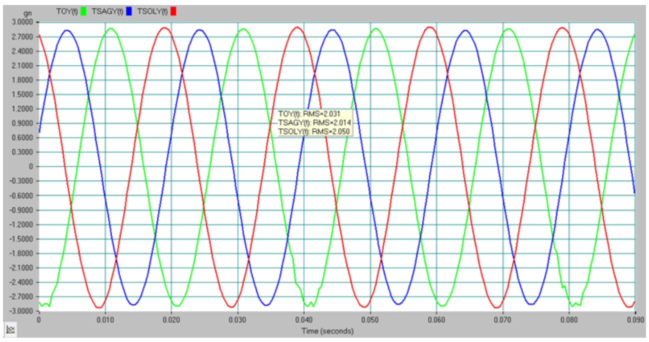

Figure 21. Acceleration measurements in the horizontal direction (TOY, TSAGY, TSOLY points) of the slip table right, left and center points

5. CONCLUSIONS

In this study, a slip table was designed to allow horizontal axial vibration test. Modal and harmonic analyses of the system were carried out using various analysis programs. As a result of the analyses, AZ91D magnesium alloys were found suitable for slip table material in terms of rigidity and lightness. Machining operations such as surface finishing, chamfering, hole drilling, etc. of the casting tables were carried out at VIG Metals Inc. Gebze facilities. According to the acceleration and displacement values obtained as a result of the vibration tests carried out, it has been found that the rigidity of the table and the natural frequencies are suitable for vibration tests.

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