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Determination of Natural Frequency Values In Bending Sheet Metals Using Finite Element Method

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Abstract:- The materials commonly used in industry today are steels and aluminum. In this study, using 6112 DKP steel sheet material and 1050 H14 aluminum sheet material, the effect of variable parameters on the natural frequency of the sheets subjected to the press brake production process was comparatively examined with the finite element method. Variable parameters for twisted sheet metal; It is determined as material, sheet thickness, bending length, bending width, bending angle and bending radius. Models with variable parameters were designed in 3D with Solidworks. These models were determined by using Ansys software using the finite element method and the effects of variable parameters on natural frequencies were determined and examined comparatively with the help of graphics. It has been determined that 1050 H14 aluminum sheet materials will resonate at higher frequencies when the model is designed with the same bending parameters.

***Keywords;-** 6112 DKP Sheet, 1050 H14 Sheet, Modal Analysis, Natural Frequency, Twist Parameters.*

I. INTRODUCTION

Today, aluminum and sheet steel materials are used in the automotive, aviation, defense industry, construction, transportation, electrical and electronics, machinery and equipment sectors, metal industry, chemical and food industry, various household goods and kitchenware, furniture and decoration products, tools and hand tools. These are materials widely used in the industry. The most commonly used materials are aluminum and steel; 1050 H14 for aluminum sheet and DKP for steel sheet are steel sheet materials [1, 2, 3]. After these sheets are produced by various methods, they can be shaped by the press brake bending process [4]. The forms of sheets shaped by the press brake bending process are; It depends on the variable factors in the twisting process. These factors; It is known as material type, sheet thickness, bending length, bending width, bending angle and bending radius. The most important features expected from sheets shaped according to variable factor values are high strength and lifetime [5]. Resonance is one of the most important parameters that must be taken into consideration in order to meet the expected properties of the designed and twisted sheet metal. These are the variable parameters that affect resonance the most for twisted sheets. Since the change of these parameters affects the resonance, that is, the natural frequency, the desired material stiffness must be ensured at the design stage [6]. Determining natural frequencies before production is important in terms of both time and cost. The finite element method is a widely used method today for the determination of natural frequencies [2, 7, 8]. Since the designed models can be analyzed in a computer environment using the finite element method and data very close to the real values are obtained, data about the resonance state of the material can be obtained before moving on to the prototype stage. When various studies conducted by researchers on this subject are examined, it is seen that the most researched topics are natural frequencies and resonance. In their study, Yılmaz et al. (2020) compared the finite element method and experimental analysis of a beam made of L-type St37 steel material. They used Solidworks Simulation and Ansys programs for the finite element method. It has been observed that there is a deviation of 1.39% to 4.35% between the natural frequencies obtained by the finite element method and the natural frequency values obtained experimentally [9]. In his study by Şentürk (2004), the vehicle body was modeled and its natural frequencies were found using the experimental and finite element method. However, since the spot welds or detail parts on the vehicle body could not be modeled exactly during vehicle modeling, the accuracy of the data could not be fully determined. A difference of 5-10% was found between the natural frequencies determined by experimental study and finite elements [10].

In the study conducted by Şekerci (2013), the arms holding the helicopter propellers were modeled in 3D. Mode shapes and natural frequencies were obtained in Ansys program using the finite element method. The same study examined experimentally the condition of a built-in support at the root of the arms holding the propellers. When experimental and theoretical data were compared, it was observed that the differences between the results were very small, and it was revealed that the finite element method could also be used in the aviation industry [11].

In this study, using 6112 DKP steel sheet material and 1050 H14 aluminum sheet material, the effect of variable parameters formed in sheets shaped by the press brake production process on the natural frequency was examined comparatively with the finite element method.

II. MATERIALS AND METHODS

Today, with the developing industry, mold making works have progressed and developed considerably. Production with press brake bending is carried out using various molds. Bending is the process of shaping sheet metal plastically by using bending stresses around the neutral axis. The neutral axis is where compressive stresses occur on the inner surface, where the stresses occurring during plastic shaping are zero, and tensile stresses occur on the outer surface. Figure 1 shows the stresses occurring on a twisted sheet metal.

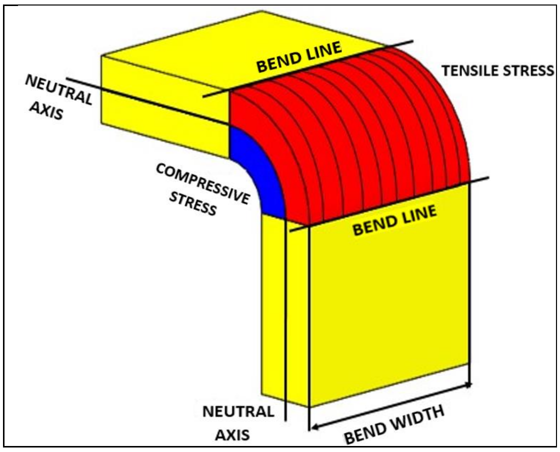

Fig. 1 Stresses on twisted sheet metal

Variable factors, molds and machine features play a major role in the bending operations performed on press brake machines. In addition, there are two more important criteria for the part designed to be manufactured by the twisting process. These criteria are the k factor determined during design for a correct bending process and the springback caused by the stresses in the material as a result of plastic deformation.

➢ *Springback*

The bending process takes place by applying a certain amount of force to the sheet material between the upper mold and the lower mold, as shown in Figure 2 below. After the bending process is completed, the force is removed from the sheet material and the sheet material stretches, albeit at a low rate. This stretching causes changes in the designed sheet material dimensions, and this situation is called springback for sheet materials. This is an undesirable situation in shaping sheet material.

Springback is an issue that needs to be taken into consideration when designing a product to be produced with press brake bending. Sometimes a remould is prepared to compensate for springback. This means more time and cost. When the required angle is not achieved in the manufacturing of parts that do not require very precise production, the same twist can be compensated by reducing the twist angle or by manually increasing the pressure of the press brake.

It varies depending on the mechanical properties of the sheet material, the internal structure of the sheet material, the thickness of the sheet material, the mold opening and how long the sheet material remains between the molds during the bending process. This period is also known as the actual twisting speed.


Fig. 2 Abkant twisting process

➢ *K Factor*

Various methods are used in sheet metal part designs to ensure that the expansion measurements give accurate results in manufacturing. K factor gives the most accurate results among these methods. With the K factor, it is possible to match the dimensions of a sheet with bends, its expansion length, between design and manufacturing. It is the ratio formed by dividing the neutral axis, that is, the neutral axis, by the sheet thickness. K factor is also known as the springback coefficient of the material. It is accepted that the k factor for all engineering materials is between 0.27-0.5. The most important factor that determines the K factor is the bending inner radius value of the sheet material. The value of the K factor cannot be greater than 0.5. The reason for this is to subject the sheet material to compressive stress by bending to change its plastic shape. The main stresses in this forming are the compressive stresses that occur on the inner surface of the sheet, that is, in the section where the inner radius is located.

➢ *Determination of Natural Frequencies*

If one of the frequencies of a periodic force applied to the structure is at the natural frequency, the structure is excited and vibrates. Resonance occurs when the stimulating frequency and the natural frequency value coincide. Two methods are used to find the natural frequency. These methods are "Finding Natural Frequency with Impact Test", which is done experimentally, and "Finding Natural Frequency with Modal Analysis", which is done using the finite element method.

The impact test method occurs in two ways. One of these methods is to hold the vibration sensor fixed at one point and hit the determined points on the object with a hammer. The effect of vibrations occurring in different places on the point where the sensor is located is measured. In the other way, a point is determined and the vibration sensor is moved around and the measurement is made while always hitting the same point with the hammer. The same results are obtained in both cases. Calculations can be verified and final

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results can be obtained with the FEA (Finite Element Analysis) method. Package programs are widely used in the industry for the finite element method. ANSYS program is one of these programs. In this package program, natural frequencies are determined under the "Finding Natural Frequency with Modal Analysis" table.

After the study to determine the natural frequency, we basically see two graphs. These graphs are called frequency response function graph (FRF) and Coherence graph graph. These graphs are interdependent graphs.

The Coherence graph is a function in the frequency domain that indicates how much of the output in the FRF is due to the input. It may be an indicator of the quality of the FRF. By repeating the same measurement, the consistency of the FRF obtained from the measurement is evaluated. The value range of the coherence function is between 0 and 1. A value of 1 at a given frequency indicates that the FRF amplitude and phase are highly repeatable from measurement to measurement. A value of 0 indicates the opposite situation. Measurements are not reproducible, possibly warning that there is an error in the test setup [12]. In Figure 3., the FRF graph and the Coherence graph are shown comparatively.

III. FINDINGS

In this study, 6112 DKP sheet and 1050 H14 aluminum sheet materials were designed and their natural frequencies were determined by the finite element method in the ANSYS analysis program. The effects of variable factors on the detected natural frequencies in twisted sheets were examined. Variable factors in the design of sheet material manufactured by press brake bending; sheet thickness, bend length, bend width, bend angle and bend radius. The variable factors in bent sheet design are shown in Figure 4 below.

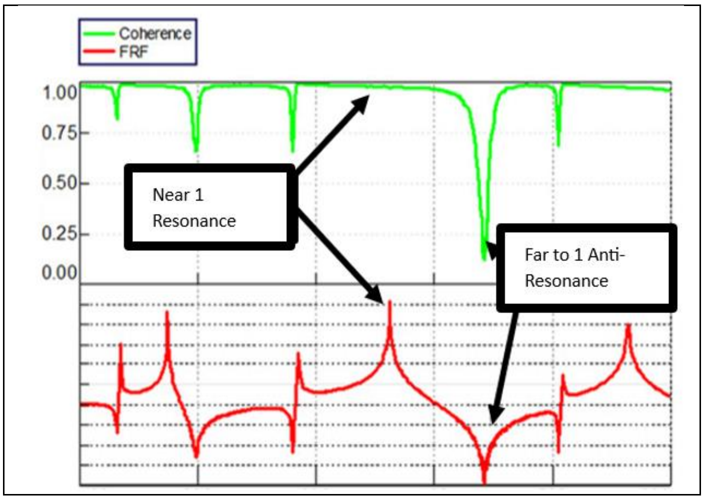

Fig. 3 Comparison of FRF and Coherence plots

➢ *Sheets and Properties*

6112 DKP sheet; It is the name given to the steel sheets formed after the slabs obtained by the continuous casting method are subjected to hot rolling and then cold rolling processes. The thickness of 6112 DKP sheets varies between 0.3 mm and 2 mm. 6112 DKP sheets; They are steel sheets with high surface smoothness, burr-free edges, decorative shiny appearance, high strength values and high weldability. It is one of the sheets widely used in industry. Although it usually comes in roll form, it is also widely used in sheet form. The dimensions of 6112 DKP sheets in sheet form are used in the industry as 1000x2000 mm, 1200x2400 mm, 1250x2500 mm and 1500x3000 mm. 6112 DKP sheets; It is widely used in the automotive, aviation, defense industry, construction and white goods sectors.

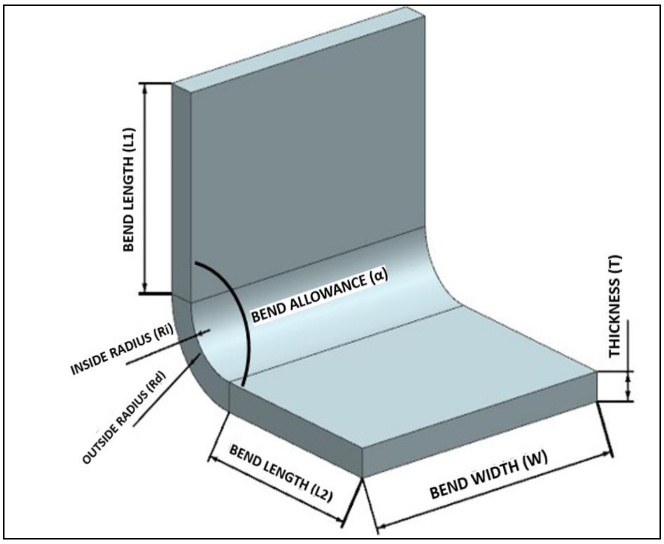

Fig. 4 Variable parameters on bent sheet metal

6112 DKP sheet; It is widely used in automobile, aircraft and tractor bodies, building roofs and medical equipment manufacturing. At the same time, 6112 DKP sheets, which have high magnetic permeability, are also used in transformers. The reasons why DKP sheets are seen in so many different areas are due to their easy shaping feature and high corrosion resistance.

6112 DKP sheets are sheets produced at the specified standard and quality. The chemical properties of these sheets are stated in Table 1. EN 10130 standard and DC01 quality specified in Table 1. It covers low-carbon, cold-rolled, cold-formable flat products with a wall thickness varying between 0.3 mm and 3 mm and a minimum width of 600 mm. Table 2 shows the chemical composition of 1050 H14 aluminum (%).

Table 1 Chemical composition of 6112 DKP steel sheet (%)

Chemical composition of 6112 DKP steel sheet (%)						
Standard	**Grade**	**Grade number**	**C**	**P**	**S**	**Mn**
EN 10130	DC01	6112	0.12	0.045	0.045	0.60

Table 2 Chemical composition of 1050 H14 aluminum (%)

Chemical composition of 1050 H14 aluminum (%)							
Fe	**Si**	**Zn**	**Ti**	**Mg**	**Mn**	**Cu**	**Al**
0,4	0,25	0,07	0,05	0,05	0,05	0,05	99,5

In this study, in addition to variable bending parameters, it was aimed to compare the resistance of aluminum and steel sheet materials against resonance. For this purpose, 6112 DKP sheet and 1050 H14 aluminum sheet materials were preferred.

No boundary conditions were applied to determine the natural frequencies of the materials, and calculations were made assuming the models were in space. The natural frequency values determined for each model are called modes. The meshes created for the models are created to be the same for each model. When the natural frequencies were determined using the finite element method for all models, the first 6 mode values were 0 or very close to 0, so these 6 mode values were not taken into account in the study. The reason why the first 6 mode values are 0 or close to 0 is because the material behaves rigidly and does not show any deformation.

Using the ANSYS package program, materials were defined to capture the real values of natural frequencies by the finite element method, and the mechanical properties of the materials were defined in the ANSYS library. Figure 4.2 below shows 6112 DKP sheet and Reference Metal 1050 H14 aluminum sheet materials defined in the ANSYS library.

- *Effect of Sheet Thickness on Natural Frequency*

Four different models were created to observe the effect of sheet thickness on natural frequency. These models; They were determined as model-1, model-2, model-3 and model-4. These models are models that have not undergone the bending process, which is the unfolding state of the sheet metal. Each model is kept fixed at 100x100 mm, and the only variable size is the sheet thickness. They are designed to be 1 mm for model-1, 1.2 mm for model-2, 1.5 mm for model-3 and 2 mm for model-4. These thicknesses were preferred because they are the thicknesses frequently used in the industry for 6112 DKP sheet and 1050 H14 aluminum sheet materials.

The designed models were loaded into the ANSYS program and their natural frequencies were determined using the finite element method. Considering the achieved values, the natural frequency of the material increased with the increase in sheet thickness. Resonance states of materials with increasing sheet thickness will occur at higher frequencies, and materials with higher sheet thickness will show more rigid behavior. At the same time, it has been determined that 1050 H14 aluminum sheet materials will resonate at higher frequencies than 6112 DKP sheet materials. In this case, 1050 H14 aluminum sheet materials exhibited more rigid behavior than 6112 DKP sheet materials. Since the gap between the change in sheet thickness and mode values is quite large, it has been observed that sheet thickness is an important factor for the resonance state. These data are shown comparatively in the form of graphs in Figure 5 and Figure 6.

- *Effect of Twist Length on Natural Frequency*

Four different models were created to observe the effect of twist length on natural frequency. These; They were designated as model-5, model-6, model-7 and model-8. These models are L-shaped models in which the sheet metal has undergone a single bending process. The first twist length (L1) of each model is kept constant, and the variable measure is designed only as the second twist length (L2). The first bending length (L1) is 100 mm for each model, and it is designed to have a sheet thickness of 2 mm, bending radius of 2 mm, bending width of 100 mm and bending angle of 900. Second twist lengths (L2); They are designed to be 50 mm for mdel-5, 100 mm for model-6, 150 mm for model-7 and 200 mm for model-8.

The designed models were loaded into the ANSYS program and their natural frequencies were determined using the finite element method. Considering the achieved values, the natural frequency of the material decreased as the bending length increased.

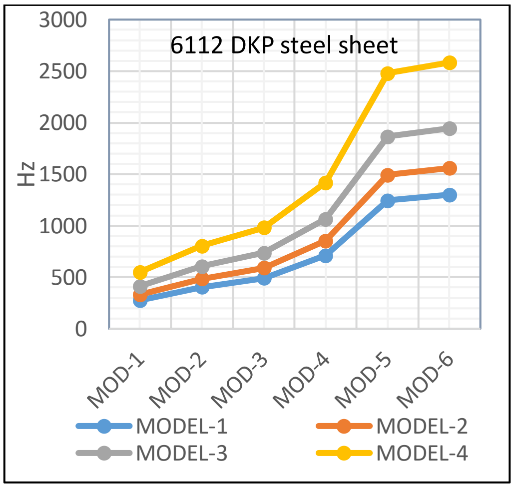

Fig. 5 mode values according to 6112 DKP steel sheet thickness

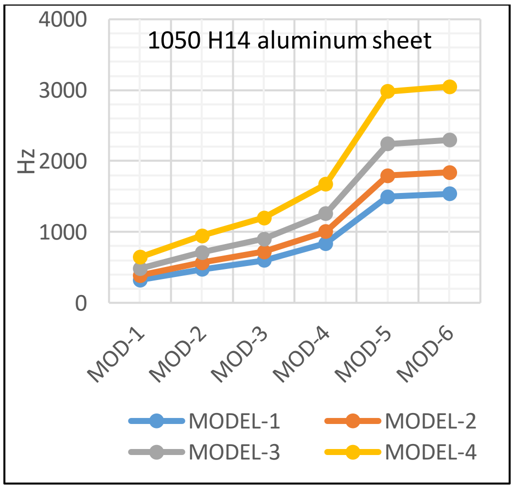

Fig. 6 mode values according to 1050 H14 aluminum sheet thickness

Resonance states of materials with increasing twist length will occur at lower frequencies, and materials with lower twist length will show more rigid behavior. At the same time, it has been determined that 1050 H14 aluminum sheet materials will resonate at higher frequencies than 6112 DKP sheet materials. In this case, 1050 H14 aluminum sheet materials exhibited more rigid behavior than 6112 DKP sheet materials. Since the gap between the variation of the twist length and the mode values is quite large, it has been observed that the twist length is an important factor for the resonance state. The values are shown in graphs in Figure 7 and Figure 8.

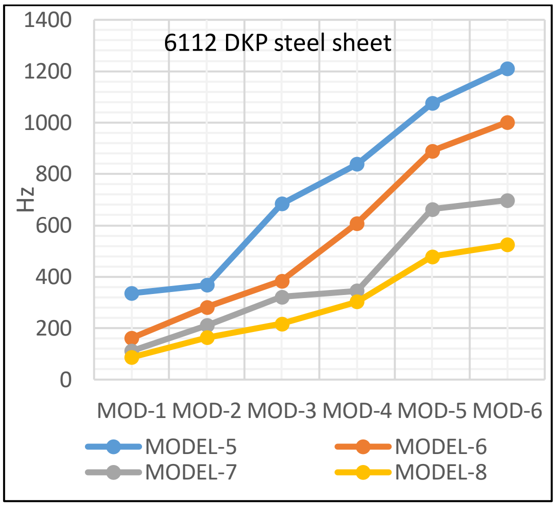

Fig. 7 mode values according to 6112 DKP steel sheet bending length

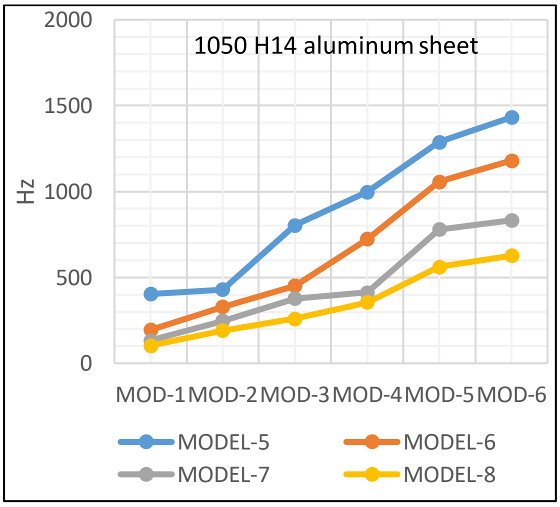

Fig. 8 mode values according to 1050 H14 aluminum sheet bending length

- *Effect of Twist Width on Natural Frequency*

Four different models were designed to observe the effect of bend width on natural frequency. These models; They were determined as model-9, model-10, model-11 and model-12. These models are L-shaped models in which the sheet metal has undergone a single bending process. The bending lengths (L1, L2) of each model are kept constant, and the only variable measure is the bending width (W). Bending lengths (L1, L2) are 100 mm for each model and are designed to have a sheet thickness of 2 mm, bending radius of 2 mm and bending angle of 900. Bending width (W); They are designed to be 50 mm for model-9, 100 mm for model-10, 150 mm for model-11 and 200 mm for model-12.

The designed models were loaded into the ANSYS program and their natural frequencies were determined using the finite element method. Data were recorded for 6112 DKP sheet and 1050 H14 aluminum sheet materials, as seen in Table 4.3. Considering the achieved values, the natural frequency of the material decreased as the bending width increased. Resonance states of materials with increasing twist width will occur at lower frequencies, and materials with lower twist width will show more rigid behavior. At the same time, it has been determined that 1050 H14 aluminum sheet materials will resonate at higher frequencies than 6112 DKP sheet materials. In this case, 1050 H14 aluminum sheet materials exhibited more rigid behavior than 6112 DKP sheet materials. Since the gap between the variation of the twist width and the mode values is quite large, it has been observed that the twist width is an important factor for the resonance state. The data are shown in graphs in Figure 9 and Figure 10.

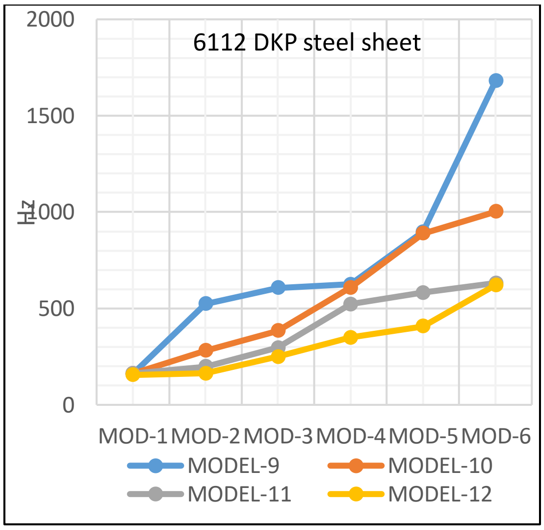

Fig. 9 mode values according to 1050 H14 aluminum sheet bending width

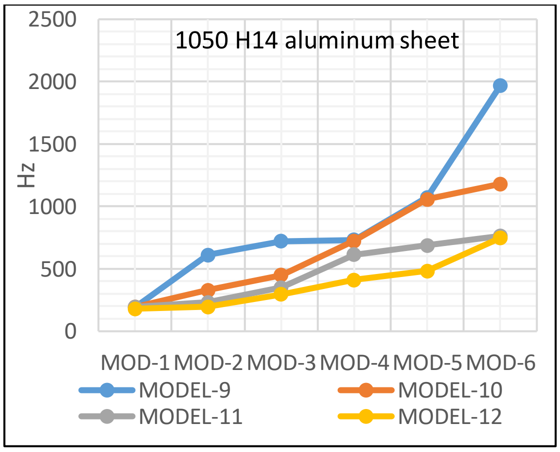

Fig. 10 mode values according to 6112 DKP sheet bending width

- *Effect of Twist Angle on Natural Frequency*

Four different models were designed to observe the effect of twist angle on natural frequency. These models; They were designated as moel-13, model-14, model-15 and model-16. These models are L-shaped models in which the sheet metal has undergone a single bending process. The bending lengths (L1, L2) of each model are kept constant, and the only variable measure is the twist angle (α). Bending lengths (L1, L2) are 100 mm for each model and are designed to have a sheet thickness of 2 mm, bending radius of 2 mm and bending width of 100 mm. Twist angle (α); They were designed to be 850 for model-13, 900 for model-14, 950 for model-15 and 1000 for model-16.

The designed models were loaded into the ANSYS program and their natural frequencies were determined using the finite element method. Considering the obtained values, it has been observed that the natural frequency values of the material change as the twist angle increases. While materials with increasing twist angle tend to decrease in mode-2 and mode-4 frequencies, other modes tend to increase, that is, rigid behavior. At the same time, it has been determined that 1050 H14 aluminum sheet materials will resonate at higher frequencies than 6112 DKP sheet materials. In this case, 1050 H14 aluminum sheet materials exhibited more rigid behavior than 6112 DKP sheet materials. Since the gap between the change of twist angle and mode values is quite small, it has been observed that the twist angle is not an important factor for the resonance state. These data are shown in graphs in Figure 11 and Figure 12.

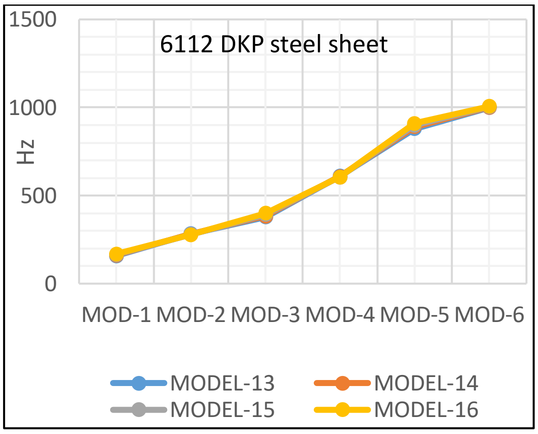

Fig. 11 mode values according to 6112 DKP steel sheet bending angle

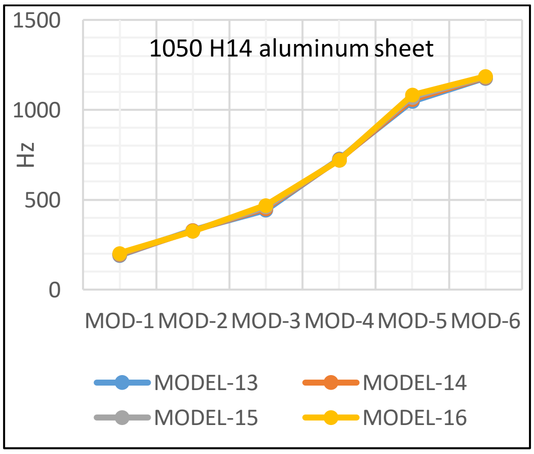

Fig. 12 mode values according to 1050 H14 aluminum sheet bending angle

➢ *Effect of Bend Radius on Natural Frequency*

Four different models were designed to observe the effect of bending radius on natural frequency. Models; They were designated as model-17, model-18, model-19 and model-20. These models are L-shaped models in which the sheet metal has undergone a single bending process. The bending lengths (L1, L2) of each model are kept constant and the only variable measure is the bending radius (Ri). The bending lengths (L1, L2) are 100 mm for each model, the sheet thickness is 2 mm, the bending width is 100 mm and the bending angle is 900. Bending radius (Ri); They are designed to be 1 mm for model-17, 2 mm for model-18, 5 mm for model-19 and 10 mm for model-20.

The designed models were loaded into the ANSYS program and their natural frequencies were determined using the finite element method. Considering the achieved values, the natural frequency of the material decreased as the bending radius increased. Resonance states of materials with increasing bending radius occurred at lower frequencies, and materials with lower bending radius showed more rigid behavior. At the same time, it has been determined that 1050 H14 aluminum sheet materials resonate at higher frequencies than 6112 DKP sheet materials. In this case, 1050 H14 aluminum sheet materials exhibited more rigid behavior than 6112 DKP sheet materials. Since the gap between the change of bending radius and the mode values is quite large, it has been observed that the bending radius is an important factor for the resonance state. These data are shown comparatively in graphs in Figure 13. and Figure 14.

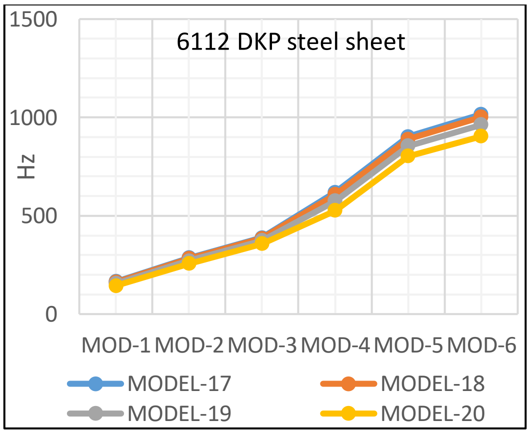

Fig. 13 mode values according to 6112 DKP steel sheet bending Radius

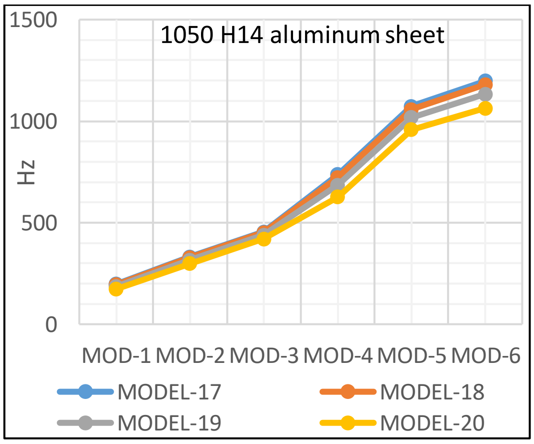

Fig. 14 mode values according to 1050 H14 aluminum sheet bending radius

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IV. CONCLUSION

In this study, using 6112 DKP steel sheet material and 1050 H14 aluminum sheet material, the effect of variable parameters on the natural frequency of the sheets subjected to the press brake production process was comparatively examined with the finite element method. According to the analysis results, the following principles were determined.

- In modeling the effect of variable factors in sheet materials on natural frequency with the finite element method, 6112 DKP sheet and 1050 H14 aluminum sheet materials were examined comparatively and when the model was designed with the same bending parameters, it was determined that 1050 H14 aluminum sheet materials resonated at higher frequencies.
- It has been determined that as the sheet thickness increases, the natural frequency of the model increases. In this study, sheet thicknesses; It is designed to be 1, 1.2, 1.5, and 2 mm. As the sheet thickness increases, the natural frequency values of the materials increase and it has been determined that the materials exhibit more rigid behavior.
- It has been determined that as the hair twist length increases, the natural frequency of the model decreases. Twisting lengths; It is designed to be 50, 100, 150 mm and 200 mm. It has been determined that as the bending length increases, the natural frequency values of the materials decrease and the materials move away from rigid behavior.
- It has been determined that as the sheet bending width increases, the natural frequency of the model decreases. Twisting width; It is designed to be 50, 100, 150 and 200 mm. As the bending width increases, the natural frequency values of the materials decrease and it has been determined that the materials move away from rigid behavior.
- Considering the values obtained for the sheet bending angle, it has been observed that the natural frequency values of the material show variable characteristics as the bending angle increases. Twist angle; It is designed to be 850, 900, 950 and 1000. Materials with increasing bending angle; It has been observed that while mode-2 and mode-4 frequencies tend to decrease, it tends to increase in other modes, that is, rigid behavior. At the same time, it has been observed that the change in bending angles and the natural frequency values are not very large and do not affect the natural frequencies of the material as much as other bending parameters.
- It has been determined that the natural frequency of the model decreases as the sheet bending radius increases. Bending radius; It is designed to be 1, 2, 5 and 10 mm. As the bending radius increases, the natural frequency values of the materials will decrease and it has been determined that the materials move away from rigid behavior.

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