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# A Study on the Vibration Reduction in Manufacturing the Deep Groove Holes with the Tool Holders and Sleeves using Design of Experiment (DOE)

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***Abstract— Deep hole drilling is a machining process with a high ratio of length to diameter (L / D). If the depth is greater than the diameter, vibration frequently occurs at the end portion of the cutting tool resulting in a product with defective hole surface and size. To solve this problem, dampened bars are installed to absorb vibration. Depending on their length, the dampened bars can lower process efficiency. Instead, a mill turret developed with a holder and sleeve could enhance quality and improve productivity while reducing vibration. In this study, an optimized model of a mill turret holder and sleeve was developed to reduce vibration and replace the dampened bar. To optimize the design parameters, a Design of Experiment (DOE) was used. A finite element analysis was performed using ANSYS. Using Modal analysis and Harmonic analysis, the control factors affecting stress and displacement were examined using a derived signal to noise (S/N) ratio.***

***Index Terms—Taguchi Method, Mill turret tool holder, Modal Analysis, Harmonic Analysis***

## I. INTRODUCTION

### *A. Background/ Objectives and Goals*

Deep hole drilling is a machining process which produces a hole with a high ratio of length to diameter (L / D). This type of drilling process is often difficult to perform because vibration of the cutting tool frequently occurs, which can be a problem. Vibration at the end portion of the drilling tool occurs when the depth of the hole is significantly greater than the diameter, and the vibration can result in product defects, both in the quality of the hole surface and hole size. To address these problems, dampened bars are typically installed to absorb and prevent vibration. Fig. 1 shows installed non-vibration bars. However, although such bars reduce vibration, depending on the length of the dampened bars, they can also reduce process efficiency. Fig. 2 illustrates the correlation between the length of the drilling tool and relative stability or vibration.

To address this problem, a mill turret tool holder and sleeve that combines various possible processes into one holder would be advantageous. This device could improve tool change time and reduce surface defects and breakage problems caused by vibration. It could also improve productivity. In this study, an investigation was carried out to study a method for reducing vibration during deep hole drilling using a mill turret holder and sleeve to replace existing non-vibration bars, and the model was optimized for vibration reduction. To optimize the design variable and the sleeve holder, the Design of Experiments was used. A finite element analysis was performed using ANSYS. Using Modal analysis and Harmonic analysis, the control factors which affect stress and displacement were examined, using a derived signal to noise (S/N) ratio.

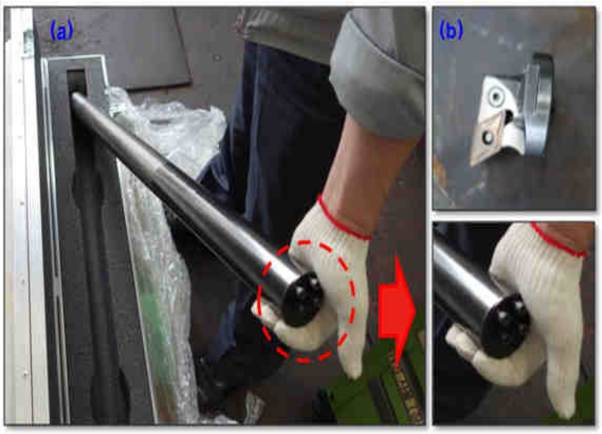


**Fig. 1 Installed non-vibration bars (dampened bars)**

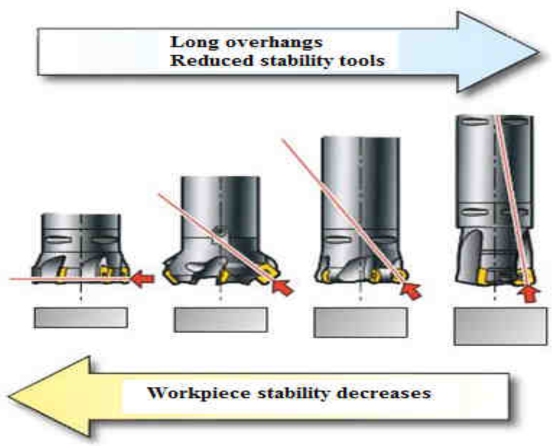


**Fig. 2 Stability distribution of tools and tool length of the workpiece**

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## II. DEEP GROOVING TOOL HOLDER OVERVIEW

Fig. 3 shows the proposed mill turret tool holder and sleeve. The mill turret consists of a sleeve, holder, and cutting tool. To replace the existing dampening bars used to absorb vibration, a product holder was made.

In conventional product drilling, depending on the hole location and its diameter, it is often necessary to replace the drill tool set, and set a new machining position. However, a mill turret tool holder such as the model shown in Fig. 4 can easily be shifted to perform a number of processes, including on the product's base, side and hole.

In this study, only the processing conditions for a center hole were used when considering the characteristics of the holder, for simplicity. The workpiece was rotated at 1000 RPM. The center hole's inner-diameter was 76 mm, and its depth was 109 mm.

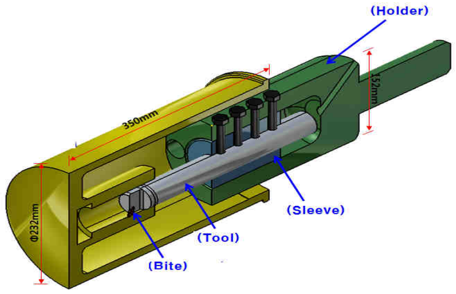



**Fig. 3 Product development schematic diagram**

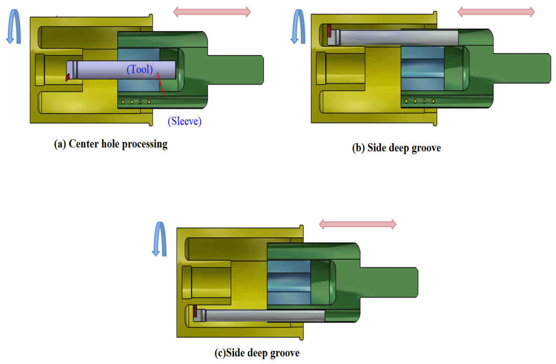



**Fig. 4 Work processes of Multi-function tool holder and sleeve**

## III. EXPERIMENTS BY TAGUCHI METHOD

To calculate the optimum design factors, the Taguchi Method, a data analysis method using the S/N ratio, was used in the parameter design. The Taguchi Method is a successful way to find the optimum processing conditions using estimation. It reduces the number of experimental tests which need to be conducted when the tests involve many control factors. The Taguchi Method is used to prepare the experimental design by arranging a table of orthogonal experiment arrays. By using the Taguchi Method, it is possible to find correlations between factors. In this study, when the processing tool was the subject, the characteristics affecting the stress and displacement of the holder and sleeve due to an exciting force, that is, vibration, was evaluated. This property is undesirable. Equation 1 is the calculation of smaller the gain characteristic.

$$SN = -10\log[\frac{1}{n}\sum_{i=1}^{n} y_i^2] \quad (1)$$

Where, n is Number of experiments and y is Experimental data.

First, to minimize the noise factor (vibration) of the sleeve and holder, it was necessary to select the optimal control parameters. In this study, the control parameters were sleeve tool depth, number of bolts and types of tool. Table 1 shows the details of these control parameters. Table 2 is a table of orthogonal arrays. The conditions were 2×2×3 = 18. To determine the selection of optimum conditions, we performed this analysis 18 times, by performing an analysis for each orthogonal array. After calculating the signal-to-noise ratio, we determined a factor representing the maximum S / N ratio. We selected the processing condition using the biggest S / N ratio factor.

**Table 1 Controlling factor and level**

| Factors | Level | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| A : Sleeve tool depth (mm) | 60 | 120 | Numbers of respondents (NR) |
| B : Number of bolts (EA) | 2 | 3 | 4 |
| C : tool types (mm) | 250-25 Φ | 300-32Φ | 400-40Φ |
| Constant factor | RPM : 1000 rpm cutting resistance | | |

**Table 2 Orthogonal arrays**

| Exp. No | Experimental procession conditions | | |
|---|---|---|---|
| | A Sleeve tool depth | B Number of bolts | C tool kinds |
| 1 | 1 | 3 | 3 |
| 2 | 1 | 3 | 2 |
| 3 | 1 | 3 | 1 |
| 4 | 1 | 2 | 3 |
| 5 | 1 | 2 | 2 |
| 6 | 1 | 2 | 1 |
| 7 | 1 | 1 | 3 |
| 8 | 1 | 1 | 2 |
| 9 | 1 | 1 | 1 |
| 10 | 2 | 3 | 3 |
| 11 | 2 | 3 | 2 |
| 12 | 2 | 3 | 1 |
| 13 | 2 | 2 | 3 |
| 14 | 2 | 2 | 2 |
| 15 | 2 | 2 | 1 |
| 16 | 2 | 1 | 3 |
| 17 | 2 | 1 | 2 |
| 18 | 2 | 1 | 1 |

## IV. THE DESIGN OF THE TOOL HOLDER

During drilling, the drilling tool generates chips from the workpiece by plastic deformation. As a consequence, the tool is subjected to force. This force is the cutting resistance. It acts at right angles to the direction of three components. The names of the force components are the main component force, power distribution and the transfer component force. In this study, cutting resistance was used in equation 2 and equation 3. We used the main component force. The specification of the Hi TECH 400L was used as the condition for the total power equation. Mainly used for the Mill turret.

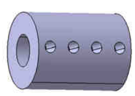
$$V_c = \pi \times D_0 \times N \tag{2}$$

$$P = F_c \times V_c \tag{3}$$

Where V = maximum cutting speed, D = workpiece an external diameter, N = spindle speeds rotational, P = total power, F = force, V = velocity.

Also, these values defined the properties of the tool holder. Table 3 provides the material properties of the components of the Mill turret tool.

**Table 3 Material properties**

| | Sleeve | Holder | Tool |
|---|---|---|---|
| |  |  |  |
| Material | SKD 61 | SKD 61 | scm 415 |
| Density | 7.80g/cm³ | 7.80g/cm³ | 7.85g/cm³ |
| Ductility | 9% | 9% | 22% |
| Yield strength | 1,650 MPa | 1,650 MPa | 440 MPa |
| Tensile strength | 1,990 MPa | 1,990 MPa | 295 MPa |
| Modulus of elasticity | 210 GPa | 210 GPa | 205 GPa |
| Poisson's ratio | 0.30 | 0.30 | 0.30 |

## V.THE OPTIMUM DESIGN OF THE TOOL HOLDER

We considered the important properties of the model design which were related to reducing vibration. First, the natural frequency of the working RPM should be avoided. Next, the tool must be able to withstand the cutting resistance. In addition, it should ensure a better reduction in vibration than the value proposed by the default model. In this study, to meet these design goals, the natural frequency was confirmed using Modal analysis. The three factors were investigated by changing aspects of the experimental design, specifically, the sleeve tool depth, number of bolts and types of tools. The Design of Experiment (DOE) was used with the Taguchi Method. After checking resonant frequencies, we calculated the main component force. By applying a conditioning load, the Harmonic analysis was carried out. Table 4 shows the results of the finite element analysis using the Taguchi Method. The main component force is 4,649 N. Fig. 5 indicates the direction of the force.

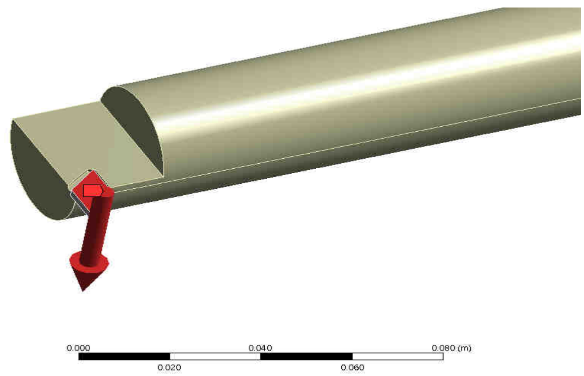



**Fig. 5 Direction of main component force**

**Table 4 Finite element analysis according to the 18 experiments planned**

| Trial No. | Natural frequency [Hz] | Equivalent Stress [MPa] | Total Deformation [mm] |
|---|---|---|---|
| 1 | 241.29 | 342.33 | 3.0918 |
| 2 | 391.38 | 469.76 | 2.3121 |
| 3 | 495.67 | 718.2 | 2.9882 |
| 4 | 241.34 | 331.64 | 3.0919 |
| 5 | 391.41 | 470.04 | 2.3115 |
| 6 | 495.71 | 745.52 | 2.9882 |
| 7 | 241.36 | 345.26 | 3.0908 |
| 8 | 391.43 | 450.4 | 2.3119 |
| 9 | 495.75 | 747.09 | 2.9879 |
| 10 | 315.58 | 268.4 | 1.5601 |
| 11 | 680.7 | 313.72 | 0.96962 |
| 12 | 1021.6 | 472.84 | 1.0028 |
| 13 | 351.74 | 314.38 | 1.5597 |
| 14 | 680.81 | 361.97 | 0.96881 |
| 15 | 1021.4 | 461.89 | 1.0043 |
| 16 | 351.65 | 286.13 | 1.5604 |
| 17 | 680.78 | 302.16 | 0.96909 |
| 18 | 1021.5 | 471.59 | 1.0039 |

## VI. RESULTS

Table 5 shows the S / N ratio obtained using the analysis results. For evaluating displacement and stress, lower results are good. The S/N ratio was calculated using the smaller, better characteristics.

**Table 5 Result of calculating the S / N ratio.**

| Trial No. | Equivalent Stress [MPa] | Total Deformation [mm] |
|---|---|---|
| 1 | -50.689 | -9.804 |
| 2 | -53.438 | -7.28 |
| 3 | -57.125 | -9.508 |
| 4 | -50.413 | -9.805 |
| 5 | -53.443 | -7.278 |
| 6 | -57.449 | -9.508 |
| 7 | -50.763 | -9.801 |
| 8 | -53.072 | -7.279 |
| 9 | -57.467 | -9.507 |



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| | | |
|---|---|---|
| 10 | -48.576 | -3.863 |
| 11 | -49.931 | 0.268 |
| 12 | -53.494 | -0.024 |
| 13 | -49.949 | -3.861 |
| 14 | -51.173 | 0.275 |
| 15 | -53.291 | -0.037 |
| 16 | -49.131 | -3.865 |
| 17 | -49.604 | 0.273 |
| 18 | -53.471 | -0.034 |

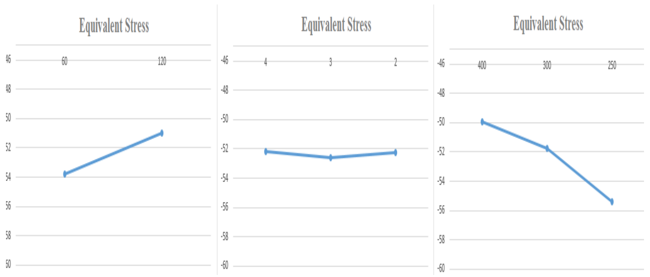


**Fig. 6 S/N ratio of the stress analysis**

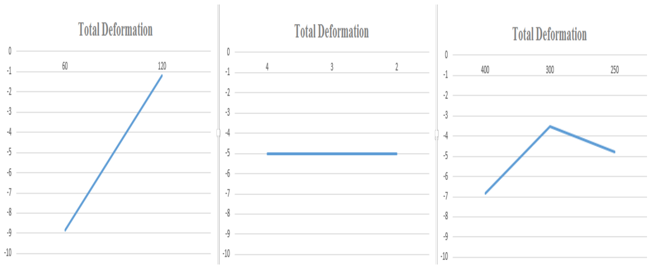


**Fig. 7 Direction of main component force**

Fig. 6 shows the S/N ratio of the stress analysis. A high S / N ratio is not good. As shown in Fig. 6, the tool type factor has the greatest impact on stress, followed by sleeve tool depth, and finally, the number of bolts. Fig. 7 shows the S / N ratio of the displacement analysis. As shown in Fig. 7, among the factors, the sleeve tool depth has the greatest impact on deformation, followed by tool types, and finally, the number of bolts. From the stress results, the minimum condition of the sleeve tool depth is –A2 (120 mm). The number of bolts is -B3 (4EA). Tool types is –C1 (200mm-25Φ). From the displacement results, the minimum condition of the sleeve tool depth is - A2 (120mm). The number of bolts is -B3 (4 EA). Tool types is –C2 (300mm-32Φ). Based on the results, if the sleeve - tool depth is greater, it will reduce the vibration and stress. For stress reduction, the tool types need to be short in length, as well as thin. But, this was only partially effective for displacement. In order to reduce both stresses and displacements, the sleeve-tool has to be deep, while the tool types should be short and thin.

## VII. CONCLUSION

In this study, a mill turret holder and sleeve were used instead of a dampened bar to reduce vibration in the optimization model. To optimize the design parameters, a Design of Experiment (DOE) design was used. A finite element analysis was performed using ANSYS. Using Modal analysis and Harmonic analysis, the control factors affecting stress and displacement were examined using the derived S/N ratio. The following results were obtained.

1) From these analysis results, it was determined that stress was generated at the sleeve. Tool types need to be as short in length as possible, and also thin. The tool types factor had the greatest impact on stress.

2) From the S/N ratio analysis results, it was determined that displacement was generated at the sleeve. The sleeve tool depth factor had the greatest impact on displacement. Depending on the sleeve length and thickness, there is a need to conduct further experimental analysis.

3) According to the analysis results, the number of bolts did not have a significant impact on stress and displacement.

4) By conducting an analysis with the previous factors, it was possible to calculate the optimum condition for each component. Using the calculated design parameters, implementing the optimal model parameters will ensure vibration reduction.

Based on the study's results, it was confirmed that the holder and sleeve will reduce vibration during the drilling process. These results are expected to be used as basic data for design.

## ACKNOWLEDGMENT

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## REFERENCES

1. W. S. Yoo, Q. Q. Jin and Y. B. Chung, "A Study on the Optimization for the Blasting Process of Glass by Taguchi Method," Journal of society of Korea Industrial and Systems Engineering Vol.30, No. 2, pp. 8 – 14, June 2007.
2. W. G. Jang, "Optimal Design of the Front Upright of Formula Race Car Using Taguchi's Orthogonal Array," Journal of society of Korea Society of Manufacturing Technology Engineers Vol. 22, No. 1, pp. 112 – 118, 2013.



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