Design and Vibration Analysis of Injection Moulding Machine Base Structure

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Abstract. In this study the dynamic behaviour and vibration parameters of Injection Moulding Machine Base Structure was performed by analysing the structure numerically as well as experimentally. Modal analysis and FRF analysis performed numerically to find the mode pattern, natural frequencies and critical points. Vibration parameters are measured by performing experimentation using FFT analyser and the data was taken by using BK (Bruel & kjaer) Connect software. The Fast Fourier Transform (FFT) analyzer is used to transform the continuous time domain data to continuous frequency domain data. The experimental results show that structure is vibrating high at clamping unit location along x-direction. Vibration level can be controlled at that particular location by increasing the stiffness of the structure.

Keywords: Modal and FRF Analysis, FFT analyser, BK Connect.

1. Introduction
Injection moulding is the cyclic process of producing plastic parts. Injection moulding machine consists of various units for performing several functions and all these units are mounted over the base frame. Base mainly consists of three frames. They are top frame, bottom frame and connecting vertical frame. All the frames are C-channel sections. Connecting vertical frame transfers weight and produced vibration to the bottom frame which is connected to the anti-vibration mount. During experimentation, Fast Fourier Transform (FFT) Analyzer is used for recording the data of vibration at different conditions.

Mathes et al [1] this paper describes about vibration parameters of two-pole induction motor. The natural and forced vibration of motor are evaluated by numerical calculations using finite element approach and validated using experimental modal analysis. Forced vibrations are calculated when the motor is operated by convertor. By using FFT analyser frequency spectrum was analysed. Torres-Martinez R et al [2], This study includes static and dynamic analysis of high-speed machining Al-Cu alloy lathe bed. Vibration characteristics like deflection, natural frequencies and vibration amplitudes were calculated by performing simulations on FEM model. A cast iron bed was considered as a parametric model used in conventional speed machining. Deflection and natural frequencies of the
machine structure was determined as per ISO standards. This study concludes that Al-Cu alloy structure was more feasible than cast iron lathe bed. Jiao M et al [3], Evaluated dynamic and static characteristics of a large machine bed by using finite element analysis. Structural topology optimization was performed for the structure. Results showed that 8.58% of mass was reduced 7.41% of stiffness was improved. Static and dynamic properties are improved for the phase of design. Yang H et al [4], The author analysed CK61125 CNC lathe bed using FEA approach. Performed static and dynamic analysis on the lathe bed and found maximum stress, strain and deformation as 100.98Mpa, 0.615 and 0.1455mm respectively. The natural frequencies of the lathe bed were obtained and results shows that 271.63 Hz, 290.41Hz and 305.88 Hz were first three resonant frequencies. Results shows that vibration characteristics of lathe bed gives strong theoretical parameters for the machine tool. Hong CC et al [5], the turning-milling CNC machine’s primary, secondary shafts and machine bed were analysed. They selected the maximum displacement and natural frequencies values as the basic data to design the CNC machine in safety condition for avoiding resonance. The natural frequencies, linear dynamic stresses and displacements of CNC machine are obtained by using the SOLIDWORKS simulation module.

2. Methodology:
In this study vibration analysis is performed both numerically and experimentally. Modal analysis is done and the behavior of the mode shapes are identified. Frequency Response Function analysis is performed by exciting the machine base with 1G acceleration and a frequency range of 0-100Hz. Experimentation is performed and the data is acquired using FFT analyser. By observing the results, the idea for reduction of vibration is suggested.

![Figure 1. Methodology](image)

3. Geometry:

![Figure 2. Injection Moulding Machine Base Structure](image)
4. Meshing:
The meshing of the geometry is done in Hyper mesh. Here the type of mesh used is Shell mesh with an element size of fifteen. After meshing, we need to ensure that the mesh of each component should not intersect and penetrate with another component. We need to check the quality index of the mesh generated. Here the weld connections are used for connecting the different components of the geometry.

![Figure 3. Enlarged View of Mesh](image)

Number of Elements: 86797
Material Properties:
All the properties of the material are assigned to each and every component along with their thickness values.
- Material: FE410
- Density: 7860 kg/m³
- Poisson’s Ratio: 0.285
- Young’s modulus: 210 GPa
- Weight of Injection unit: 1Tonne
- Weight of Clamping unit: 3Tonne

5. Boundary Conditions:
- Eight mounting points are restricted in all DOF.
- Frequency range: 0-200 Hz.
- Excited Acceleration: 1G (For FRF).
- The injection and clamping unit masses are laid through their CG points on the base.

![Figure 4. Wire Frame Modal Showing Constraints](image)
6. Results:

6.1 Modal Analysis Results:
Modal analysis is done and the natural frequencies are obtained and from this modal analysis the behaviour is identified from its mode shapes.

![Figure 5](#)

**Figure 5.** Mode No.1
From Figure.5, the type of mode is lateral mode along X-axis at frequency 12.49 Hz.

![Figure 6](#)

**Figure 6.** Mode No.2
From Figure.6, the type of mode is mixed mode along X & Y-axis at frequency 24.38 Hz.

![Figure 7](#)

**Figure 7.** Mode No.3
From Figure.7, the type of mode is bending mode along Z-axis at frequency 43.99 Hz.

![Figure 8](#)

**Figure 8.** Mode No.4
From Figure.8, the type of mode is vertical mode along Y-axis at frequency 54.76 Hz.
Table 1 Types of Modes

| Mode   | Frequency (Hz) | Type of Mode            |
|--------|----------------|-------------------------|
| Mode 1 | 12.49          | Lateral mode along X-axis |
| Mode 2 | 24.38          | Mixed mode along X & Y-axis |
| Mode 3 | 43.99          | Bending mode along Z-axis |
| Mode 4 | 54.76          | Vertical mode along Y-axis |

Operating Frequency – 41.66Hz

6.2 Frequency Response Analysis (FRF):

The Frequency response analysis is done and the critical points are identified shown in Figure 9. In X-Direction the peak values are observed at point 3 and 10 with frequency 44Hz. (Figure.10) In Y-Direction the peak values are observed at point 3 and 19 with frequency 44Hz. (Figure.11) In Z-Direction the peak values are observed at point 15 with frequency 24Hz and 4, 19 with frequency 12Hz (Figure.12)

Figure 9. Critical Points of FRF Analysis

Figure. 9, shows the critical points of the model in FRF analysis The responses of the structure are captured at these critical points by exciting the structure with 1G acceleration.

Figure. 10. Acceleration Vs Frequency (X-Direction)
7. Experimentation Set Up:
The Experimentation is done and the values are recorded at the critical points attained from FRF analysis. Here the FFT analyser and BK connect software are used for recording and analysing the experimental data.
7.1 Experimental Results:

**Figure 15.** Data Acquisition System

**Figure 16.** Measuring Point

**Figure 17.** Acceleration Graph in X-Direction
8. Conclusion:

From the experimental results, the acceleration values in X-Direction are observed high at point 19 i.e., 5.42 m/s². In Y-Direction, the highest acceleration value is observed at point 15 i.e., 0.98 m/s². In Z-Direction, the highest acceleration value is observed at point 15 i.e., 0.73 m/s². The acceleration values in both Y and Z-Directions are less than 1 m/s², but when compared to these directions the acceleration value in X-Direction is very high. So, the maximum vibration is producing at the point 19. The vibration...
amplitude at that particular location in the structure can be reduced by introducing ribs which serves as support and increases stiffness of the structure.

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