OTEKON 2012
6. Otomotiv Teknolojileri Kongresi
04 – 05 Haziran 2012, BURSA

DYNAMIC STIFFNESS INVESTIGATION OF AXLE ATTACHMENT POINTS OF A COMMERCIAL VEHICLE

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ABSTRACT

Dynamic stiffness at the interfaces of a vehicle body is major concern in vehicle NVH. In this study dynamic stiffness of some chosen suspension attachment points on a commercial vehicle are under investigation. After the correlation between the Finite Element (FE) Analysis and the test results was maintained, the structure was reinforced using FE Analysis to meet the target stiffness values.

Keywords: Dynamic Stiffness, Attachment point, Interface design, FE Analysis -Test Correlation, Point FRF test

BİR TİCARİ ARACIN AKS BAĞLANTI NOKTALARI İÇİN DİNAMİK KATILIK İNCELEMESİ

ÖZET

Araç gövdesi arayüzlerindeki dinamik rijidlik araç NVH açısından önemli bir ilgi alanıdır. Bu çalışmada bir ticari aracın aks bağlantı noktaları dinamik rijidlikleri incelenmiştir. Sonlu Elemanlar (SE) analizleri ve test arasındaki tutarlılık sağlandıktan sonra SE analizleri kullanılarak belirlenen rijidlik hedefleri yapının geliştirilmesi suretiyle tutturulmaya çalışılmıştır.

Anahtar kelimeler: Dinamil rijidlik, Bağlantı noktaları, Arayüz tasarımı, SE analizleri -Test korelasyon, Noktasal FRF Testi

1. INTRODUCTION

The mount systems on the interfaces of the vehicle (such as engine and suspension system interfaces) are usually very interesting looking from NVH aspect. The mounting systems should perform well in order to maintain an overall good quality NVH. Aside from the stiffness and damping characteristics of mounts, the attachment points on the body for these also play an important role. The attachment points shall provide sufficiently stiff base for the mounts in order to ensure a respectable performance. In this study, attachment point stiffnesses of engine and suspension systems are investigated on a *body-in-white (BIW) of a commercial vehicle.* In the mean time a parallel FE Analysis was performed with some effort for the correlation too. This becomes important if it is necessary to come up with a solution to a possible failure on the body structure (according to stiffness targets) since it is much easier to try different structural configurations on the virtual environment. Thus, after ensuring the correlation is robust, enhancements on the body structure can be easily carried out on the virtual environment. This study was repeated for all engine and suspension points of the body under study. However points and axes that have questionable stiffnesses are presented. To summarize:

- Measurements on the vehicle were performed
- Correlation was maintained
- Enhancements on the body according to target values were made

2. BACKGROUND

The dynamic stiffness generically could be defined as

$$|K(\omega)| = \frac{|F(\omega)|}{|X(\omega)|} = \frac{1}{|H_c(\omega)|} \quad \textbf{Eq. 1}$$

where K is the dynamic stiffness, F is the excitation force, X is the displacement and $H_c(\omega)$ is the dynamic compliance. These quantities are of course on frequency domain. When the mount performance is of concern and only static stiffnesses of mounts will be considered the phase information is not interesting. In fact in order to determine the efficiency of the mounts, **only *equivalent static stiffness*** of the attachment point is enough which can be defined as:

The *stiffness value that is read from the dynamic stiffness plot on 0-2 Hz region after the rigid body modes are extracted from the system.* Rigid body mode extraction can be really difficult to apply on measurement results. However it is applicable on a well-correlated FE analysis. For this reason a correlation effort has also been spent for this study.

Another aspect to analyze could be possible modal weaknesses. In the other words equivalent static stiffness of a certain attachment point may meet the targets but further along the frequency domain certain drops may be observed. That is also a major concern. In addition it is important to identify any kind of significant drop in dynamic stiffness if it is due to a global flexible mode or not. If not, necessary structural modifications could be made.

3. TEST

The dynamic response tests are crucial in this study; ensuring the FE Analysis scheme which is used for identifying any possible drops or over all inadequacy of the point structural stiffness and of course the coming up with good possible solutions.

3.1. Setup

The common way of obtaining the dynamic stiffness by test is to measure the acceleration. So point FRFs of the points under concern collected with a single accelerometer and an impact hammer. The tools for Impact Hammer Tests are listed as:

- Head Acoustics HEADLab system (labPWR l.2, labCTRL l.1, labV6
- B&K Type 4507 B Accelerometer
- B&K Type 8206 Impact Hammer

The BIW structure is hanged with reasonably elastic strings on to the roof to simulate the free-free condition. One of the axle attachment points can be seen on Figure 1. The measurements are taken via a cube attached to one of the bolt holes. The FE Analysis point definition was also made accordingly.

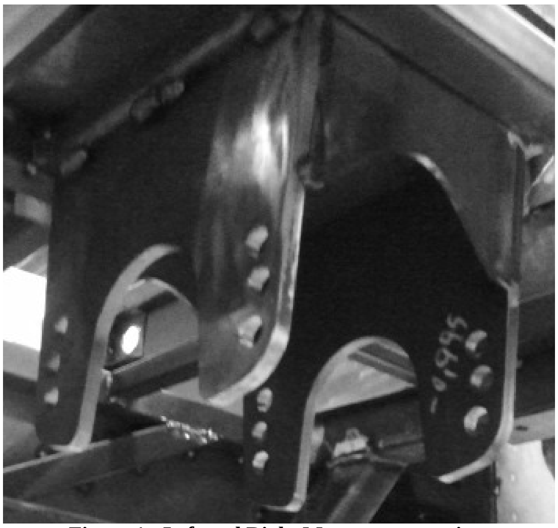

Figure 1 - Left and Right Measurement points

3.2. Coherence

All point FRFs were checked for quality via coherence indicator. Figure 2 shows a sample coherence plot from right measurement point x-direction. (See Figure 3)

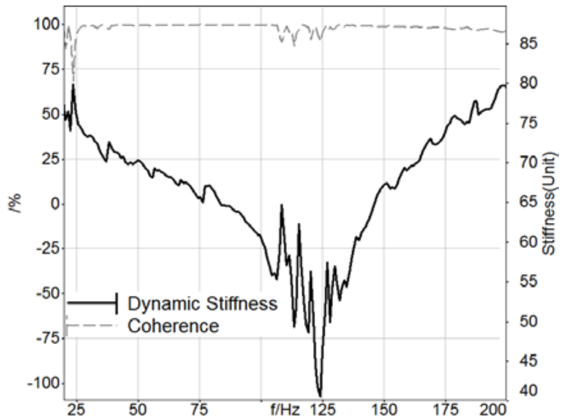

Figure 2 - Coherence Plot, Right measurement point x-direction

After the point FRFs were checked for possible inconsistencies and verified studies for coherence were initiated.

4. INITIAL RESULTS AND CORRELATION

After careful testing and accurate FE modeling the agreement of results were quite acceptable. There were some inconsistencies at the engine attachment points but they were improved by changing the FE model especially in terms of coherence and structural modifications.

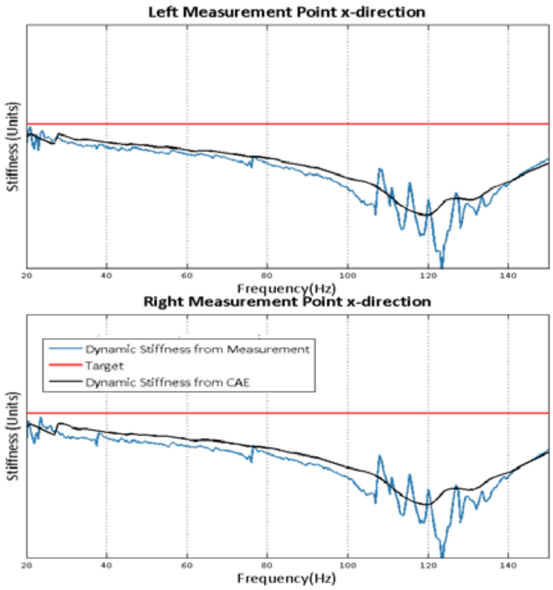

Figure 3 - Dynamic Stiffness- Test vs. FE Analysis x-directions

The initial results and the indication of "how correlated the model is" can be seen on Figure 3. This initial configuration will be addressed as the *base configuration* from here and on.

Looking at the result one can immediately detect the modes around 125 Hz at x-axis and 80 Hz at z-axis on both left and right measurement points. In this case the system does not bear load across y-axis so the y component of stiffness is ignored. Over all stiffness levels being under the red target curve is also a major concern.

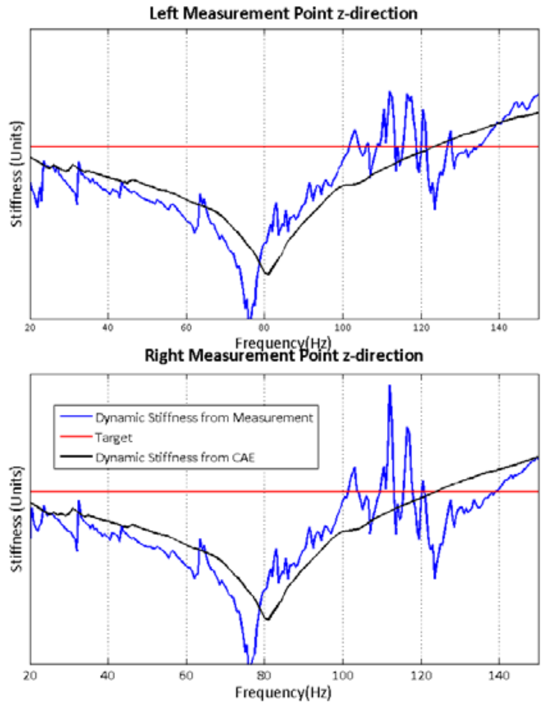

Figure 4- Dynamic Stiffness- Test vs. FE Analysis z-directions

According to what has been put below, two main concerns exist for the points of interest:

- The levels of stiffness values over all frequency band is below the target levels
- There are two strong modes in each z and x direction which causes very low stiffness values around local frequency points.

5. ITERATIVE MODIFICATIONS

Thirteen different modification configuration was applied to the body structure housing the attachment point under concern but only four of them are presented in this paper. The results are presented on Figure 5, Figure 6 as dynamic stiffness and on Figure 7 as equivalent static stiffness.

Configuration #6 and #13 are the best solutions to both of the problems stated above, namely in terms of equivalent stiffness and dynamic stiffness.

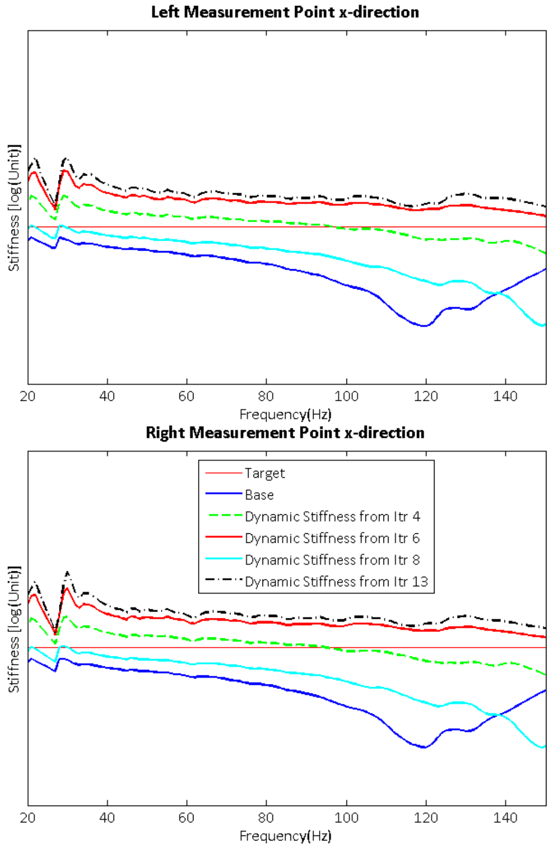

Figure 5-Dynamic Stiffness- FE Analysis iterations x-directions

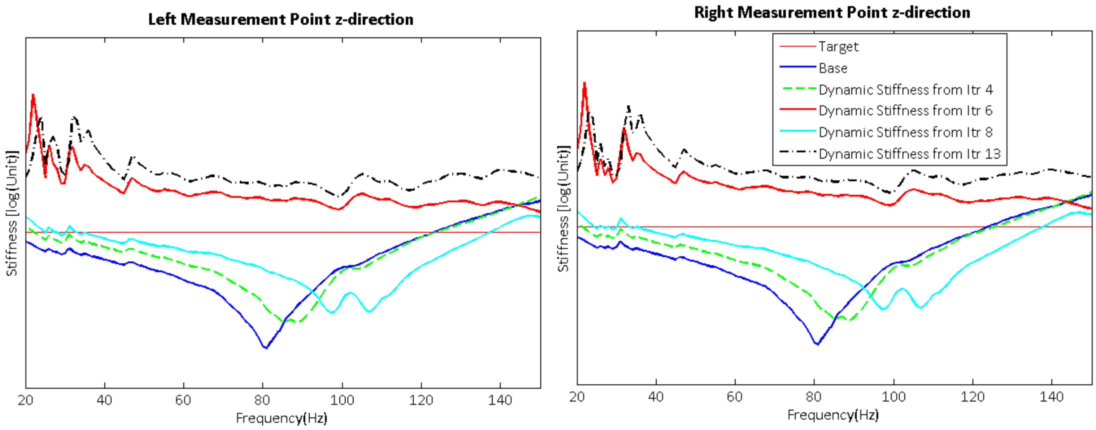

Figure 6 - Dynamic Stiffness- FE Analysis iterations z-directions

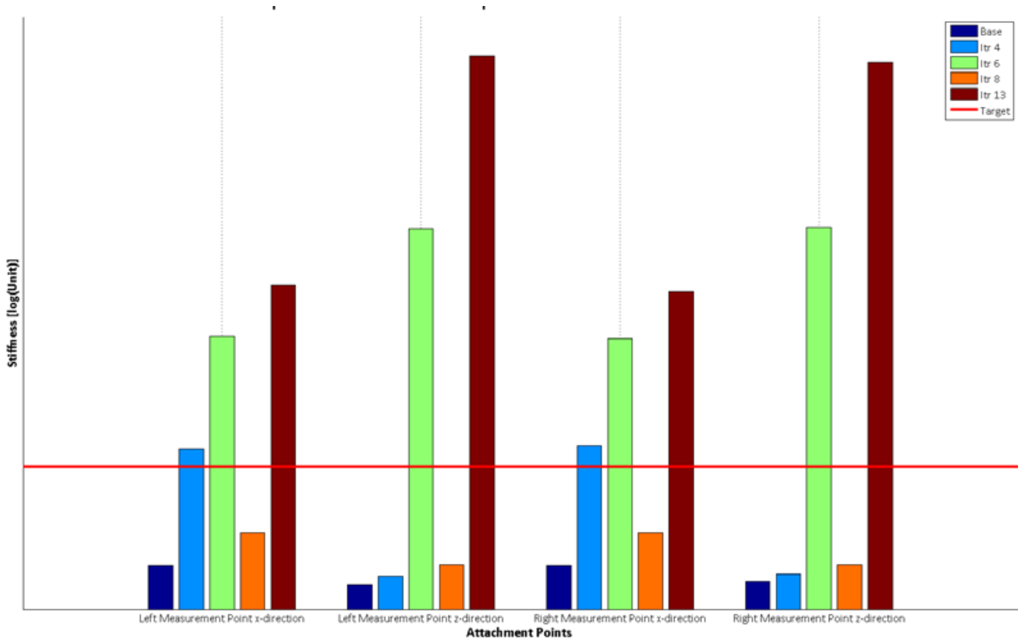

Figure 7 - Equivalent Static Stiffness comparison between base and alternative configuration

Figure 8 shows the base structure. Configuration 6 (Figure 9) reinforces x and z directions by small brackets attached around the profiles where they meet with the thick rails of the body. Also their thickness is increased to the limit set by producibility.

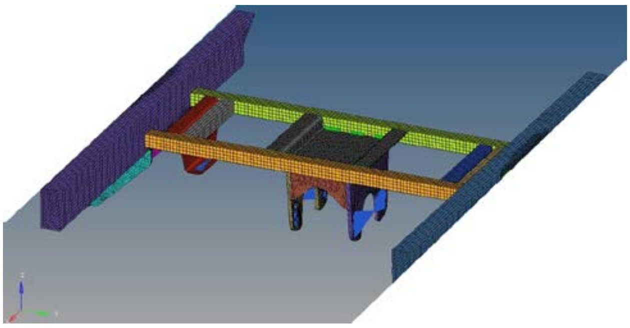

Figure 8 - Base Configuration

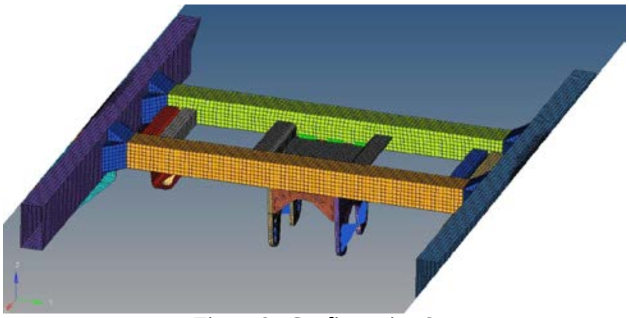

Figure 9 - Configuration 6

At configuration 13 instead of increasing the thickness of the profiles to the limit four of small profiles were added along the z direction and a small amount of thickness added to the profiles. The brackets on top are also kept and the rest was cleaned up.

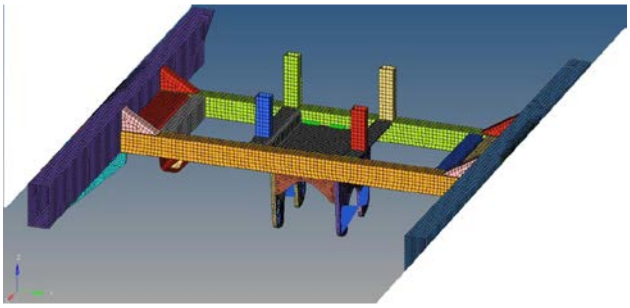

Figure 10 - Configuration 13

6. CONCLUSION

The results show that the configuration 13 shows the best results in terms of meeting the target dynamic stiffness as well as the target dynamic stiffness. Since the main interest of this study is on lower frequency region, it has not been checked wheter the dominant modes of each x and z directions could shift the higher frequency region or not. This question could appear to be valid if higher frequencies may ever be of concern.

References

Ewins, D. J. (2000). *Modal Testing: Theory, Practice and Application.* Badlock,Hertfordshire: Research Studies Press Ltd.