# A Survey of Eigen Solution Methods in LS-DYNA®

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## Abstract

*LSTC has been adding several new methods for solving a variety of eigenvalue problems in LS-DYNA. This talk will give a survey of two new methods including MCMS (our implementation of the AMLS algorithm), and an iterative based method based on the Locally Optimal Block Pre-Conditioned Conjugate Gradients Method (LOBPCG). These methods will be contrasted with our standard method of Block Shift and Invert Lanczos. We will also describe our implementation of Sectoral Symmetry, a method to vastly reduce the problem size for models with a high degree of rotational symmetry such as fan blades.*

## Introduction

The customer base for LSDYNA has been requesting more and more features based on the Implicit Mechanics and Implicit Linear capabilities. Historically LSDYNA has had one eigensolver which is based on the Block Shift and Invert Lanczos. To respond to customer requests we have added three new eigensolution capabilities to address special focus areas. This talk will survey and contrast the different capabilities.

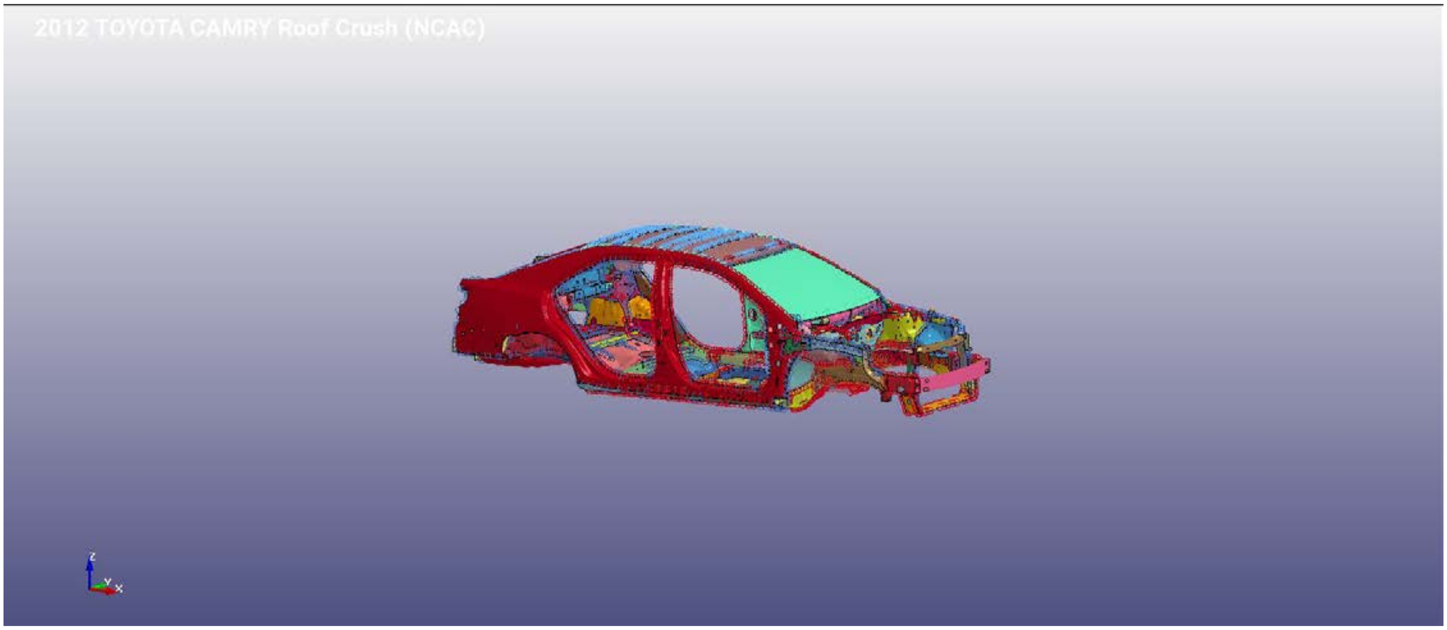
## Block Shift and Invert Lanczos

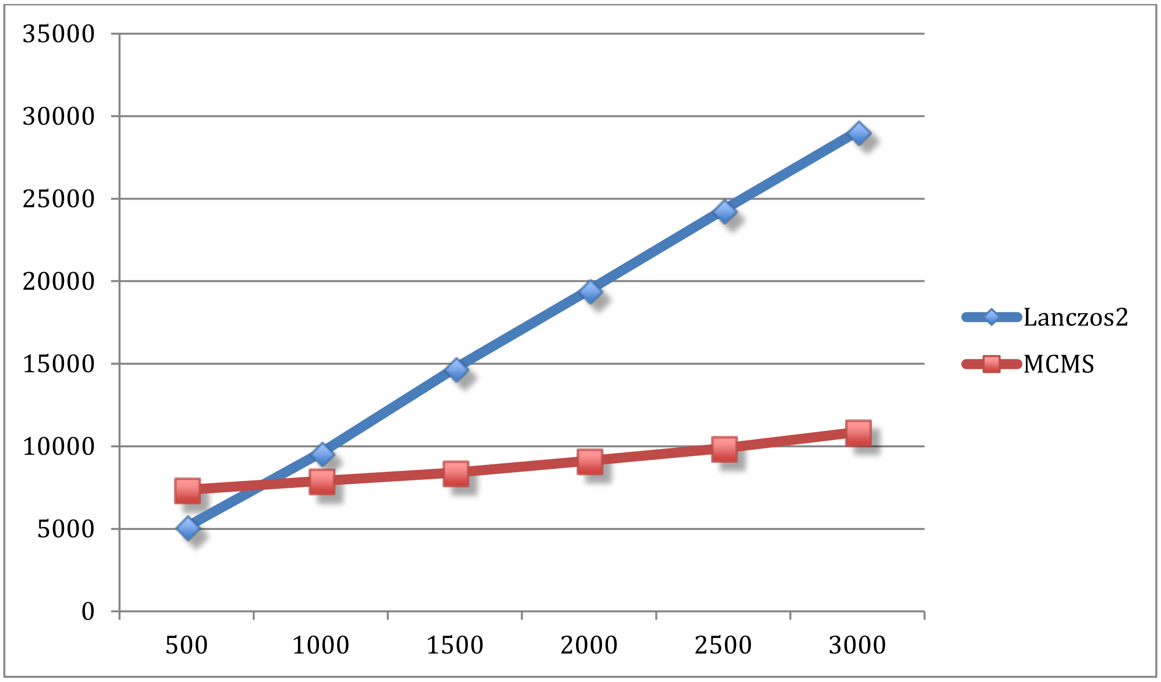
The eigensolution method based on Block Shift and Invert Lanczos has been in LSDYNA for 15+ years. It has proven to be a robust and reliable and efficient eigensolver. Lanczos computes the eigenmodes to the highest accuracy possible using numerical methods on current computers. We have both an SMP and MPP implementation. Currently it is the only eigensolver available in MPP. It should be the method of choice for computing 10 to 100s of eigenmodes or anytime accurate solutions are required. Its biggest drawback is in the area of model verification when the model has 100s of rigid body modes.

## Multi-level Component Synthesis

Multi-level Component Synthesis (MCMS) is LSTC implementation of the Algebraic Multilevel Substructuring Method (AMLS). MCMS computes an approximation to the eigenmodes compared to Lanczos which is computing the eigenmodes to nearly machine precision. MCMS eigenmodes will usually have an error of 3% to 5%. AMLS, and our implementation MCMS, is best used to compute 1000 to 5000 modes. This kind of computation is usually the first step for analyses in the frequency domain. MCMS is available in Release 11 of LS971 but only in SMP. The distributed memory implementation is under design but no implementation has been started.

The following is a comparison of the SMP implementation of Lanczos and MCMS for a BIW model of the Camry model from the NCSA model.


2012 TOYOTA CAMRY Roof Crush (NCAC)

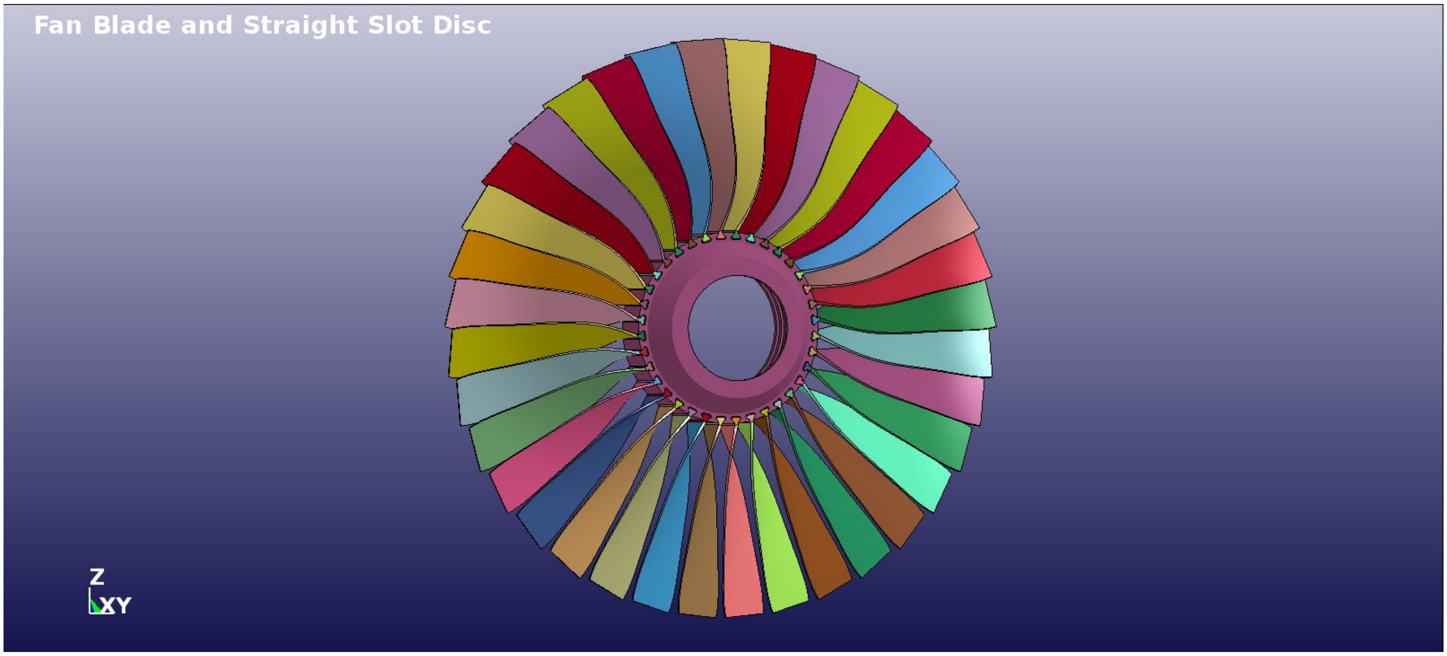

35000
30000
25000
20000
15000
10000
5000
0
500
1000
1500
2000
2500
3000
Lanczos2
MCMS

## Locally Optimal Block Preconditioned Conjugate Gradient

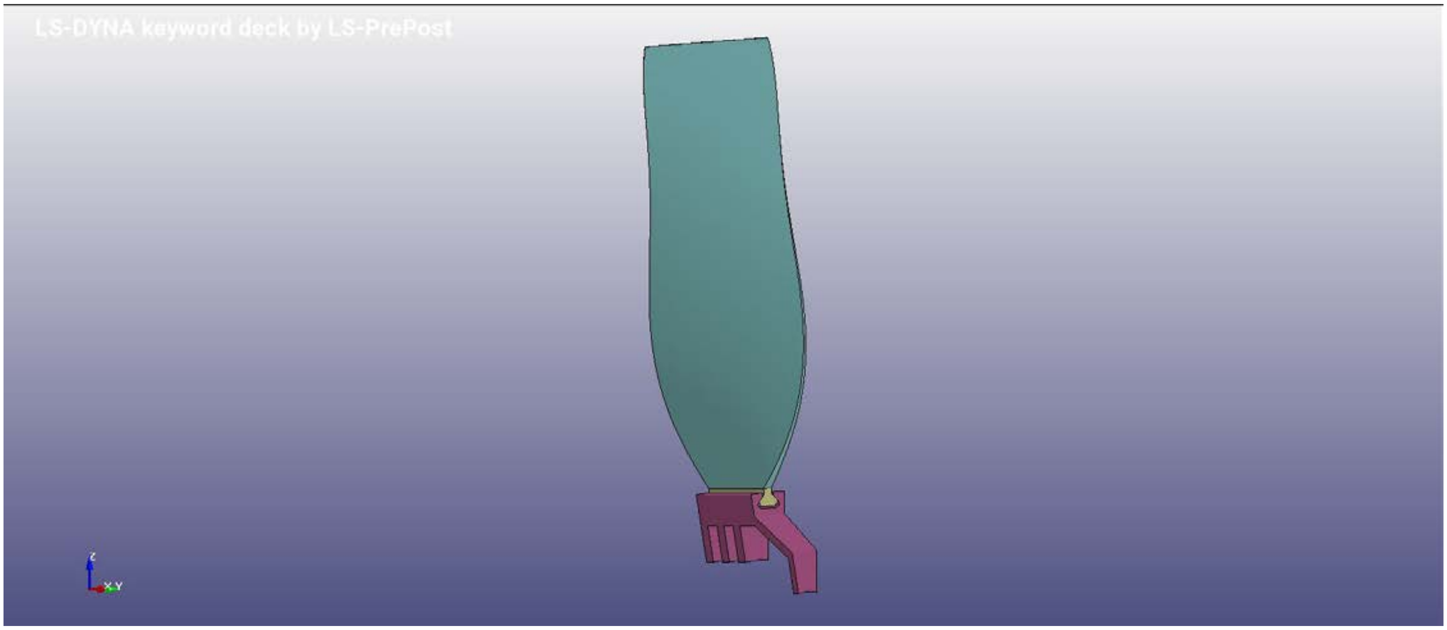
Locally Optimal Block Preconditioned Conjugate Gradient (LOBPCG) is an iterative based algorithm for computing a small number of eigenvalues for the same eigenvalue problem as Lanczos and MCMS. Instead of the direct factorization of K-σM used by Lanczos LOBPCG computes an approximate factorization of K using the Block Low Rank option in MUMPS. Because it does not perform a direct factorization it uses less computer resources than Lanczos. Our current implementation is still under development but does work well for computing a small number of eigenmodes near zero. LOBPCG requires a approximate factorization to use as a preconditioner. Our current implementation uses MUMPS and is SMP only. It is only in the development version of LS971 (that is it is not currently in Release 11). Our testing to date shows that in SMP LOBPCG scales better than Lanczos and is more efficient for computing up to 20 or 30 modes. The features of LOBPCG makes it a good choice for computing a small number of modes on a desktop workstation.

## Sectoral Symmetry

Sectoral Symmetry can be used to reduce the size of the eigenmode computation for models with a large amount of rotational symmetry. Consider a model of a fan blade and hub




Instead of using the full model with 36 fan blades we can instead focus on just a single fan blade




If the analyst wants to perform a detailed study using 1 million solid elements for each fan blade plus 4 million more solid elements to represent the hub the eigensolver will need to deal with 40 million solid elements or 120 million rows in the matrices. This size problem will require a large MPP compute cluster. Instead sectoral symmetry can be used to reduce the model by 1/36. That would be approximately 1.1 million elements or 3.3 million rows. The eigenvalue problem is transformed from real symmetric to complex Hermitian but the size reduction might make this analysis possible on a capable desk side workstation. The drawback to this analysis is that you have to perform one analysis for each harmonic index to get the complete spectrum. In this case that is 1+36/2 or 19 separate analyses. LSTC implementation of Sectoral Symmetry is under development and is available in SMP in the development version of LS971. It should be noted that we are using a complex Hermitian version of LOBPCG to perform the actual eigencomputation once the matrices are formed. The MPP implementation of Sectoral Symmetry will be tied to the MPP implementation of LOBPCG. And that is dependent on the BLR methodology for the approximate factorization being available in MPP.

## Summary

We have presented an overview of the three new capabilities in LSDYNA for eigenvalue computations. We highlighted MCMS capability for efficiently computing good approximations for 1000s of modes. We demonstrated LOBPCG is effective for computing a small number of eigenmodes. And we showed the new Sectoral Symmetry feature for models with a high degree of rotational symmetry.