

Figure 23: Constrains on an existing FE model of crankshaft

7.5 Mesh Generation

A fine tetrahedral element was generated according to the quality specification. These quality specifications are gathered from the hyper mesh. All the quality criteria’s were maintained with in the default values in the hyper mesh. Quality criteria are mentioned as follows.

1. Quality criteria & Internal angles
2. Warpage & Chordal deviation
3. Aspect-ratio & Jacobean
4. Skew angle & Length
5. Tetcollapse.

Warpage angle

If one node of the plane element deviates from the plane then the angle between node and the plane is called warpage angle.

Twisting of either 2D or 3D element is also called warpage angle.

This angle should not be more than 5 degrees.

Aspect-ratio

It is defined as the ratio of maximum length of the element to the minimum length of the element.

It should not be more than 5

Skew angle

It is defined as the angle between two altitudes of the vertices in a triangle element

Should not more than 60 degrees

Chordal deviation

It defined as the deviation of the finite element model from actual geometric model.

Should not be more than 0.1

Internal angles

Perfect square element is an ideal element

Minimum angle should not be less than 45 deg

Maximum angle should not be greater than 135 deg

Length

Length is defined as the distance between tow nodes in the element

Minimum length should not be less than 65% of the element size

Jacobian.

It is a matrix; it is defined as the partial derivatives of natural coordinates w.r.t the global coordinates.

Perfect square element has a jacobian value 1

Tetcollapse

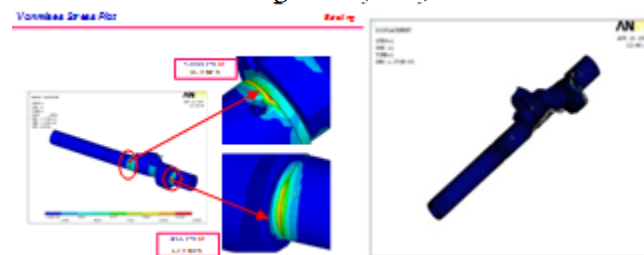
It is a quality criterion which is used for tetrahedron elements.

Value of the tetcollapse should not be less than 0.5.

8. Results and Discussions

8.1 Structural Static Analysis

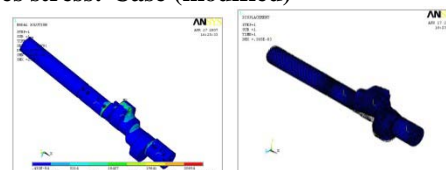
8.1.1 Results of existing shaft:(Case)



Displacement- Case (existing)

8.1.2 Results of modified shaft:

Vonmises stress:-Case (modified)



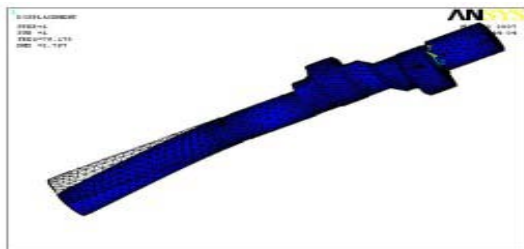
Displacement:-Case (modified)

8.2 Modal (Free-Free) Analysis (Existing):

frequency table for existing design.

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	79.178	1	1	1
2	80.743	1	2	2
3	164.61	1	3	3
4	327.51	1	4	4
5	401.51	1	5	5
6	404.77	1	6	6
7	449.30	1	7	7
8	471.23	1	8	8
9	659.83	1	9	9
10	769.23	1	10	10

Sub step frequency deformed shape.

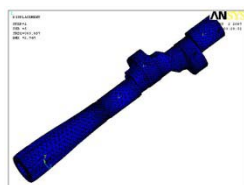


8.3 Modified-Design

Frequency table for modified design.

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	72.611	1	1	1
2	73.795	1	2	2
3	301.32	1	3	3
4	378.37	1	4	4
5	385.07	1	5	5
6	400.54	1	6	6
7	402.30	1	7	7
8	419.37	1	8	8
9	563.51	1	9	9
10	691.14	1	10	10

sub step frequency deformed shape.



9. Results Comparisons

Table 5: Details of FEA model

S.No	Type of Design	Material	Nodes	Elements	Element Type	Element Size
1	Existing	AISI 1118	48077	28998	SOLID92	0.3inch
2	Modified	AISI1118	40045	22770	SOLID92	0.3inch

Table 6: Material properties of aAW5520EXN Compressor Crankshaft

S. No	property	value
1	Young's modulus	7870Kg/m ³
2	Poison's ratio	0.29
3	Mass(existing)	0.938Kg
4	Mass(modified)	0.863Kg

Table7: Static analysis results

S.No	Type of Design	Stresses Case(Mpa)		Mass (Kg)	FOS	
		Min	Max			
1	Existing	63.8	95.8	59.28	0.938	3.28
2	Modified	107.8	161.75	118.54	0.863	1.947

Allowable yield tensile strength: 315Mpa

Table 8: Modal analysis (free-free) results:(range: 0-10000Hz)

Motor frequency: 60 Hz Pump frequency: 58.5 Hz

S.No	Mode freq	Existing(Hz)	Modified(Hz)	Rated freq(Hz)
1	1 st mode	79.178	72.611	58.5
2	2 nd mode	80.743	73.795	117
3	3 rd mode	164.61	301.32	175.5
4	4 th mode	327.51	378.37	234
5	5 th mode	401.51	385.07	292.5
6	6 th mode	404.77	400.54	351
7	7 th mode	449.30	402.30	409.5
8	8 th mode	471.23	419.37	468
9	9 th mode	659.83	563.51	526.5
10	10 th mode	769.23	691.14	585

10. Conclusion

The following conclusions were drawn from the above investigation:

- Study is made on the compressor of Air conditioning system.
- One of the components, Crankshaft is chosen for the analysis by reducing its weight. So that, cost of the compressor may be brought down.
- Weight of crankshaft is reduced by making hallow shaft using UG NX3.
- The solid shaft and hallow shaft is analyzed in ANSYS 10.

The results obtained are reviewed and drawn the following conclusions....

1. In case of New Compressor Crankshaft the maximum stress is not in critical section (design stress is 161.7 mpa which is far less than maximum stress of Compressor Crankshaft i.e. 315 mpa). So the crankshaft is under safe permissible limits.
2. The factor of safety of existing crankshaft is 3.28 but the factor of safety of a modified crankshaft is 1.947. Even though decrease in FOS, the modified crankshaft is under designed conditions.(FOS of any component must be greater than 1.5 times of design stress)
3. The existing Compressor Crankshaft weight is 0.938Kg. Whereas the weight of the modified crankshaft is 0.863Kg. So, 75grams of weight is reduced from existing crankshaft.(i.e.7.5% of weight reduction from the existing crankshaft)
4. The vibrations of modified crankshaft are lower than the existing crankshaft. The data is shown in table8. These vibration frequencies are compared with rated frequencies. They are far away from the rated frequencies. So, the resonance may not occur in the crankshaft and the component is under permissible noise limits, under safe condition.
5. In mass production due to weight reduction the cost of the Compressor is may also reduce.

11. Suggestions

- Change of title from Weight Optimization of crankshaft of AC compressor To Weight Reduction and stress analysis of AC compressor's crankshaft
- Incorporated the theories of failures and vonmises criteria

These suggestions are incorporated in the thesis report

12. A Review Published In Journal

Steel to Gain Market Share in Engine Crankshaft Applications

Material's ability to reduce weight and improve performance encourages growth. DETROIT, MI, October 9, 2000 - The use of bar steel in crankshafts will increase by as much as 50 percent, from 40 to 60 percent of the market share, by mid-2002 because of the material's capability to improve engine performance and reduce weight, at economical costs, according to a recent study by American Iron and Steel Institute (AISI) Bar and Rod Market Development Group (BRMDG). This growth would be at the expense of cast iron, which currently possesses 60 percent of the crankshaft market.

The BRMDG initiated the study, "Steel's Technical and Economic Progress in the Production of Lighter and Smaller Engine Components," in 1998 in response to the automotive industry's quest to increase fuel economy, reduce costs and weight, and improve customer satisfaction. The report provides an in-depth look at how crankshafts produced from bar steel forgings contribute to achieving these goals.

Additionally, the report explains that this potential increase in steel market share is due to innovative steel forming and processing technologies that have advanced the state of the art during the past decade.

12.1 Improved Performance

An engine crankshaft attaches to connecting rods, which fastens to pistons, and transfers engine power to the transmission. Forged steel crankshafts offer a host of benefits compared to cast iron units including greater durability, improved Noise Vibration Harshness (NVH) characteristics and higher load-bearing capacity for torque at lower engine speeds (RPMs), resulting in fuel efficiency improvements.

Automakers currently using forged steel crankshafts include: Ford Motor Co., DaimlerChrysler, Honda, British Leyland, Saab, Volkswagen, Mitsubishi and Volvo.

12.2 Lightweight

As automakers strive to reduce weight in vehicles, the powertrain continues as a key focus in helping achieve that goal. Using forged steel in place of cast iron reduces the mass of the crankshaft by eight percent according to Krupp Gerlach, an automotive component manufacturer that recently completed a study demonstrating the benefits of forged steel compared to cast iron crankshafts in an actual series production engine. The crankshaft's total length is also reduced by nine percent as a result of steel's unique mechanical properties, particularly the ratio of yield point to tensile strength.

The new generation of steels, including vanadium micro alloys and Air-Cooled Forging Steels (ACFSs), features

improved strength and fatigue properties, enhanced machinability and greater consistency due to specific, controlled testing processes (sensitive to defects) performed during each production phase. These improvements enable forgers to produce crankshafts that are near-net shape, reducing production cycle and try-out times and, in turn, cost as there is less need for machining and rework.

12.3 Benefits vs. Costs

Modern engineered steels, coupled with innovative processing and forming technologies, have significantly decreased the manufacturing costs associated with producing forged steel crankshafts.

- Light weight
- High performance
- Greater torsional stiffness
- Improved NVH characteristics
- Greater durability
- Net or near-net shape
- Less machining
- Less or no rework
- Lower rejection rates
- Greater consistency and product repeatability
- Inspection simplicity
- Fewer warranty claims
- Improved customer satisfaction

"As the steel industry continues to make technological advancements, forged steel crankshafts will improve in quality, performance and cost making them even more viable for engine applications," said Jürgen Kneller, author of the study.

References

- [1] Mott, Robert L, "Applied Strength of Materials", 4th edition, Prentice-Hall, 2002, ISBN 0-13-088578-9
- [2] Beer F.P., Johnston E.R., et al, Mechanics of Materials, 3rd edition, McGraw-Hill, 2001, ISBN 0-07-248673-2
- [3] Timoshenko S., Strength of Materials, 3rd edition, Krieger Publishing Company, 1976, ISBN 0-88275-420-3
- [4] Drucker D.C., Introduction to mechanics of deformable solids, McGraw-Hill, 1967.
- [5] Shames I.H., Cozzarelli F.A., Elastic and inelastic stress analysis, Prentice-Hall, 1991, ISBN 1-56032-686-7
- [6] Den Hartog, Jacob P., Strength of Materials, Dover Publications, Inc., 1961, ISBN 0-486-60755-0
- [7] Popov, Egor P., Engineering Mechanics of Solids, Prentice Hall, Englewood Cliffs, N. J., 1990, ISBN 0-13-279258-3