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Validation of Office Chair for BIFMA standard using FEA Tool

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ABSTRACT

The study presents finite element analysis (FEA) based validation of a new chair concept with unique connecting mechanism obeying business & institutional furniture manufacturing association (BIFMA) standard. Business & institutional furniture manufacturing association standard is followed by all commercial and office chair manufacturer for global business. However, it is not followed for local business because chairs manufacturing lacks design innovations. The work is an effort to validate the strength and quality enhancement upon application of business & institutional furniture manufacturing association on chair design. Linear structural analysis of given load case is carried out using finite element analysis software. Hypermesh is used for preprocessing; LS-Dyna for solving mathematical equations and Hyperview is used for result interpretation. Design modifications are incorporated iteratively so that the model fits into the regulation. Comparison of the FEA results and experimental test results was done to verify the obtained results.

Keywords: CAD Model, Material Datasheet, Finite Element Analysis, BIFMA Standard, Nonlinear Structural Analysis

I. INTRODUCTION

In the era focused on technological advancement, office chair is one of the most basic necessities with much influence on the productivity of employees through the extent of comfort and flexibility it offers. Simultaneously, the chair is supposed to be durable to reduce the maintenance cost to the firm. Office chairs are often used by the user working in front of a computer. Office chair is meant to keep the users back in an upright position, facilitating the arm rest on table at 90 degree while the user is sitting in front of a computer or reading and writing on paper. Additionally, the office chair should allow some adjustments on the chair to suit individual's comfort as mostly people have long working hours that require sitting for long duration. A comfortable chair is characterized by ability to switch its positions, height and angle of the back and its strength. The durability of office chair is crucial so that it can also sustain obese individual. Also, backrest strength is crucial as its breakage can cause accidents that may be fatal if it leads to serious head injury.

Business & institutional furniture manufacturing association (BIFMA) standard, provides regulations to ensure the strength and quality of chair suitable for rough use. For validation of chair quality, BIFMA standard provides test set up of process of testing on which finite element analysis (FEA) model [1] is built and respective analysis were run. In this study, all major component of Chair are analysed for Backrest strength test based on BIFMA by using FEA tool.

Development of BIFMA standards is organized by BIFMA Engineering Committee, which involves formation of working groups and canvass lists, drafting & revision of standards, publication and frequent review of accepted standards. The standard is aimed at providing a common basis for evaluating safety, durability, and structural adequacy of a specified furniture, irrespective of construction materials. The standards define specific tests, laboratory equipment and test conditions, and minimum acceptance levels to be used in evaluating products [2]. The analytical solutions considering two type of approach in compliance with static and dynamic stress analysis are performed utilizing Hypermesh for model building (Meshing) , Radioss and LS Dyna [3] for solving and Hyperview for result interpretation [4].

In this study displacement, stress, and strain are investigated and the von Misses stress obtain from the FEA is compared with yield stress of respective material to identify whether chair satisfies the BIFMA standard criteria for given load case. Design modification is performed in the cases of failed tests and followed by similar FEA analysis until the chair pass in given load case. In order to find best possible design under some given circumstances, design method is generally an iterative process. Designer proposes a design based upon old design references and then analytical method is used for verification, where stress and displacement characteristics of the frame are maintained analytically. The validation is often complemented by application of mechanical tests on a prototype. Further, possible modifications are done to improve the design and satisfy unfulfilled requirements. The new design is analysed, and the process is iterated to achieve optimal design. Similar approach has been applied in this study, to obtain office chair design which satisfies BIFMA standard.

Office chair design is validated for all required tests as per BIFMA standard to ensure safety and durability. The studied chair design is based on a new concept, having all structural parts with plastic material. Therefore, it is important to check the strength of chair structure for user safety.

The proposed of work include

- Literature review of requisites of BIFMA standard.
- Study of FEA procedure for BIFMA standard.
- Detailed design and mechanism study of Office chair
- Identification of force transfer path for load case.
- Modeling of chair in finite element software (Hypermesh)
- Application of loading and boundary condition
- Set up of specified test in finite element model
- Submission of finite element model to solver to solve complete algorithm.
- Result interpretation against allowable limit, given test standard using post processing software (Hyperview)
- Von Misses stresses and deflection
- Design modification in chair structure (if required)

II. Literature Review

The material presented in BIFMA standards was developed by the members of BIFMA International and are reviewed by a broad representation of interested parties, government organizations and commercial testing and procurement and interior design organizations [3].

BIFMA standard defines specific tests, laboratory equipment, conditions of test, and recommended minimum level to be used during the test and for safety evaluation, durability evaluation, and to check structural adequacy of general-purpose office chairs. BIFMA standard is first proposed in 1974 by the BIFMA Engineering committee, the subcommittee on chair standards conducts frequent reviews of the BIFMA standard to ensure that tests precisely describe the proper method of evaluations. The reviews produced revisions and additions to the various test procedures that improve the procedures and provide consistency. BIFMA standard follows the guidelines of ANSI (American National Standards Institute) accredited standards developer, and the BIFMA standard was subsequently submitted to the American National Standards Institute for approval as an American National Standard. BIFMA received approval by ANSI [10].

The American National Standards Institute (ANSI) approved the newly developed safety and performance standard for educational seating: ANSI/BIFMA X6.1-2012: Educational Seating – Tests [9]. The Business and Institutional Furniture manufacturers Association's (BIFMA) Seating Subcommittee created industry consensus standard using several test methods from existing ANSI/BIFMA seating standards as a basis. ANSI/BIFMA X6.1-2012 involved the development of several unique tests relevant to the educational environment, including tests for educational products, such as convertible benches, chair desks, and backpack hooks.

Emerging research suggests that asymmetry may be an important new dimension in the design of low back support for chairs. A recent study to quantify the amount of support users wanted in the lower back found that approximately 70% of seated individuals is more comfortable when allowed to self-select asymmetric low back support – more support to the left side of the back or vice versa. Asymmetry may be considered by the designers of lumbar supports for chairs in order to maximize comfort while sitting [7].

Objectives

- To design office chair and study working mechanism of office chair
- To perform design validation of Office chair using FEA
- To test the structural strength of design and check if meets the BIFMA standard
- To perform iterative design modifications and validation using FEA until the design satisfies BIFMA standard

Backrest Strength Test

The purpose of this test is to evaluate the ability of the chair to withstand stresses such as those caused by the user exerting a rearward force on the backrest of the chair.

III. Methodology

The study comprises of three major steps: preprocessing, equation solving using LS-Dyna, and post processing. The details of the steps are illustrated in Fig. 1. The prototype thus obtained goes through experimental testing and results of experimental test should show close approximation with FEA result. Chair should pass the BIFMA standard in experimental testing too. The experimental testing is beyond the scope of our study and is limited to prototype generation.

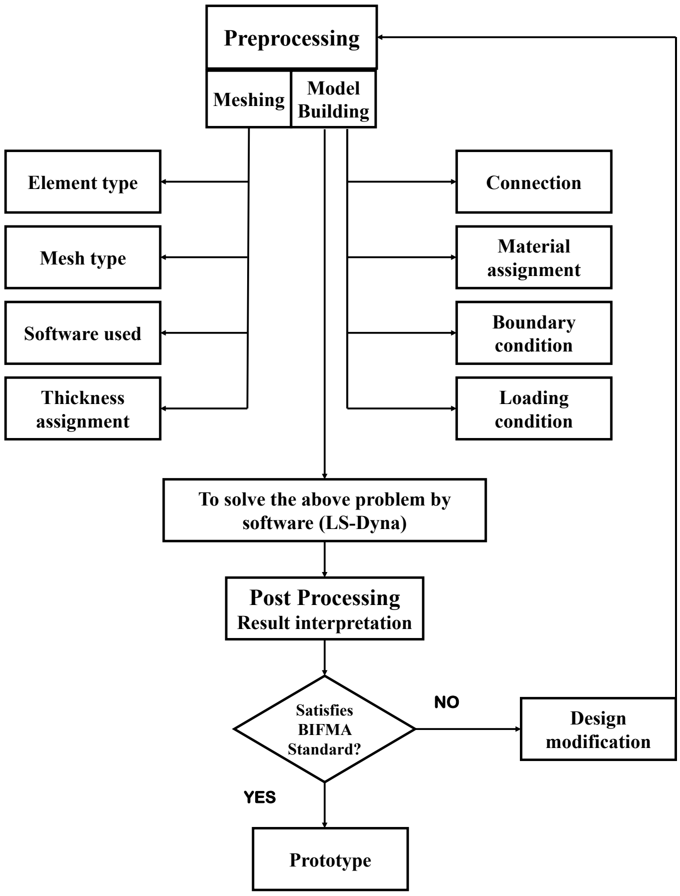


Figure 1: Flowchart of FEA

Test Setup

Step 1

The chair is placed on a test platform in an upright position and the base is restrained from movement, but movement of the backrest or arm of the chair is not restricted. Fig.2. shows one acceptable method of restraining the chair [9].

Step 2

If adjustable features are available, all adjustments should be set at normal use conditions, except for the height adjustable pivoting backrest which should have pivot point set at its maximum height or 406 mm (whichever is less).

Step 3

After making the above adjustment, a point is determined, 406 mm and 452mm above the seat. These points are marked on the vertical centre line of the backrest.

i) If the top of the load bearing structure/surface of the backrest is greater than or equal to 452 mm above the seat, the Centre of the form fitting device should be positioned above the seat.
ii) If the top of the load bearing structure/surface of the backrest is less than 452 mm above the seat, top of the form fitting device should be positioned even with the top of the load bearing structure/surface.
iii) If the unit has a pivoting backrest that stops at a position less than or equal to 20 degrees rearward, form fitting device should be positioned like previous rule. If the unit has a pivoting backrest that stops at a position greater than 20 degrees rearward of the backrest, the centre of the form fitting device should be positioned at the height of the pivoting point.

Step 4

A loading device (front push or back pull) is attached to the horizontal centre of the backrest as determine above. With the backrest at its back stop position, a force is applied that is initial 90 degrees ± 10 degrees to the plane of the backrest. Force is not intended to maintain 90 degrees throughout the loading of the backrest. If the load is applied with a cable and pulley system, the cable must initially be a minimum of 762 mm in length from the attachment point to the pulley.

Acceptance level

There should be no loss of serviceability to the chair. Induced stresses should be less than the yield of the material.

Test procedure

Step 1

A force of 890 N should be applied to the backrest at the backstop position for one minute. If the backrest/tilt lock mechanism will not accept the load due to gradual slipping of the adjustment mechanism during the load application, the backrest is set to its most rearward position, and then the specified load is applied.

Step 2

The load is removed. Fig. 2 shows loading and boundary condition for FEA as per BIFMA.

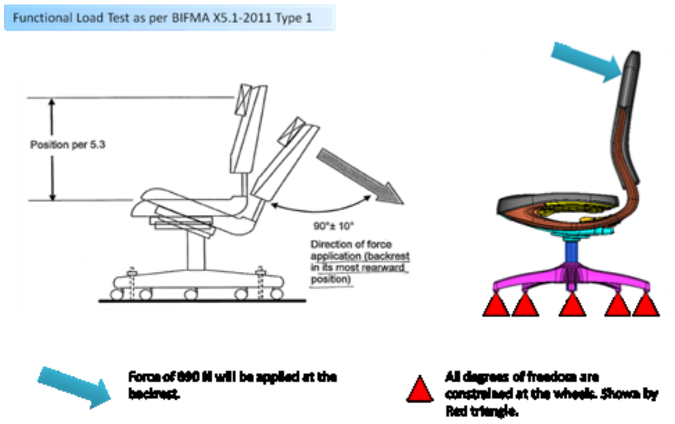


Figure 2: Office Chair test setup (BIFMA standard)

Connection Scheme

When all the components are connected with each other as per given connection scheme, it forms the chair assembly (Fig. 3).

Figure 3: Chair Assembly

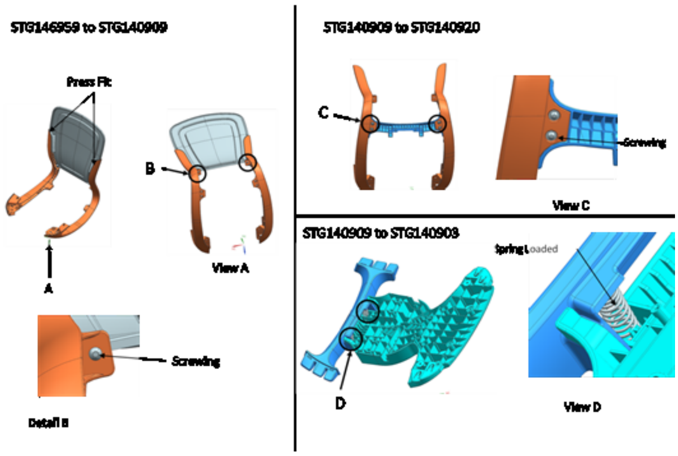


Figure 4. Study of connection scheme

Connections of chair-components are shown in Fig. 4. The major connecting components are screw, spring, heat stakes and contacts.

Finite Element analysis

Preprocessing is a discretization process known as Meshing, where the elements are known as 'Finite' because of their finite size [1]. Hypermesh is FEA software in which engineering problem solution can be obtained at a reasonable financial cost and time duration. The procedure for the is followed by three procedures.
Pre-processing involves fixing of the geometry, importing(if needed) for free edges and reducing the model to a mathematical model using meshing and creating finite elements [10].Geometry Fixing means conversion of the CAD model into FEA geometry, which makes Hypermesh simple to capture all the features in the geometry. Hypermesh is one the most popular tool for meshing, because it is user friendly and each element can be controlled during meshing. The choice of the meshing element type 2-d or 3-d isdone by the user based on his/her past experiences [4].

Step 1

The geometry is imported in Hypermesh and then topology option is selected tovisualize the free edges (if any)as red line and green edges with joint surfaces. The surfaces with free edges are fixed by the creation of surface. Toggle edge option is used for fixing edges. Upon cleaning up the surfaces some of the green edges are suppressed so to get a good quality mesh with good flow of the elements and lesser failed elements. The suppression of the edges are made according in such a way that the elements do not collapse. The editing of the shared edges are based on the behavior of the finite elements and experience in analysis.
Hypermesh follows below unit system.
Displacement: mm
Modulus: MPa
Force: Newton
Mass: Tonne
Density: Tonne/mm^3

Step 2

The cleaning of the surfaces isdone to mesh the geometry. Before the mesh the unnecessary parts such as the nut bolts, bushings, and spherical joints are eliminated. As the nut bolts, rigid joints can be replaced by the 1-d rigid and joints in Hypermesh. This way saves the meshing time and errors coming from meshing the parts. The links connections were kept for the analysis.

Fig. 5 shows meshing of Seat Base and Spine with reliable elements and assembly of meshed chair.

Figure 5. Preprocessing/Meshing of office chair

Step 3

After meshing and material assignment, mass is checked. Mass of FE model should match with actual model. In our study, mass of actual model is 10.98 Kg whereas mass of FE model is 10.73 Kg (Fig. 6.). As, there is no objectionable difference in mass hence the meshing process is right.
Actual mass = 10.98 Kg
Mass of finite element model is given in below image Fig. 6.

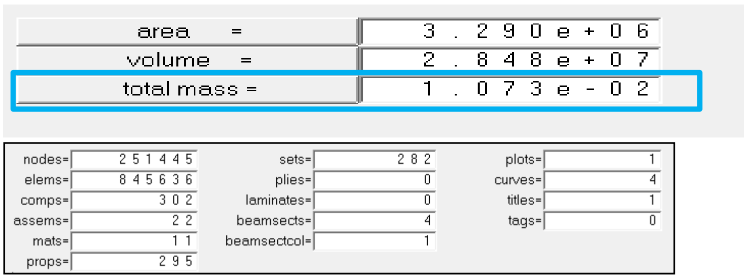


Figure 6. Mass of finite element Model and related details

Analysis involves definition of material properties, geometry, boundary conditions and loading conditions. These are the steps in setting up the analysis in order to be followed with a solution needed. In this case nonlinear static analysis is carried out with given force at given location as per BIFMA statdard. Detailed description about material assignment is given in Fig. 7 and Fig. 8. Shows datasheet of material i.e. PA6.

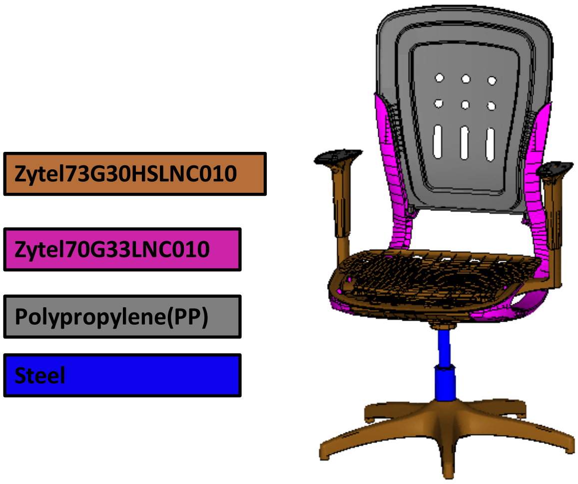


Figure 7. Material wise representation of office chair

DuPont™ Zytel® 70G33L NC010

NYLON RESIN

Product Information

Common features of Zytel® nylon resin include mechanical and physical properties such as high mechanical strength, excellent balance of stiffness and toughness, good high temperature performance, good electrical and flammability properties, good abrasion and chemical resistance. In addition, Zytel® nylon resins are available in different modified and reinforced grades to create a wide range of products with tailored properties for specific processes and end-uses. Zytel® nylon resin, including most flame retardant grades, offer the ability to be coloured.

The good melt stability of Zytel® nylon resin normally enables the recycling of properly handled production waste. If recycling is not possible, DuPont recommends, as the preferred option, incineration with energy recovery (-31kJ/g of base polymer) in appropriately equipped installations. For disposal, local regulations have to be observed.

Zytel® nylon resin typically is used in demanding applications in the automotive, furniture, domestic appliances, sporting goods and construction industry.

Zytel® 70G33L NC010 is a 33% glass fiber reinforced polyamide 66 resin for injection moulding.

General information	Value	Unit	Test Standard
Resin Identification	PA66-GF33	-	ISO 1043
Part Marking Code	>PA66-GF33<	-	ISO 11469
Rheological properties	**dry / cond**	**Unit**	**Test Standard**
Viscosity number	145 / *	cm³/g	ISO 307, 1157, 1628
Moulding shrinkage, parallel	0.3 / *	%	ISO 294-4, 2577
Moulding shrinkage, normal	1.1 / *	%	ISO 294-4, 2577
Mechanical properties	**dry / cond**	**Unit**	**Test Standard**
Tensile Modulus	10500 / 8000	MPa	ISO 527-1/-2
Stress at break	200 / 140	MPa	ISO 527-1/-2
Strain at break	3.5 / 5	%	ISO 527-1/-2
Flexural Modulus	9300 / 6210	MPa	ISO 178
Flexural Strength	290 / 200	MPa	ISO 178
Tensile creep modulus			ISO 899-1
1h	* / 8000	MPa	
1000h	* / 5500	MPa	
Charpy impact strength			ISO 179/1eU
23°C	85 / 100	kJ/m²	
-30°C	70 / 75	kJ/m²	
Charpy notched impact strength			ISO 179/1eA
23°C	13 / 17	kJ/m²	
-30°C	10 / 10	kJ/m²	
-40°C	10 / 10	kJ/m²	
Izod notched impact strength			ISO 180/1A
23°C	12 / 15	kJ/m²	
-30°C	10 / 10	kJ/m²	
-40°C	10 / 10	kJ/m²	

Figure 8. Material data sheet of Spine

Post-processing involves use of the graphical interface and a technique in Hyperview tool to display results after the analysis is performed. Coloured spectrums are used to display the results for displacement and stresses as per the command [11].

After analysis force is checked in output file. If the output force is equal to given force then it validates the processes used are right and result complies with the force.

Base Model

Force Vs time in output file is shown in Fig. 9, which is close to the applied force in input file used for analysis.The obatined result shows deflection of chair due to applied load is 451.67 mm which is in backrest of chair. Deflection is within limit but, Induced von Misses stress is175.34 MPa which is in spine of chair. Induced stresses are more than the yield of material which is 140 MPa. In the Fig. 10. it is visible where stresses are existing. The reason of stress is because bulging is happening in the spine. Which suggeststhat spine in that area is very weak and geometry is not correct. Cross sectional view of Spine is shown in fig. 11. Given fig.11 shows there is changes at shown location. Chair may break due to applied load. And hence chair does not fullfill the BIFMA requirement. Hence, there is modification in spine to reduce the von Misses stresses.

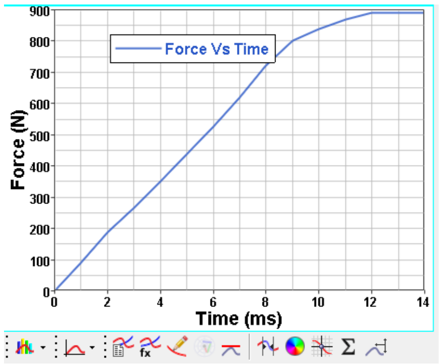


Figure 9. Force Vs time graph

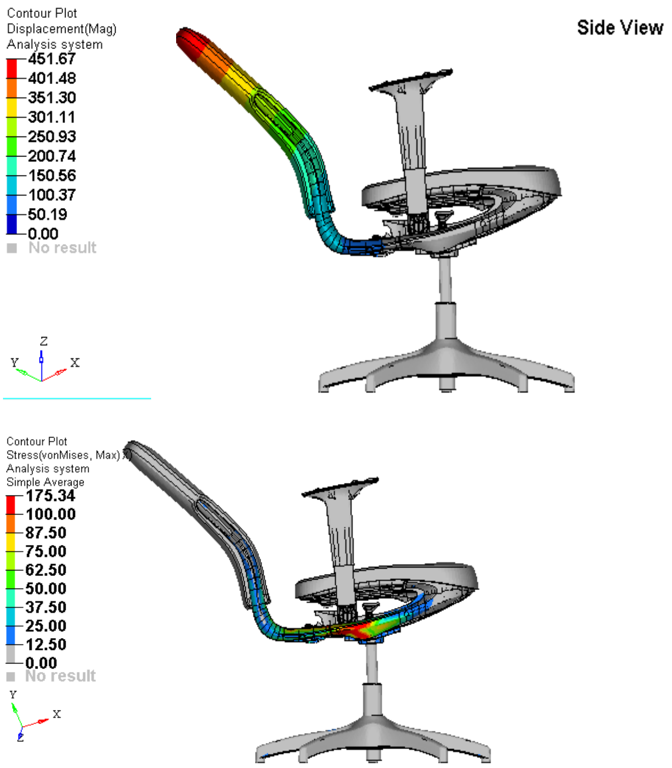


Figure 10. Induced deflection and stresses due to applied force (890N)

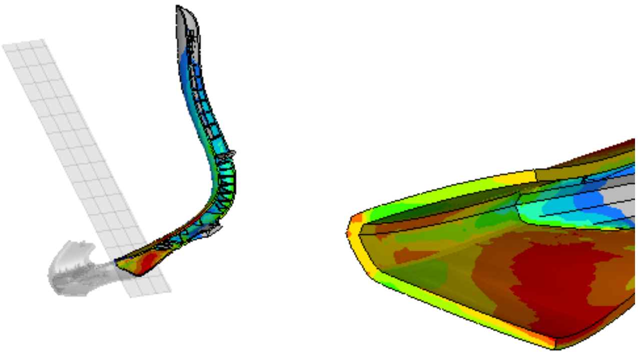


Figure 11. Crossectional view of spine

From above results fig.10 it is clear that Spine may fail during operation. From the first iteration it is obvious that in chair assembly main culprit from design point of view is Spine. Hence design changes are made in Spine and simulation is run to check stresses in new design. And this process (Fig. 1) is followed until Spine got pass as per BIFMA standard.

Variant 1

Design modification is made in Spine of base model (Fig. 12.) and simulation is run to check stresses in new design with changed spine refered as Variant1.

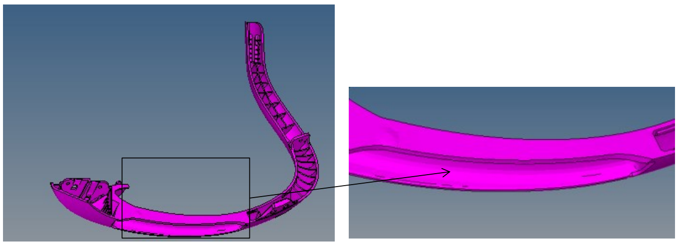


Figure 12. Modified Spine : Variant1

The changes made in spine are shown in Fig. 12. In the base model spine cross section is of "v" shape which has less stiffness with more bending behavior. Now the spine structure is like "L" shape with more stiffness and less bending because the material is added in failure region. In base model thickness of base is 2.5mm but in variant1, thickness of base is more than 4mm. Addition material increase the stiffness of structure because it increases the resistance against applied forces. All FEA method like preprocessing, model building, solving and post processing is done with modified Spine and result is observed (Fig. 13). The deflection in variant1 is 352.86 mm and induced von Misses stress is159.76 MPa which is again more than the yield of material. Induced stresses are in spine and at the same place as base model. But magnitude of stresses reduced drastically, which shows that modification in spine is done at right place. However it doesn't pass the standard but it gives clear idea about the area of improvement i.e. Spine. Therefore, Spine is modified again for right result.

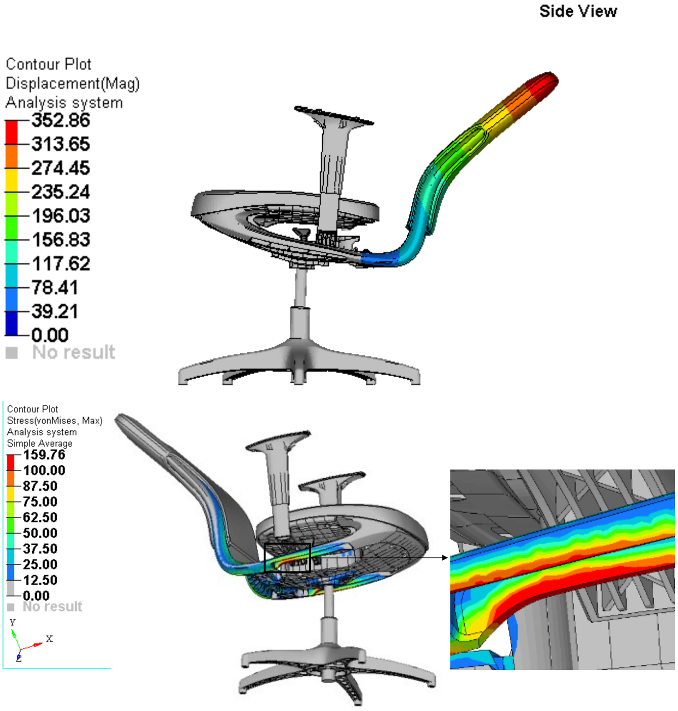


Figure 13. Induced deflection and stresses -Variant 1

Variant 2

Design modification is made in Spine of Variant1 (Fig. 14) and simulation is run to check stresses in new design with changed spine refered as Variant2

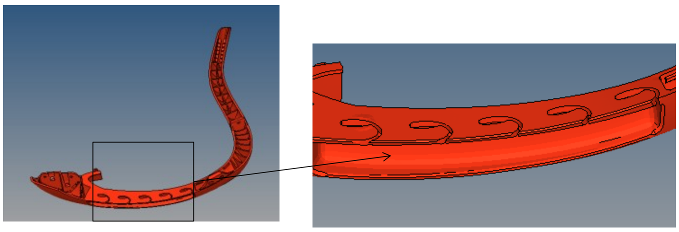


Figure 14. Second Modified Spine: Variant2

CAD of Variant2 (Fig. 14.) illustrates that the critical area where stresses are high has been changed. The shape of spine is same as Variant1 but there some changes in critical region to balance deflection and stresses. The critical region is design in such a way that the spine will bend initially when load is applied but after 5mm of deflection their teeth which are going to lock with base of Spine and resist further bending. These teeth are thicker than base and provides good stiffness in this region which is critical. Due to these extra thick teeth the Spine becomes much stiffer than base model and variant1 and hence gives better result than Base Model and Variant1.

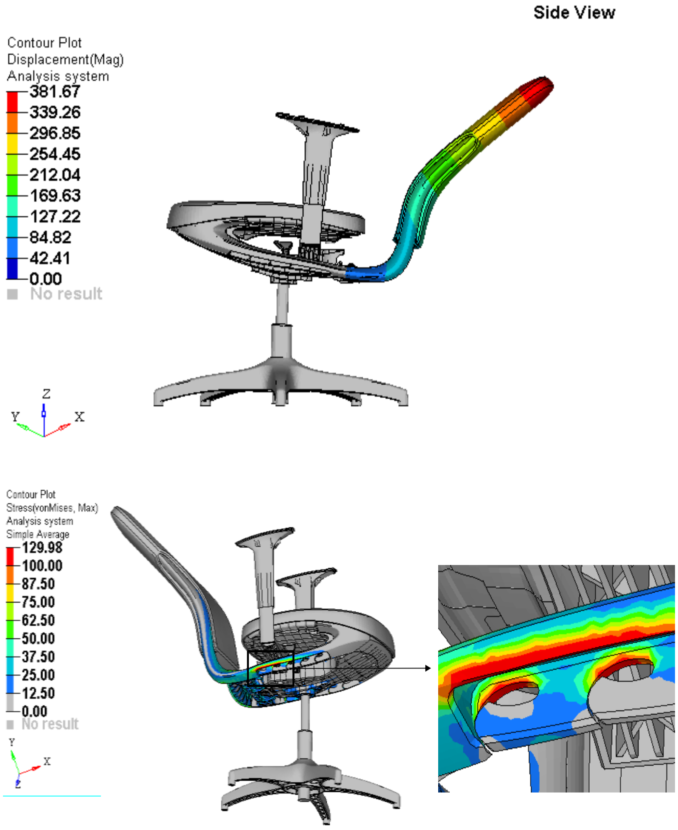
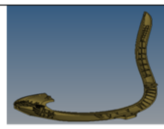
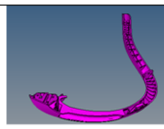
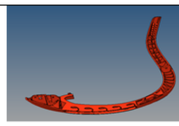
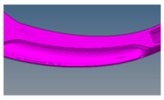
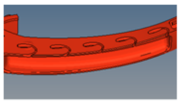


Figure 15. Induced deflection and Stresses-Variant 2

Deflection due to applied load in Variant2 is 381.67mm and von Misses stress is129.98 MPa. Induced stress is less than the yield of material and the chair may pass the BIFMA standard in case of Variant2.

FIG. 16. COMPARATIVE ANALYSIS OF BASE MODEL, VARIANT1 AND VARIANT2

Component	***Base model***	***Variant1***	***Variant2***
Spine			
Enlarged View			
Deflection (mm)	**451.67**	**352.86**	**381.67**
Von Misses Stress (MPa)	**175.34**	**159.76**	**129.98**

The comparative analysis of Base model, Variant1 and Variant 2 depicts the improvement in the stresses w.r.t. design modification (Fig. 16). Final modification – Variant2 satisfies the BIFMA standard. Further, the generated model is subjected to the experimental testing and the results are validated. Due to data confidentiality policies of project funding bodies, the experimental test results are not presented here.

IV. CONCLUSION

BIFMA standard is used to design the office chair and it is validated using FEA tools. The methodology consisted of Pre-processing using Hypermesh, analysis using LS-Dyna, and post-processing using Hyperview. Upon iterative modifications and validations, a final chair-model satisfying the BIFMA standard is obtained. The final model generation mainly involved Spine concentric modification and analysis. Prototype of final model is manufactured and experimental testing is done by funding bodies. However, experimental testing is beyond the scope of this study. FEA results and experimental results are compared and it showed close approximation with each other. Further, minor changes are made in spine to improve results after experimental testing.

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VI. REFERENCES

[1]. Bellingar, T.A., Benden, M.E., New ANSI/BIFMA Standard for Testing of Educational Seating. Ergon.Des. Q. Hum. Factors Appl., 2015, 23, pp. 23-27.
[2]. Springer, T., The future of ergonomic office seating. Knoll Workplace Res., 2010.
[3]. Zhang, J., Mason, M., Hodgson, A., Guo, B., et al., An inter-laboratory comparison study of the ANSI/BIFMA standard test method M7. 1 for furniture, in: Proceedings of the 9th International Healthy Buildings Conference and Exhibition, 2009, pp. 13-17.
[4]. XIONG, Z., LUO, H., Preprocessing technology of FEA based on HyperMesh software J. Drain. Irrig. Mach., 2006, 3, pp. 009.
[5]. Gantner, P., Bauer, H., Harrison, D.K., De Silva, A.K., FEA-simulation of bending processes with LS-DYNA, in: Proceedings of 8th International LS-Dyna Users Conference, Troy, MI, USA, 2004.
[6]. Kurowski, P.M., Finite element analysis for design engineers, SAE Technical Paper, 2004.
[7]. Dar, F.H., Meakin, J.R., Aspden, R.M., Statistical methods in finite element analysis. J. Biomech., 2002, 35, pp. 1155-1161.
[8]. Mao, K.M., Sun, C.T., A refined global-local finite element analysis method. Int. J. Numer. Methods Eng., 1991, 32, pp. 29-43.
[9]. Citipitioglu, E., Nicolas, V.T., Tolani, S.K., Finite element method in stress analysis practice, SAE Technical Paper, 1977.
[10]. Eckelman, C.A., Erdil, Y.Z., Performance Test Method for Intensive Use Chairs-FNEW 83-269: A Description of the Test Method with Drawings. n.d.