ANALYSIS OF ALUMINIUM ALLOYS FOR THEIR VIBRATION CHARACTERISTICS USING FEA

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Abstract: Study of Finite element analysis of aluminium alloys (380,B390,AZ91D,AM60B,Al6061-T6) for their vibration characteristics have been investigated. Effect of alloying for their chemical, physical & mechanical properties has been studied. Various parameters such as alloy composition, ultimate tensile stress and ductility of Al alloys have been studied. It is clear from the investigation that, there is an improvement in the mechanical properties by the addition of certain alloying elements. An attempt has been made to analyze the stress distribution (Von-Misses) using ANSYS. The results for the above alloys revealed that, the stress distribution and deformation decreases in 380 alloys. In addition, ANSYS results confirm the experimental value. Aluminum (Al) die casting alloys have a specific gravity of approximately 2.7 g/cc, placing them among the lightweight structural metals. The majority of die castings produced worldwide are made from aluminum alloys. Six major elements constitute the die cast aluminum alloy system: silicon, copper, magnesium iron, manganese, and zinc. Each element affects the alloy both independently and interactively. This aluminum alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for 11 aluminum die casting alloys. This data can be used in combination with design engineering tolerance guidelines for aluminum die casting and can be compared with the guidelines for other alloys in this section aim the design engineering section. The effect of Ti and Mg on the damping behavior of in situ aluminum composites damping capacity of in situ TiB_2 particulate reinforced aluminum composites with Ti and Mg excess were investigated. The composites were fabricated with an exothermic reaction process via K_2TiF_4 and KBF_4salts. The damping behavior of materials over a temperature range of 30–300 °C was investigated by using a dynamic mechanical thermal analyzer. Experimental findings indicate that the damping capacity of composites with Ti, Mg excess, respectively is lower than that of Al/5 wt.% composite when temperature is below 180 °C and is higher than of Al/5 wt.% composite above 180 °C. The main effects of these elements are the formation of thin layers on TiB_2 particulates, which resulted in the change of damping capacity.

***Index Terms* – FEA, Aluminium alloy, Vibration, Material Properties.**

I. INTRODUCTION

Aluminum (Al) die casting alloys have a specific gravity of approximately 2.7 g/cc, placing them among the lightweight structural metals. The majority of die castings produced worldwide are made from aluminum alloys. Six major elements constitute the die cast aluminum alloy system: silicon, copper, magnesium iron, manganese, and zinc. Each element affects the alloy both independently and interactively. This aluminum alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for 11 aluminum die casting alloys. This data can be used in combination with design engineering tolerance guidelines for aluminum die casting and can be compared with the guidelines for other alloys in this section aim the design engineering section. Aluminum is a white silverish metal with very strong resistance towards corrosion. Being easily malleable, highly reflective, and machinable, this light metal relatively of 2.7 specific gravity is known as a good conductor of heat and electricity. To form alloys it is often mixed with other metals like manganese, zinc, copper, magnesium or silicon. These Aluminium alloys carry the qualities of both the elements and thereby make the alloy better than the constituent elements in many regards. They resist corrosion far effectively and are lighter as well. Aluminium alloy metal is never found existing independently in the environment. Owing to the fact that aluminum is a very reactive metal, it is always found as a compound with other elements like silicon and oxygen and thus has to be extracted from these compounds first. Then it is purified through the Bayer's process to get alumina or the Aluminium oxide. After procuring alumina, Aluminium is extracted by the Hall Heroult process in which it is mixed well with a cryolite and is then subjected to electrolysis. A lot of energy is spent in this entire procedure and is a strenuous exercise for the Aluminium alloy manufacturers.

The extraction process used by the Aluminium alloy manufacturers is quite comprehensive. The very first step requires the raw material to be charged in the furnace and quality control is done. Then, the alloying element is added to it and checked on spectrometer. Firstly, sample checking is done and then it undergoes the process of de- grassing, grain refining and the final sample checking. After this, it is subjected to ingot casting before it is color coded and thus is ready to dispatch

Guo-cong li [1] presented specific damping characteristics of certain steels, cast irons and other metals damping capacity of a wide range of engineering metals has been determined at direct cyclic stresses up to the fatigue limit. A recently developed damping apparatus was used in which the specimen vibrated in its fundamental free-free longitudinal mode, driven by a magnetostrictive vibrator. The energy dissipation was determined from the rate of rise of temperature at different sections of the specimen. Below the cyclic stress sensitivity limit, δL, the damping of ferromagnetic materials was principally due to the magneto mechanical effect, i.e. the stress-induced movement of domain boundaries. The magneto mechanical damping mechanism is non-damaging and usually causes a peak in the damping-stress relationship. Suppressing the magneto mechanical effect by applying a saturating magnetic field showed that the damping of plain carbon steels was virtually independent of stress provided δL was not exceeded. Above this stress, the damping increased rapidly owing to micro plastic strain and was a function of stress history. Re-testing at lower amplitudes showed that the effective value of δL was considerably less than that for virgin material. Ageing at room temperature allowed some recovery. A specific damping capacity of 26 % was recorded for Coniston, a commercial high-damping manganese/copper alloy. This was exceeded only by a coarse flake graphite cast iron and annealed nickel (magneto mechanical). The damping of cast irons is due to the shape of the graphite inclusions rather than to the quantity of free graphite in the steel matrix. The aluminium and copper alloys gave the lowest values of damping, but all were markedly stress-dependent except Duralumin. Brasses with a small free lead content had considerably higher damping than otherwise identical but lead-free materials. **R.D.Adams et.al, [2]** presented damping capacity of high strength-damping aluminum alloys prepared by rapid solidification and powder metallurgy process. Two kinds of high strength-damping aluminum alloys (LZ7) were fabricated by rapid solidification and powder metallurgy (RS-PM) process. One material was extruded to profile aluminum directly and the other was extruded to bar and then rolled to sheet. The damping capacity over a temperature range of 25–300 °C was studied with damping mechanical thermal analyzer (DMTA) and the microstructures were investigated by optical microscopy (OM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The experimental results show that the damping capacity increases with the test temperature elevating. Internal friction value of rolled sheet aluminum is up to 11.5×10−2 and that of profile aluminum is as high as 6.0×10−2 and 7.5×10−2 at 300 °C, respectively. Microstructure analysis shows the shape of precipitation phase of rolled alloy is more regular and the distribution is more homogeneous than that of profile alloy. Meanwhile, the interface between particulate and matrix of rolled sheet alloy is looser than that of profile alloy. Maybe the differences at interface can explain why damping capacity of rolled sheet alloy is higher than that of profile alloys at high temperature (above 120 °). A **Hazrati Niyari et.al, [3]** showed damping is a useful parameter for controlling vibration and movement in the design of the structure. In many structural applications, damping provides sufficient energy dissipation by suppressing resonant amplitudes of vibration. The present paper is concerned with the utilization of the finite element-based modal strain energy method for predicting the modal loss factor of laminated composite beams. Finite element analysis is performed to study the effects of layer wise in-plane displacements on specific damping capacity for Duocel aluminum foam core sandwich composite beams. The core was sandwiched between two face sheet graphite/epoxy laminates with a constant thickness. A numerical modeling of the damping response in axis symmetrical conditions was performed using the ABAQUS commercial software. All calculations about the theoretical approach were performed using the MATLAB Version 7.8 (Mathworks Inc.). A good match between the finite element modeling and the theoretical approach was obtained. **Yijie Zhang et.al,[4]** presented effect of Ti and Mg on the damping behavior of in situ aluminum composites damping capacity of in situ TiB2 particulate reinforced aluminum composites with Ti and Mg excess were investigated. The composites were fabricated with an exothermic reaction process via K2TiF4 and KBF4salts. The damping behavior of materials over a temperature range of 30–300 °C was investigated by using a dynamic mechanical thermal analyzer. Experimental findings indicate that the damping capacity of composites with Ti, Mg excess, respectively is lower than that of Al/5 wt.% composite when temperature is below 180 °C and is higher than of Al/5 wt.% composite above 180 °C. The main effects of these elements are the formation of thin layers on TiB2 particulates, which resulted in the change of damping capacity.

II. EXPERIMENTAL SET UP

The experimental procedure involves the following steps to analyze the feasibility of Alumunium alloy for their vibartional characteristics using a software package that is Finite Element Analysis (FEA)

1. ***Aluminum Extrusion Method Used to Extract Aluminum from Its Source***: Aluminium extrusion is one of the most preferred method of manufacturing the complicated profile shapes to be used in the industry of aeronautics, construction as well as automotive. Under this process, the billet of aluminum is basically pushed in the die land in order to attain the product shape with the help of RAM. During this process, the most challenging thing in front of the manufacturers is about ensuring the mold cavity of the aluminum alloys in the best possible way, however, temperature is kept quite low. Aluminium extrusion process also involves application of high pressure so that thermo- mechanical process can be undertaken in the most appropriate way and resultantly, we get small deformations of solid die. The deformations as well as stresses in many cases, affect badly the requirement of specific dimensions which is a necessary condition for the extruded profile of aluminium alloys. Through this process of aluminium extrusion manufacturer, aluminium alloys are added with the properties including shear temperature as well as thinning. Both of these properties help largely in the application of aluminium alloys in different uses including packaging, purity process, and electrical transmission, construction of building materials, water treatment, and heat sinks for the electrical appliances like CPUs and transistors and powered aluminium alloys for the purpose of paint. The wide application of aluminium alloys is just because of its versatile characteristics that make the alloys highly usable. First of all, aluminium alloys are highly durable, lightweight, soft and malleable in nature. On the other side they have high resistance to corrosion and are good conductors of electrical as well as thermal conductivity. As far as density of aluminium alloys is concerned, they have high density and are highly ductile in nature. In other words, all these characteristics make aluminiumalloys a versatile substance to be used for different applications

2. ***Selecting Aluminum Alloys:*** Aluminum (Al) die casting alloys have a specific gravity of approximately 2.7 g/cc, placing them among the lightweight structural metals. The majority of die castings produced worldwide are made from aluminum alloys. Six major elements constitute the die cast aluminum alloy system: silicon, copper, magnesium, iron, manganese, and zinc. Each element affects the alloy both independently and interactively. This aluminum alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for 11 aluminum die casting alloys. This data can be used in combination with design engineering tolerance guidelines for aluminum die casting and can be compared with the guidelines for other alloys in this section and in the design engineering section.

Alloy A360 (ANSI/AA A360.0) offers higher corrosion resistance, superior strength at elevated temperatures, and somewhat better ductility, but is more dive cult to cast. While not in wide use and difficult to cast, alloy 43 (ANSI/AA C443.0) offers the highest ductility in the aluminum family. It is moderate in corrosion resistance and often can be used in marine grade applications.
Alloy 390 (ANSI/AA B390.0) was developed for automotive engine blocks. Its resistance to wear is excellent; its ductility is low. It is used for die cast valve bodies and compressor housings in pistons.
The different alloying elements and their effects were discussed in the following Table 1

III. RESULTS AND DISCUSSION

The aim of the analysis is usually to determine whether the element or collection of elements, usually referred to as a structure, can safely withstand the specified forces. This is achieved when the determined stress from the applied force(s) is less than the ultimate tensile strength, ultimate compressive strength or fatigue strength, the material is known to be able to withstand, though ordinarily a factor of safety is applied in design. The factor of safety is a design requirement for the structure based on the uncertainty in loads, material strength (yield and ultimate), and consequences of failure. Often a separate factor of safety is applied to the yield strength and to the ultimate strength.

Factor of Safety = Ultimate Tensile Strength/Maximum allowable stress

When performing stress analysis, a factor of safety is calculated to compare with the required factor of safety. The factor of safety is a design requirement given to the stress analyst. The Analyst calculates the design factor. Margin of safety is another way to express the design factor.

ALLOYING ELEMENT	EFFECTS
1.Copper,Cu	Increase tensile strength and hardness but reduces ductility. its content does not exceed 9%
2.Silicon,Si	Gives low shrinkage value, casting fluidity, clean sharp castings ,good ductility, better resistance to corrosion, good mechanical properties used from8-14%
3.Manganese,Mn	Improves resistance to corrosion and renders metal readily weld able. added up to 1.5%
4.Aluminium,Al	Light in weight and gives equal strength to steel when alloyed in proper proportions.

Design Factor = Ultimate Tensile Strength / Maximum Calculated Tensile Stress

A key part of analysis involves determining the type of loads acting on a structure, including tension, compression, shear, torsion, bending, or combinations of such loads.

Sometimes the term stress analysis is applied to mathematical or computational methods applied to structures that do not yet exist, such as a proposed aerodynamic structure, or to large structures such as a building, a machine, a reactor vessel or a piping system. The finite element method is a numerical method for solving problems of engineering and mathematical physics. It is useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained.FEA is a technique that discretizes a given physical or mathematical problem into smaller fundamental parts called elements. An analysis of each element is conducted. A solution to the problem as a whole is obtained by assembling the individual solutions of the elements. Complex problems can be tackled by dividing the problem into smaller and simpler problems that can be solved using existing mathematical tools.

- Consider an element of a continuum (represented by a cube)
- The nodal points are defined as the end points of the edges
- The elements are connected through the nodal points
- Any deformation of the body caused by external loads induces certain displacements at the nodes

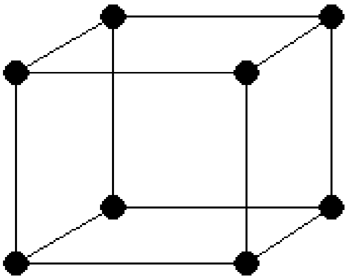


Fig 1 Single Cubic Element of the Continuum

1. 380 ALLOY & ALLOY 390

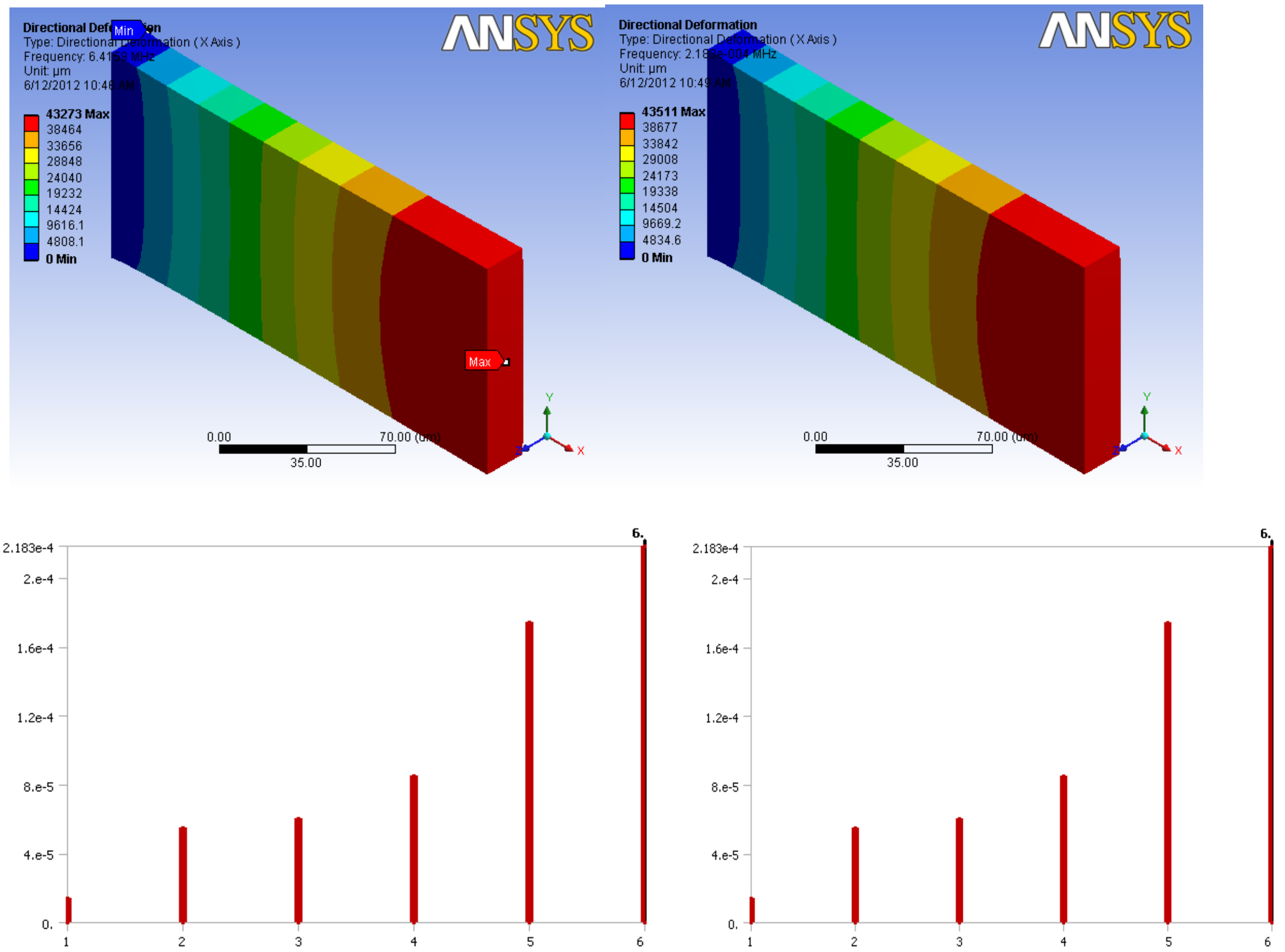
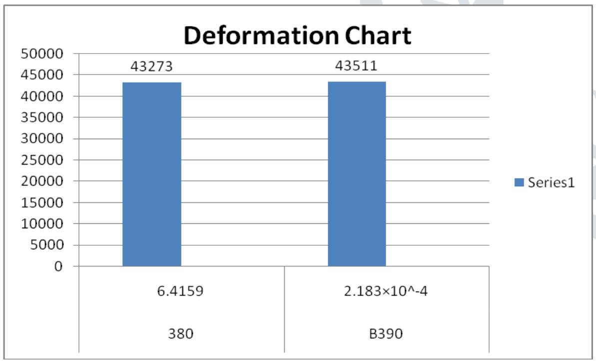


Fig 2 Frequency at each calculated mode

2. ALLOYS & THEIR DEFORMATION



Alloy no	Alloy	Frequency, MHz	Deformation, µm
1	380	6.4159	43273
2	B390	2.183×10^-4	43511

IV CONCLUSIONS

The work presented in this thesis was aimed at the study of effect of vibration characteristics of alloys. From this exhaustive study following conclusions were made

- The presentation and discussion of the results of effects of vibration on the alloys.
- From the analysis it is concluded that as the copper and silicon content in the alloys increases deformation decreases inversely.
- The boundary conditions, material properties and load are added interactively.
- The harmonic analysis has been made to determine frequency characteristics.
- The analysis program reads the data from the input file processes the data and creates the output file containing the nodal displacements and nodal stress values of different stresses.
- Young's Modulus and the ultimate tensile strength of the 380 alloys increase with the increase in copper and silicon content.

- Deformation is least in the case of 380 alloys.
- ANSYS results confirm the least deformation in case of 380 alloys.
- Since ANSYS is a commercial available numerical tool it has been employed to determine the deformation characteristic of alloys.

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