Design And Analysis of Escalator Frame

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Abstract: The main objective of this study was to explore weight reduction opportunities for a structural steel escalator frame. This thesis is focused on the comparative analysis of escalator frame, with the aim of extending its life, by taking results from the simulation as a feedback. This has entailed performing a detailed load analysis. Therefore, this study has dealt with two subjects, first, static load stress analysis of the escalator frame, and second, optimization for weight. The conventional material is optimized with aluminum alloy material and titanium for the same loads. In this project, structural systems of escalator frame can be easily analyzed using finite element techniques. So first a proper finite element model is developed using software pro/e wildfire. Then the finite element analysis is done to determine the total deformation in the existing escalator frame for the given loading conditions using finite element analysis software ansys workbench. In the first part of the study, the static loads acting on the escalator are determined, after that the work is carried out for material optimization. Based on the observations of the static finite element analysis (fea) and the load analysis results of the three materials, the suitable material was selected. The results were also used to determine the total deformation for the three materials

Keywords: escalator, fea, aluminium alloys, pro/e, ansys

I.INTRODUCTION

An escalator is a moving staircase – a conveyor transport device for carrying people between floors of a building. The device consists of a motor-driven chain of individually linked steps that move up or down on tracks, allowing the step treads to remain horizontal. Escalators are used around the world to move pedestrian traffic in places where elevators would be impractical. Principal areas of usage include department stores, shopping malls, airports, transit systems, convention centers, hotels, arenas, stadiums, train stations (subways) and public buildings.

Escalators have the capacity to move large numbers of people, and they can be placed in the same physical space as a staircase. They have no waiting interval (except during very heavy traffic), they can be used to guide people toward main exits or special exhibits, and they may be weatherproofed for outdoor use. A non-functioning escalator can function as a normal staircase, whereas many other conveyances become useless when they break down.

Fig 1. Model of the Escalator and its frame

The track system is built into the truss to guide the step chain, which continuously pulls the steps from the bottom platform and back to the top in an endless loop. There are actually two tracks: one for the front wheels of the steps (called the step-wheel track) and one for the back wheels of the steps (called the trailer-wheel track). The relative positions of these tracks cause the steps to form a staircase as they move out from under the comb plate. Along the straight section of the truss the tracks are at their maximum distance apart. This configuration forces the back of one step to be at a 90-degree angle relative to the step behind it. This right angle bends the steps into a shape resembling a staircase. At the top and bottom of the escalator, the two tracks converge so that the front and back wheels of the steps are almost in a straight line. This causes the stairs to lay in a flat sheet like arrangement, one after another, so they can easily travel around the bend in the curved section of track. The tracks carry the steps down along the underside of the truss until they reach the bottom landing, where they pass through another curved section of track before exiting the bottom landing. At this point the tracks separate and the steps once again assume a staircase configuration. This cycle is repeated continually as the steps are pulled from bottom to top and back to the bottom again. The steps themselves are solid, one piece, die-cast aluminum or steel. Yellow demarcation lines may be added to clearly indicate their edges. In most escalator models manufactured after 1950, both the riser and the tread of each step is cleated (given a ribbed appearance) with comblike protrusions that mesh with the comb plates on the top and bottom platforms and the succeeding steps in the chain. Seeberger- or "step-type" escalators (see below) featured flat treads and smooth risers; other escalator models have cleated treads and smooth risers. The steps are linked by a continuous metal chain that forms a closed loop. The front and back edges of the steps are each connected to two wheels. The rear wheels are set further apart to fit into the back track and the front wheels have shorter axles to fit into the narrower front track. As described above, the position of the tracks controls the orientation of the steps.

II.LITERATURE REVIEW

There are many claims to the invention of the Escalators, but it is like that it was known, at least in some place in ancient times.

Here some of the milestones in the history of the device.

Invention and manufacturers:

Nathan Ames, a patent solicitor from saugus, Massachusetts, is credited with patenting the first "Escalator" in 1859.He noted that steps could be upholstered or made of wood, and suggested that the units might benefit the infirm within a household use.

In 1889,leamon Souder successfully patented the "stairway", an escalator type device that featured a "series of steps and links joined".

In 1892, Jesse W. Reno patented the "Endless Conveyor or Elevator"(he actually called it the "inclined elevator")

Osman Altuğ AKYOL described about strength analysis of the frame of the escalator using the finite element method and calculation of the drive system.

In this study, by doing stress analyses for static loading conditions of a frame of escalators, determining the critical points of frame and optimization are aimed.

For the stress analysis, firstly, the loads effecting on the structure are calculated. Then the frame is modeled. After introducing the material properties, loads effecting on frame and the boundary conditions to the software (ANSYS), the stress analysis is performed.

The results obtained by the analyses are compared with the strain gauge measurement values.

American Public Transportation Association described about Heavy-Duty Transportation System Escalator Design Guidelines.

This design guideline is the result of the combined efforts of the members of the APTA Elevator and Escalator Technical Forum over the past several years.

The objective is to address the specific heavy-duty escalator needs of North American transportation systems.

It is intended as a guideline of technical provisions for the design and construction of escalators that can provide safe, reliable service in the harsh, heavy-usage, high-abuse environment of transportation systems.

Membership of the Technical Forum includes transportation systems, consultants and escalator/component manufacturers.

There is various type of escalator given below:

Escalators like moving walkways, powered by constant speed altering current motors and move at approximately 1-2 feet (0.30-0.61m) per second.

The maximum angle of inclination of an escalator to the horizontal floor level is 30 degrees with a standard rise up to about 60 feet (18m).

A single width escalator travelling at about o.5m(1.5 feet) per second can move about 2000 people per hour.

Escalators are available with design features such as dual speed (90 and 120 fpm), mat operation and flat steps.

The data on the escalator motor is as follows:

19HP, 460V, 3 Phase 60Hz, 1170 RPM, Frame type 280 Lock motor KVA Code H (6.3 – 7.09) 20.1 Amp, Full load current

Modern escalators have single piece aluminum or steel steps that move on a system of tracks in a continuous loop layout.

The costs of these devices to make automatic operation of escalators vary from \$8000 - \$10000 for uni-directional operation and \$16000 - \$18000 for reversible escalators.

Escalators have three typical configuration options:

Parallel (up and down escalators "side by side or separated by a distance", seen often in multilevel motion picture theatres),

Crisscross (minimizes structural space requirements by "stacking" escalators that go in one direction, frequently used in department stores and shopping centers), and

Multiple parallel (two or more escalators together that travel in one direction next to one or two escalators in the same bank that travel in the other direction)

III.METHODOLOGY

MODELING

The escalator frame model has been entirely modeled by PRO E software. First of all sketch command of the pro e is opened. Then by using 2d commands sketch is created. Then the 3D model of escalator frame is created by extrudes command in pro e.

TRANSFORMATION OF MODEL

Then the model is converted in to the IGES format which is most suitable and easy access for any other software's.

Using the IGES format we can import the escalator frame model from pro e to ANSYS. Now we can make structural analysis.

MESHING

After the complete structure is modeled, escalator frame is meshed. This has been done by using ansys workbench software. The last step to be completed before meshing the model is to set the meshing controls, i.e. the element shape, size, the number of divisions per line, etc. Selecting the various parts of the model, one by one finite element mesh is generated. The critical portions are plates with sharp corners, curvature etc. These areas can be remeshed with advance mesh control options. "Smart element sizing" is a meshing feature that creates initial element sizes for free meshing operation. Proper care has to be taken to have the control over the number of elements and hence the number of degrees of freedom associated with the structure. This is done to have a control over the solution time. However, no compromise is made on the accuracy of the results.

LOADING

The types of loading that can be applied in a structural analysis include:
Externally applied forces and pressures
Steady-state inertial forces (such as gravity or rotational velocity)
Imposed (nonzero) displacements

ANALYSIS

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

IV.MATERIAL PROPERTIES

STRUCTURAL STEEL :

Structural steel is steel construction material, a profile, formed with a specific shape or cross section and certain standards of chemical composition and mechanical properties. Structural steel shape, size, composition, strength, storage, etc., is regulated in most industrialized countries.

Structural steel members, such as I-beams, have high second moments of area, which allow them to be very stiff in respect to their cross-sectional area.

Mechanical Properties:

Structural Steel > Constants

Structural	
Young's Modulus	2.e+005 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg/mm³
Thermal Expansion	1.2e-005 1/°C
Tensile Yield Strength	250. MPa
Compressive Yield Strength	250. MPa
Tensile Ultimate Strength	460. MPa
Compressive Ultimate Strength	0. MPa
Thermal	
Thermal Conductivity	6.05e-002 W/mm·°C
Specific Heat	434. J/kg·°C
Electromagnetics	
Relative Permeability	10000
Resistivity	1.7e-004 Ohm·mm

ALUMINIUM ALLOY:

6061 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S" it was developed in 1935.[1] It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminium for general purpose use.

It is commonly available in pre-tempered grades such as 6061-O (solutionized) and tempered grades such as 6061-T6 (solutionized and artificially aged) and 6061-T651 (solutionized, stress-relieved stretched and artificially aged).

Mechanical properties:

Aluminium Alloy (6061) > Constants

Structural	
Young's Modulus	6.9e+005 MPa
Poisson's Ratio	0.33
Density	2.7e-006 kg/mm³

TITANIUM:

Titanium is a chemical element with symbol **Ti** and atomic number 22. It is a lustrous transition metal with a silver color, low density and high strength. It is highly resistant to corrosion in sea water, aqua regia, and chlorine.

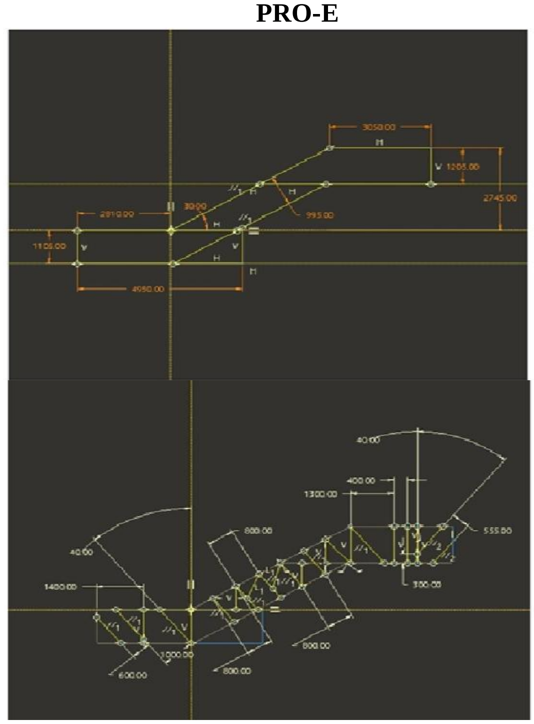
Titanium can be alloyed with iron, aluminium, vanadium, and molybdenum, among other elements, to produce strong, lightweight alloys for aerospace (jet engines, missiles, and spacecraft), military, industrial process (chemicals and petro-chemicals, desalination plants, pulp, and paper), automotive, agri-food, medical prostheses, orthopedic implants, dental and endodontic instruments and files, dental implants, sporting goods, jewelry, mobile phones, and other applications.

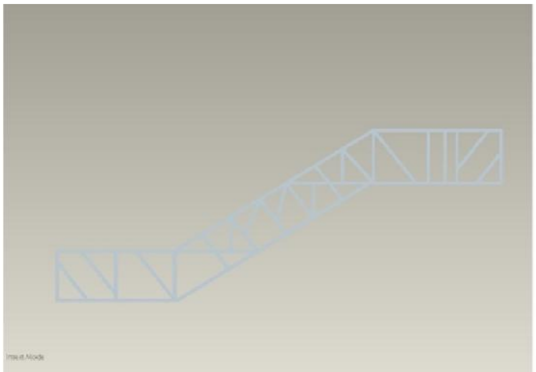
The two most useful properties of the metal are corrosion resistance and the highest strength-to-density ratio of any metallic element. In its unalloyed condition, titanium is as strong as some steels, but less dense. There are two allotropic forms and five naturally occurring isotopes of this element, Ti through Ti, with Ti being the most abundant (73.8%) Although they have the same number of valence electrons and are in the same group in the periodic table, titanium and zirconium differ in many chemical and physical properties.

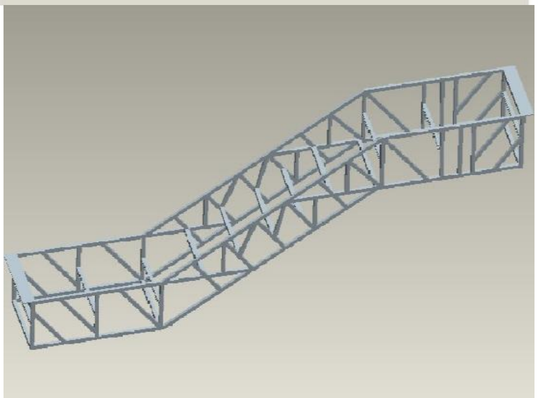
Mechanical Properties:

	Density (g/cm³)	Elastic modulus (GPa)	Yield strength (MPa)	Tensile Strength (MPa)	% Elongation at break
cp-Titanium and Titanium Alloys					
cp-Ti (Grade 4) or ASTM F67 30 % Cold Worked	4.5		485	760	15%
Ti-6Al-4V or ASTM F136 annealed	4.5		830	900	14%
Tantalum					
Tantalum Annealed	16.6		138	345	20-30%
Tantalum 30% Cold Worked	16.6		207	517	2%

V.DESIGN OF ESCALATOR FRAME BY USING PRO-E







VI.THEORETICAL CALCULATIONS

Loads affecting the inclined sections of the escalator:

Passenger load F_1:

F_1= G_1×g= (m×B×N_1× φ)×g = (80×15×2×1)×9.81= 23544 N

Step load F_2:

F_2=N_2×m_2×g=15 x15x 9.81=2207N

Total load affecting the upper station F_u:

F_u=0.5×g×(G_u+(N_u+5)×mb.+ N_u×m)=0.5×9.81×(550+(2+5)×15+2×80)

F_u =3997.55 N

Total load affecting the bottom station F_b:

F_b=0.5×g×(G_b+(N_b+5)×mb+ N_b×m)=0.5×9.81×(312+(2+5)+2×80)

F_b=2830.16 N

Total force F_t:

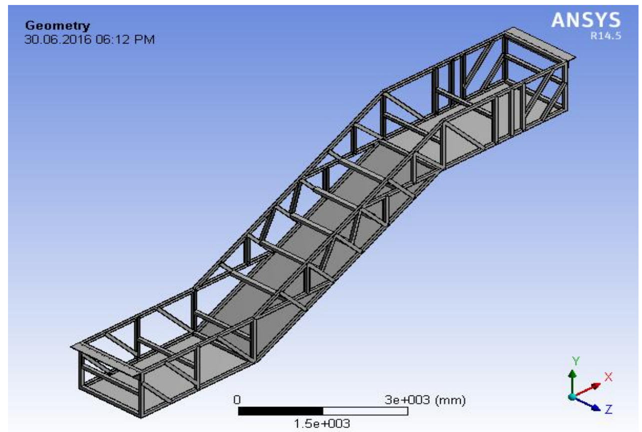
F_t =F_1+ F_2+ 2×F_u+2×F_b

= 23544+2207+ (2x3997.55) + (2x2830.16)

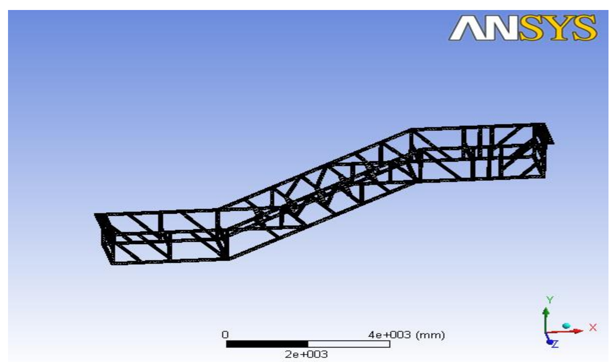
F_t =39406.42N

VII.ANALASYS OF ESCALATOR FRAME USING ANSYS

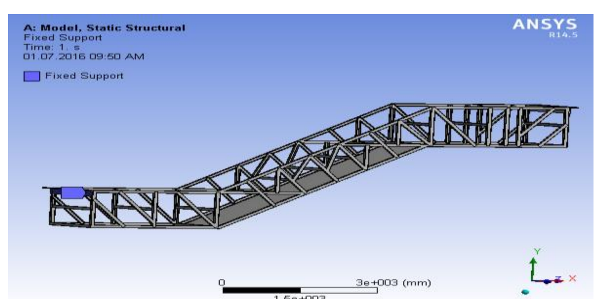
Geometry View Of Escalator Frame In Ansys Workbench



Mesh View Of Escalator Frame In Ansys Workbench

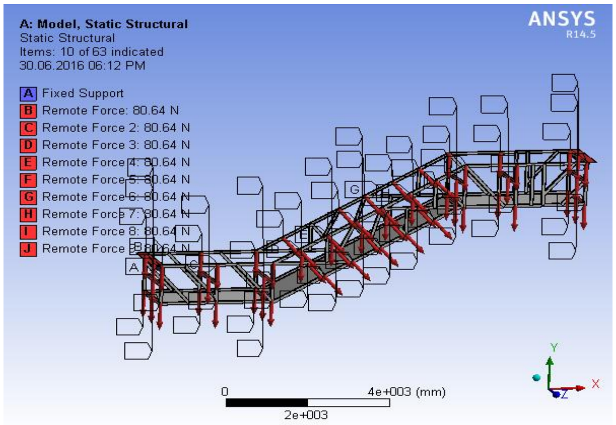


Fixed Support Defined On Escalator Frame In Ansys Workbench



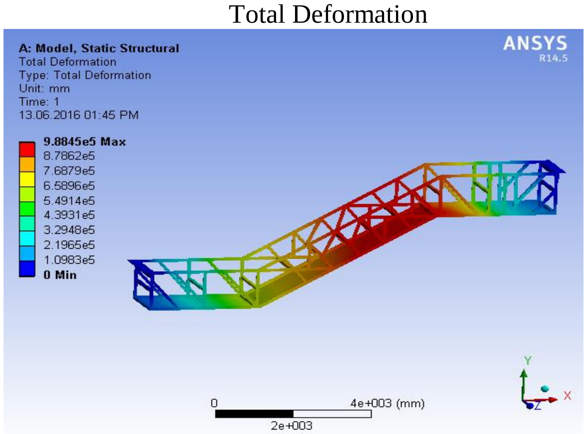
Inputs Given For The Static Structural Analysis Of Escalator Frame

Remote Force On Escalator Frame – 80.64 N

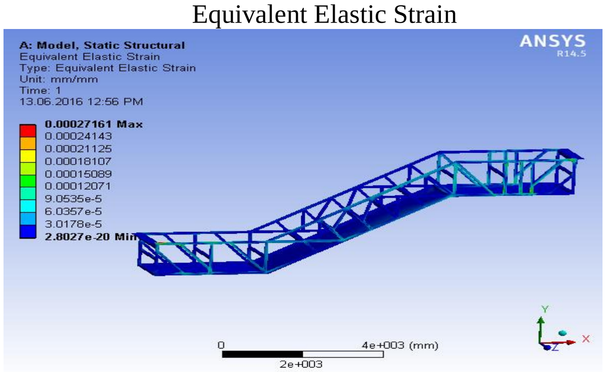


VIII.RESULTS:

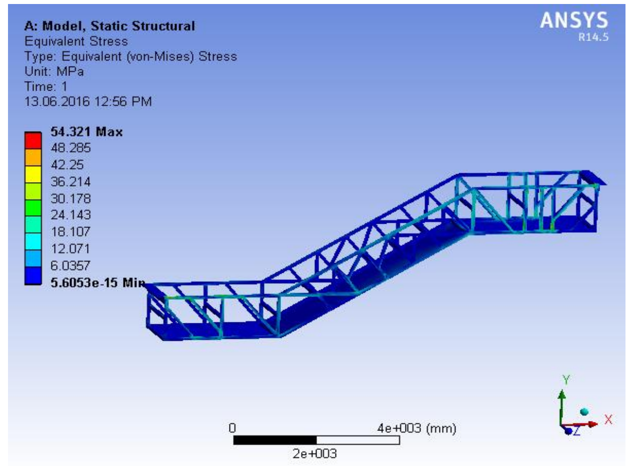
Conventional Escalator Frame
Results For Structural Steel
Total Deformation



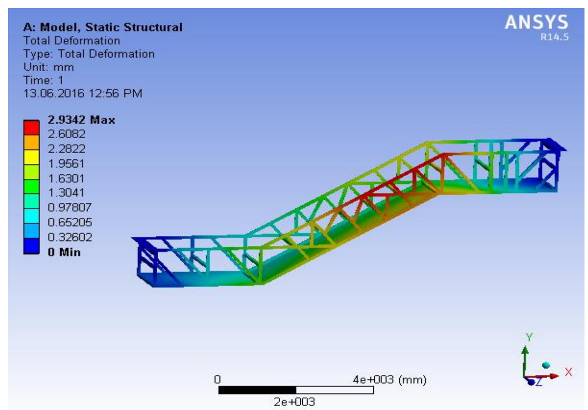
Equivalent Elastic Strain



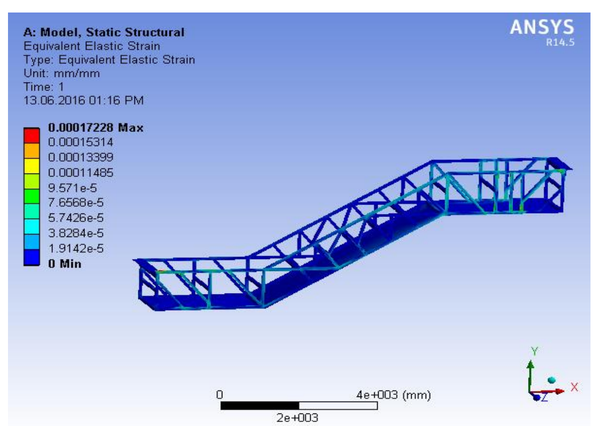
Equivalent Stress



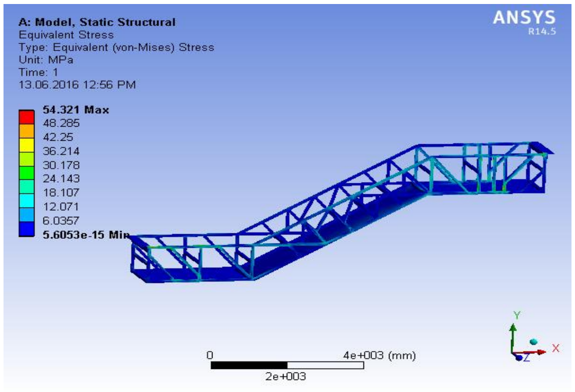
Optimized Escalator Frame
Results For Aluminium Alloy (6061)
Total Deformation



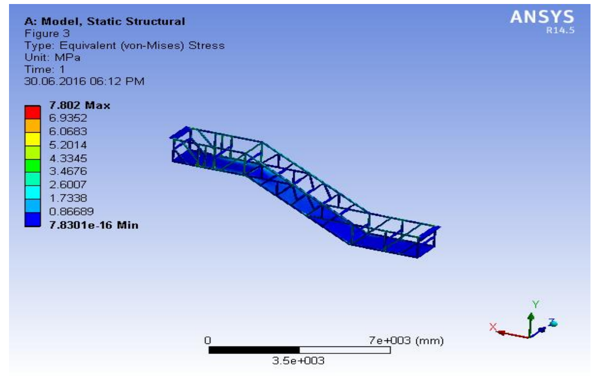
Equivalent Elastic Strain



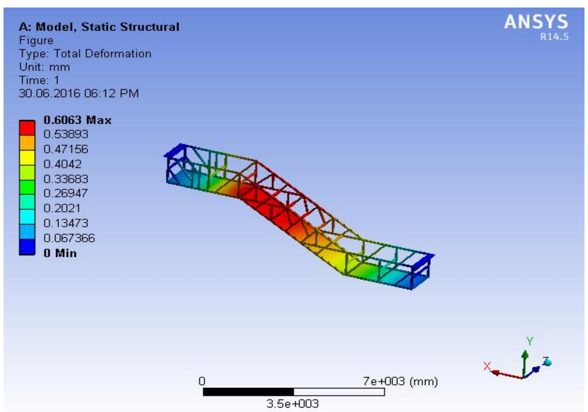
Equivalent Stress



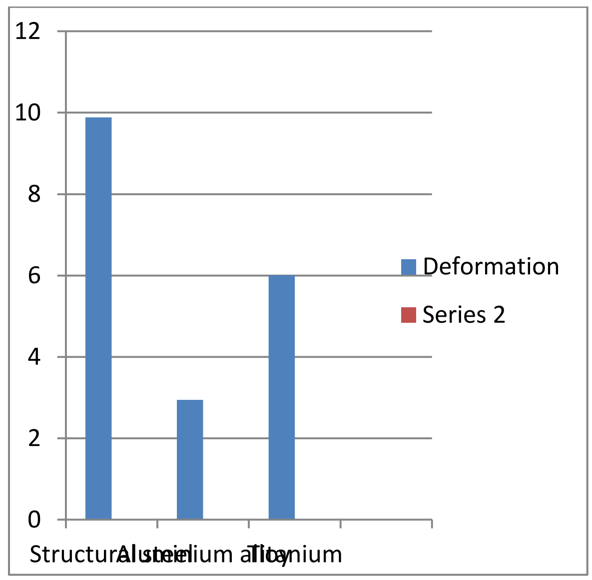
Equivalent Stress



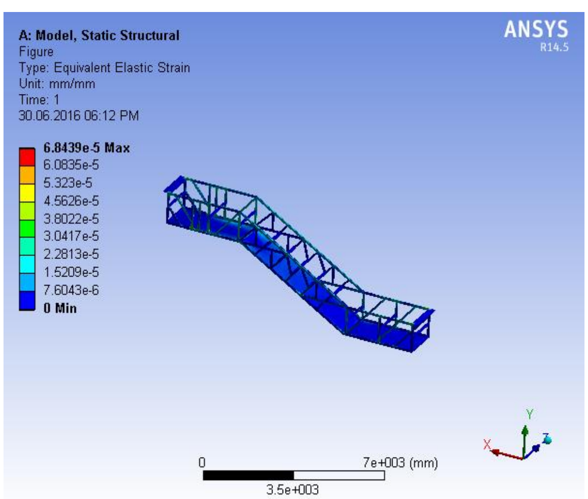
Another Optimized Escalator Frame
Results For Titanium
Total Deformation



Graph
Material Vs Deformation



Equivalent Elastic Strain



Conventional Escalator Frame Results Of Above Remote Force

8.6.1 STRUCTURAL STEEL

STRUCTURAL STEEL	MIN	MAX
Total deformation (mm)	0	9.8852
Equivalent Elastic Strain	5.7999e--15	0.0002413
Equivalent stress	0	141.74

Optimized Escalator Frame Results Of Above Remote Force

8.6.2 ALUMINIUM ALLOY (6061)

ALUMINIUM ALLOY (6061)	MIN	MAX
Total deformation (mm)	0	2.9432
Equivalent Elastic Strain	2.9365e-20	0.0001722
Equivalent stress	0	54.321

Another Optimized Escalator Frame Results Of Above Remote Force

8.6.3 TITANIAM

TITANIAM	MIN	MAX
Total deformation (mm)	0	6.0063
Equivalent Elastic Strain	0	0.0006312
Equivalent stress	7.8301e-16	78.02

IX.CONCLUSION

Experimental results from testing the conventional escalator and optimized escalator under remote force are listed in the Table. Analysis has been carried out by static. The Structural Steel material is used. The results for static structural such as total deformation, equivalent elastic strain, and equivalent stress are determined. Comparing the optimized escalator and the conventional escalator, optimized escalator has the low values of total deformation, stress and strain. Hence it is concluded optimized escalator is suitable.

The project carried out by us will make an impressing mark in the industrial field. While carrying out this project we are able to Study about the 3Dmodelling software (PRO-E) and Study about the analyzing software (ansys) to develop our basic knowledge to know about the design.

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