DEVELOPMENT OF MESH-STRUCTURE APPLIED GUM METAL ARTIFICIAL MEDICAL PRODUCTS

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Abstract: It is interested in this study to develope mesh-structure applied Gum Metal (one kind of titanium alloy, also called Gum Titanium) plates with high biocompatibility, elastic deformability and comparatively lower elastic modulus for implant applications. Meshed gum metal plates with excellent 3-demensional flexibility and light-weight performance compared to usual metal plate implants are designed parametrically using 3D CAD tools for different bone graft applications. Mechanical properties like tensile/compression and bending stiffness and volume densities of sample meshed gum metal plates are experimentally and analytically evaluated with respect to different design parameters like basic mesh shapes, mesh line width etc.

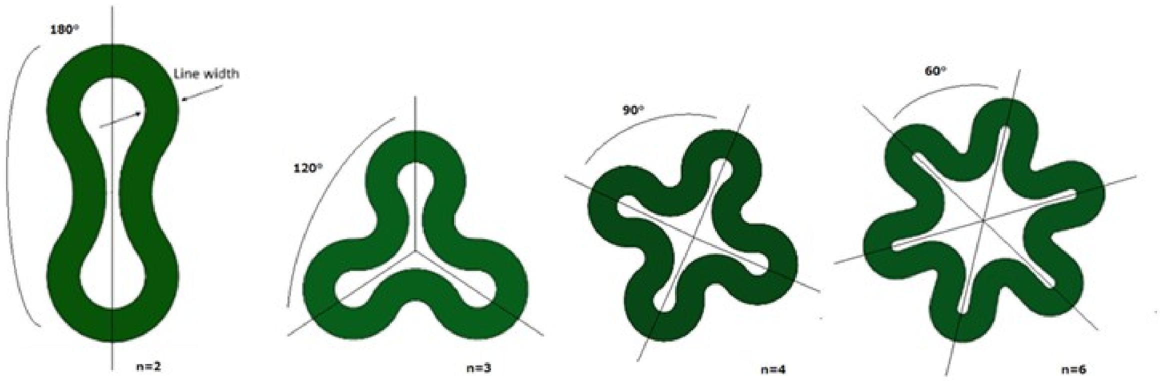
Keywords: Meshed Gum Metal plates, High flexibility, Mechanical property, Experiment, FEM analysis

Introduction

It is interested in this study to develop mesh-structure applied Gum Metal (one kind of titanium alloy, also called Gum Titanium) plates with high biocompatibility, elastic deformability and comparatively lower elastic modulus for implant applications. Table1 shows the mechanical properties of Gum Metal material under different working types. Sample meshed GUM METAL plate specimens with excellent 3-demensional flexibility and light-weight performance compared to usual metal-alloy plate implants are designed parametrically using 3D CAD tools for different medical devices applications. Mechanical properties like tensile/compression and bending stiffness and volume densities of sample meshed Gum Metal plates are fabricated using laser cutting processes for experimental and analytical evaluations with respect to different design parameters like basic mesh shapes, mesh line width etc. as shown in Fig. 1.

Table 1. Material property of gum metal plates based from different working process.

Type of Working	Cold Working	Hot Working
Yong's Modulus (GPa)	30～60	85～95
0.2% Proof Strength (MPa)	900～1100	1400～1700
Tensile Strength (MPa)	1000～1200	1500～1800
Density (g/cm^3)	5.6	



(a)180° axisymmetric shape (b)120° axisymmetric shape (c)90° axisymmetric shape (d)60° axisymmetric shape

Fig. 1. Four Samples of basic mesh shapes designed for experimental evaluations.

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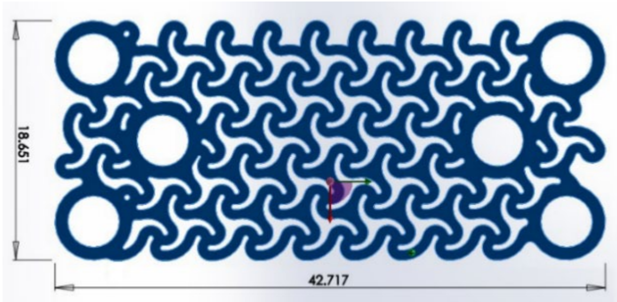
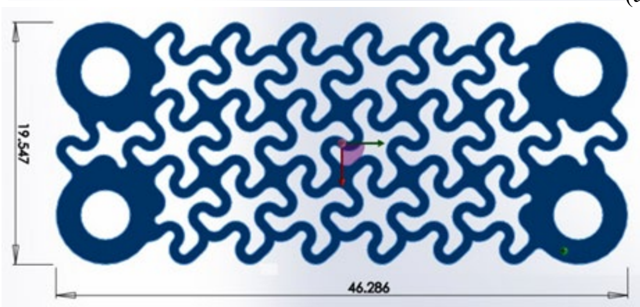
3D models designed for meshed Gum Metal plate specimens

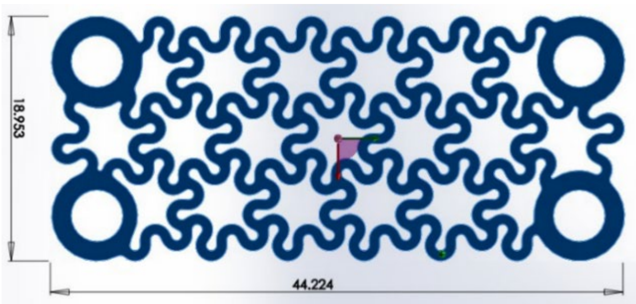
Three dimensional models for sample meshed GUM METAL plate specimens with higher flexibility and light-weight performance are designed parametrically using CAD software Solidworks. Fig. 2 shows the meshed plate shape models for tensile property evaluations with 0.8 mm mesh line width. Fig.3 shows four types of meshed plate shape models for compressive and bending property evaluations with 1.0 mm mesh line width.



(a) 120° axisymmetric specimen (0.8mm)

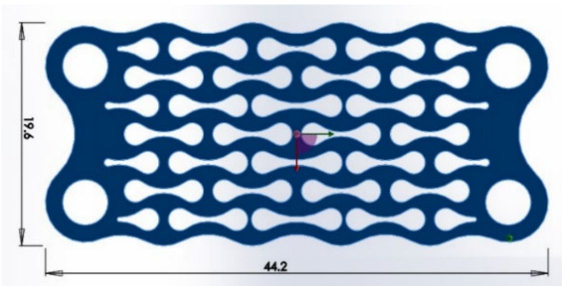


(b) 90° axisymmetric specimen (0.8mm)

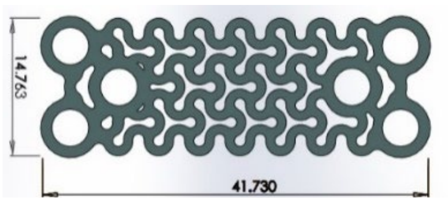


(c) 60° axisymmetric specimen (0.8mm)

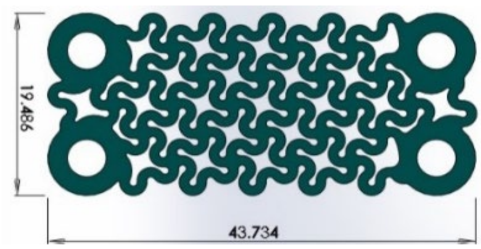
Fig. 2 Meshed plate shape models for sample specimen evaluations (Tensile specimens)



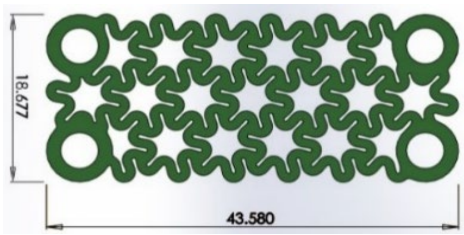
(d) 180° axisymmetric specimen (1.0mm)



(e) 120° axisymmetric specimen (1.0mm)



(f) 90° axisymmetric specimen (1.0mm)



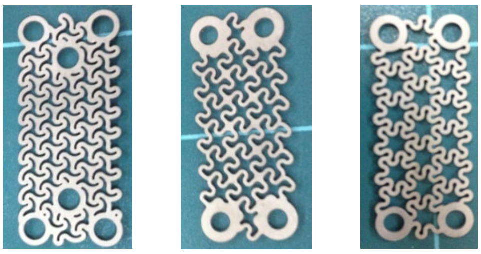
(g) 60° axisymmetric specimen (1.0mm)

Fig. 3. Meshed plate shape models for sample specimen evaluations (Compressional and bending specimens)

Evaluation on mechanical properties of sample meshed Gum Metal plate specimens

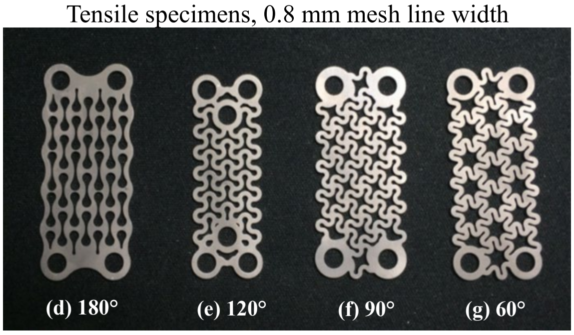
Experimental evaluation

Sample meshed Gum Metal plate specimens are fabricated using laser cutting process and shown in Fig. 4. Fig.5 shows the examined volume densities of different sample meshed Gum Metal plate specimens compared with original Gum Metal material. One can see that sample meshed Gum Metal plate specimens with different basic mesh shapes are resulted in light-weight structures compared with original Gum Metal plates.



(a) (b) (c)

Tensile specimens, 0.8 mm mesh line width



Compressive and bending specimens, 1.0 mm mesh line width

Fig.4. Meshed gum metal plate specimens for mechanical property evaluation

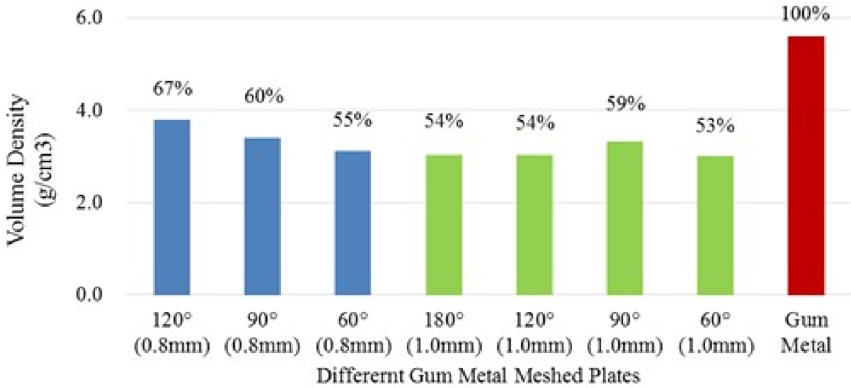


Fig. 5. Volume density of sample meshed gum metal plate specimens

Analytical evaluation

Based on the three dimensional models for sample meshed GUM METAL plate specimens shown in Fig. 2, analytical evaluation on tensile, compressional and 3-point bending experiments on those sample meshed Gum Metal plate specimens are executed for comparison with experimental results. Fig. 6 shows the analytical models for three experiments of meshed Gum Metal plate specimens and Fig.7 shows the sample image of finite element mesh for compressive analysis of meshed gum titanium plates. Table 2 shows the material properties of Gum Metal for analytical inputs.

Table2. Material property of Gum Metal for analytical approach

Density (kg/m^3)	5600
Young's Modulus (GPa)	40.0
Poison's Ratio	0.32

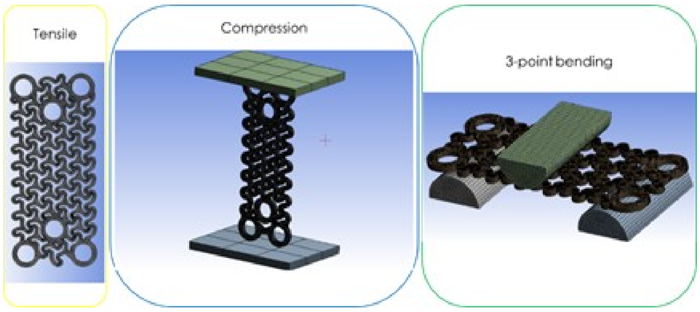
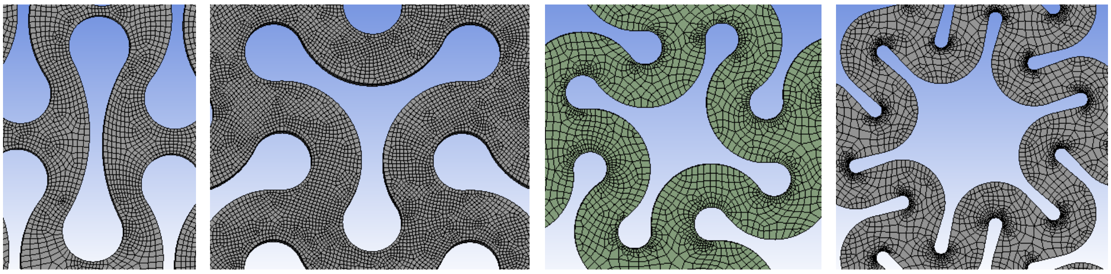


Fig. 6. Analytical approaches on mechanical properties of meshed Gum Metal plates

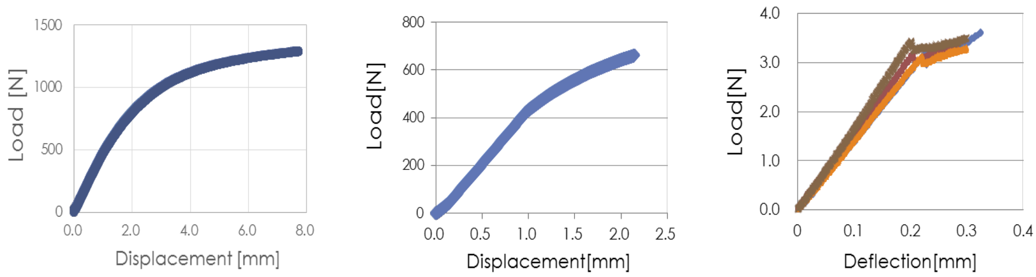


180° 120° 90° 60°

Fig.7. Image of finite element mesh for compressive analysis of meshed gum titanium plates

Results and Discussion

Fig. 8 shows the typical loading-displacement results obtained from tensile, compression and 3-point bending experiments of sample meshed Gum Metal plate specimens based on different JIS standards. Fig. 9 shows the comparison on quasi- tensional and compressional elastic modulus of sample meshed gum titanium plates. From these results, quasi- tensile, compressional and bending elastic moduli are evaluated and the radar chart of mechanical properties of sample meshed Gum Metal plate specimens are shown in Fig. 10. From these experimental results, sample meshed Gum Metal plate specimens introduced here with different basic mesh shapes are resulted in tensile, compressive and bending flexible plate structures.



(1) Tensile (2) Compression (3) Bending

Fig. 8. Typical experiment results for mechanical property evaluation of meshed Gum Metal plate specimens

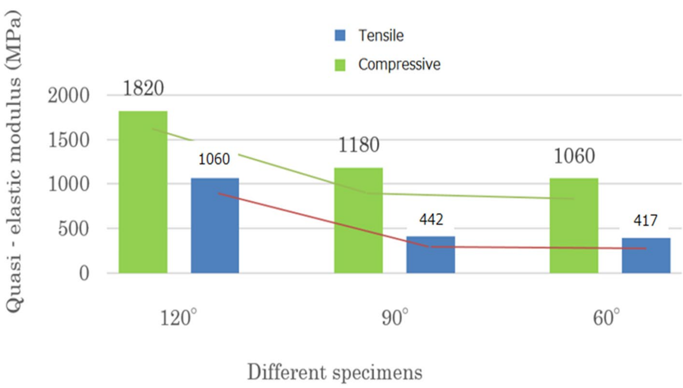


Fig. 9. Comparison on tensile and compressive properties of meshed Gum Metal plate specimens

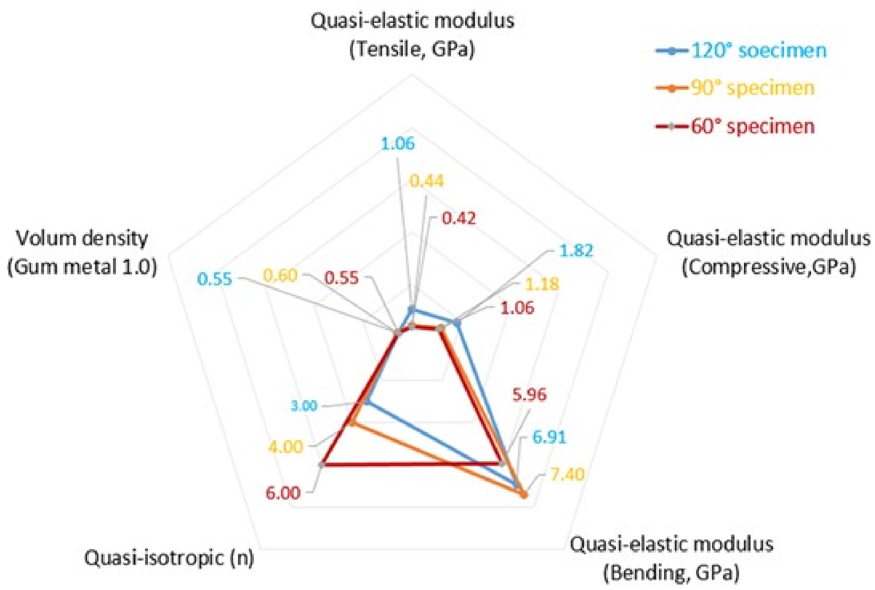


Fig. 10. Radar chart on mechanical properties of sample meshed Gum Metal plate specimens

Fig. 11 shows typical analytical Von Mises stress result obtained for tensile experiment of meshed Gum Metal plate specimens. From these analytical results, comparison between analytical and experimental tensile, compressive quasi-elastic modulus and bending deflections are shown in Fig. 12 to Fig. 14. These comparison on analytically obtained pseudo-tensile elastic modulus, pseudo-compression elastic modulus and bending rigidity of meshed Gum Metal plate specimens with experimental results validate the analytical approach method adopted in this study.

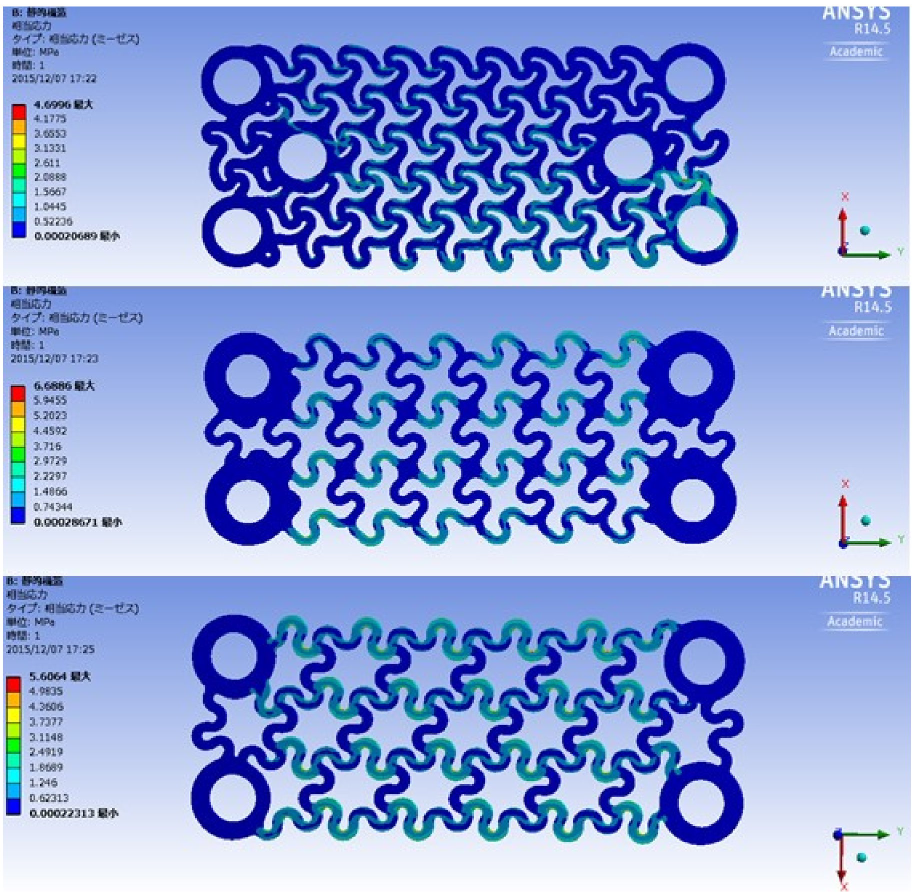


Fig. 11. Analytical results of tensile meshed gum titanium plate specimens (Von Mises Stress).

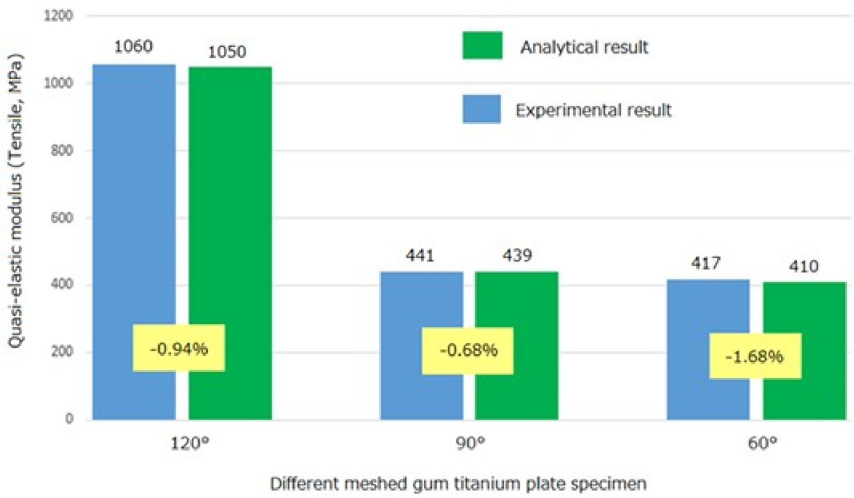


Fig. 12. Comparison between experimental and analytical results of tensile quasi-elastic modulus

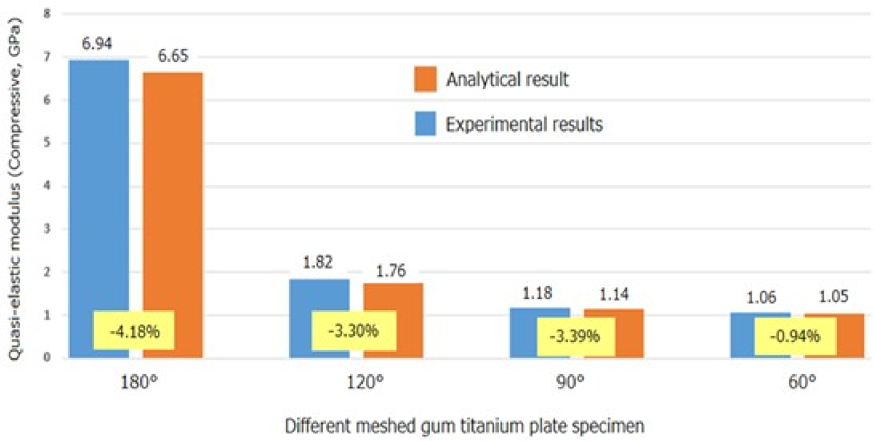


Fig. 13. Comparison between experimental and analytical results of compressive quasi-elastic modulus

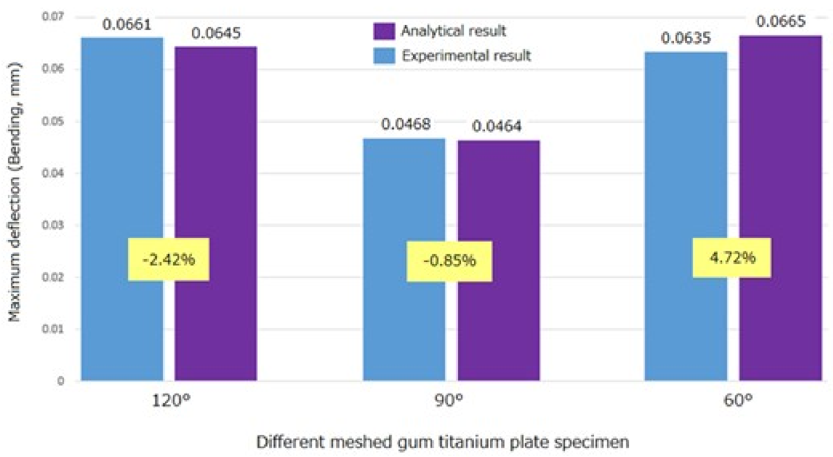


Fig. 14. Comparison between experimental and analytical results of bending deflection

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Conclusion

Mechanical properties of meshed Gum Metal plates designed for medical devices applications were experimentally and analytically evaluated and the following points were clarified.

(1) Sample meshed Gum Metal plate specimens with different basic mesh shapes are fabricated through laser cutting process, resulting in light-weight and flexible plate structures
(2) In order to improve the structural flexibility of meshed Gum Metal plates, it is considered better to design the basic mesh shape with higher priority.
(3) It is considered that the in-plane pseudo-tensile elastic modulus and the in-plane pseudo-compressive elastic modulus of meshed Gum Metal plates are greatly affected by pseudo-isotropy (rotational axis-symmetry) due to the basic mesh shapes.
(4) For out-of-plane bending rigidity and pseudo-bending modulus, the influence of pseudo-isotropy due to due to the basic mesh shapes is considered to be small.
(5) Comparison on analytically obtained pseudo-tensile elastic modulus, pseudo-compression elastic modulus and bending rigidity of meshed Gum Metal plate specimens with experimental results validate the analytical approach method adopted in this study.

Parametrical investigations on mechanical properties of meshed plate models can be carried outies analytically due to different design variables to develop databases dealing with different medical devices applications.

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