

Relationship between Void Distribution Function of Soft Polyurethane Foam and Mechanical Property (Compression Force - Displacement Characteristic)

- (Third Report) Compression Force - Displacement Characteristics Studies and Estimation by Machine Learning Using Void Distribution Function -

Minoru Inoue¹⁾²⁾³⁾ **Keisuke Suzuki**²⁾ **Hiroyuki Ito**⁴⁾ **Hiroyuki Ito**¹⁾

¹⁾ Mazda Motor Corporation

3-1 Shinchi, Fuchu-cho, Aki-gun, Hiroshima, 730-8670, Japan (E-mail: inoue.min@mazda.co.jp)

²⁾ Kagawa University

2217-20 Hayashimachi, Takamatsu, Kagawa 761-0396, Japan

³⁾ Digital Monozukuri (Manufacturing) Education and Research Center, Hiroshima University

3-10-32 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-0046, Japan

⁴⁾ Toyo Seat Co., Ltd.

1-6-25 Kuninobu, Kaita-cho, Aki-gun, Hiroshima, 736-0002, Japan

KEY WORDS: Vehicle development, Seating/lighting, Design simulation, Polyurethane Foam, Mechanical Property (B2)

The CAE methodology to evaluate the mechanical properties of the soft polyurethane foams (compression force - displacement characteristics, hereafter F-S characteristics) using void distribution functions was presented, verified and improved in the preceding papers (1-3). Using this CAE methodology, F-S characteristics studies by changing void distribution function curves were performed and executed. Then material properties and parameters related to void distribution functions which affect compression F-S characteristics are clarified. Also, Machine Learning was applied to the CAE results of F-S characteristic studies and possibilities to control F-S characteristics of soft polyurethane foams are presented.

In this report, using the validated CAE methodology, 117 case CAE runs regarding the void distribution functions along with the Young's Modulus E and strength level of stress-strain curves of urethane materials were done. Then how F-S characteristics are affected by void distribution function, major void radius and Young's Modulus E and so are clarified. And it was found that F-S characteristics can be widely controlled and designed by void distribution functions. This will result in weight reduction or improving performances regarding the urethane foams without mass increase.

And Machine Learning (ML) was applied to 117 case CAE results. After checking 8 ML algorithms to fit best to this problem by Leave-One-Out Cross-Validation (LOOCV), Random Forest was found best. Then 2 new arbitrary void distribution functions were applied to this ML database and prompt F-S results were gained. Also, conventional FEM models from 2 new arbitrary void distribution functions were also made by the proposed CAE methodology and are submitted to supercomputer. Comparison of F-S curves between ML and conventional FEM came very closely.

Our final research goal is to control and design F-S characteristics of the soft polyurethane as we like in the early stage of vehicle development. This report proved that our final goal is possible technically.

- (1) F-S characteristics of soft polyurethane foam can be controlled and designed by void distribution functions.
- (2) ML can be applied to this problem and can estimate F-S characteristics of soft polyurethane foam promptly and accurately.

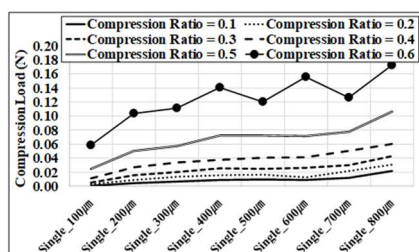


Fig.1 FEM F-S characteristics vs Void Radius

Applied Algorithm	LOOCV time (sec.)	Learning Performances		
		RMSE	NRMSE	R2
1 Linear Regression	0.8	0.43	0.13	0.64
2 LASSO	6.1	0.42	0.13	0.67
3 SVR (Support Vector Regression)	2.1	0.72	0.23	-0.01
4 Random Forest	85.4	0.25	0.08	0.87
5 Gradient Boosting (GBDT)	150.1	0.22	0.07	0.90
6 XGBoost	59.4	0.27	0.08	0.86
7 LightGBM	42.2	0.28	0.09	0.85
8.1 MLP (Multi-Layer Perceptron)	7.3	50.81	32.55	-32837
8.2 MLP Normalized	18.0	0.28	0.11	0.73

Table 1 ML Algorithm Study

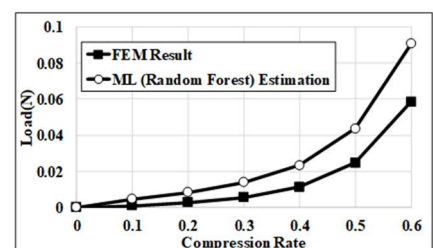


Fig.2 F-S Comparison between CAE and ML (Worst Case Result)