Is G_{IIc} an adhesive material property?
(An artificial neural network analysis)

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Introduction

Mode II fracture toughness (G_{IIc}) of adhesive materials has been studied by several authors. A routine test approach to obtain the shear fracture energy is using 3-point bending test using end-notched flexure specimens. But substrate materials, joint geometry, and test conditions affect significantly the obtained G_{IIc} [1]. Different values of G_{IIc} reported for a particular adhesive raises this question that is G_{IIc} an adhesive property? This study provides the novel aspects of the G_{IIc} of adhesives and analyzes the impact of effective parameters and their interactions by aid of the artificial neural network (ANN). Using ANN leads to the possibility to estimate the G_{IIc} of adhesives using the mechanical property and geometry of the joints.

Experimental methodology

In current study, over 40 data for G_{IIc} of ENF specimens were collected from previous studies. Fig. 1 illustrates the configuration of investigated ENF specimens and the range of geometrical, material, and loading rate of the studied ENFs are provided in Table 1.

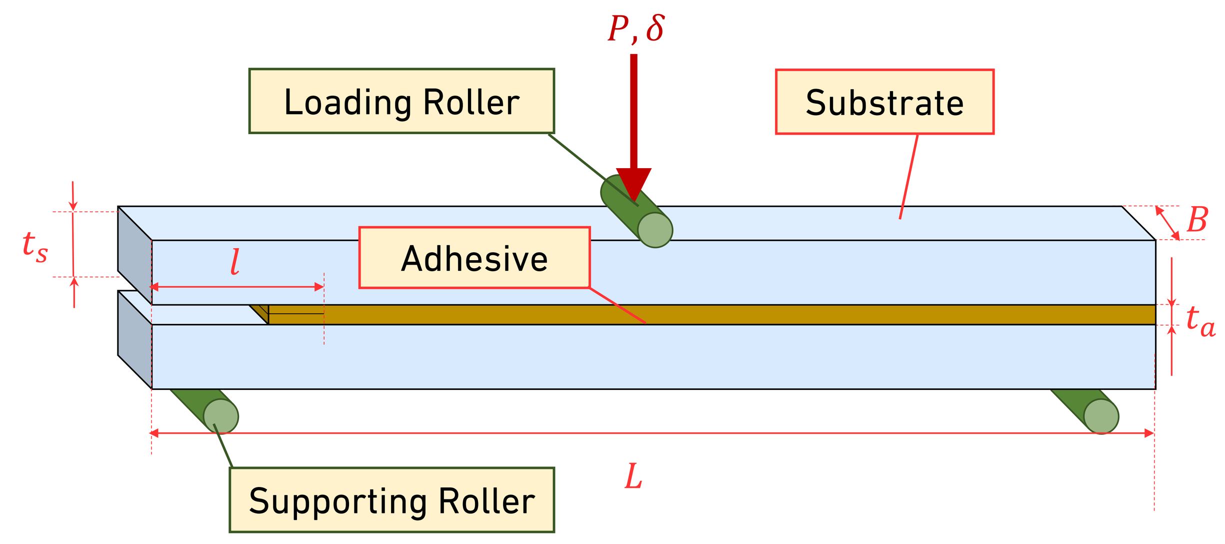

Figure 1 – Schematic of ENF specimen.

Table 1 – The range of various parameters considered in this study

Variable	Range of variables
Substrate length, *L* (mm)	100-300
Substrate width, *B* (mm)	12-30
Adhesive thickness, t_{adh} (mm)	0.2-1
Substrate thickness, t_{sub} (mm)	3-12.7
Crack length, *l* (mm)	2-140
Adhesive stiffness, E_{adh} (MPa)	255-4890
Adhesive strength, σ_{adh} (MPa)	21.63-47.6
Adhesive strain, ε_{adh} (%)	1.21-65
Substrate stiffness, E_{sub} (MPa)	70000-210000
Loading rate, *r* (mm)	0.2-3
Crack-span ratio, *l/p*	0.01-0.47
Thickness ratio (t_{sub} / t_{adh}), t_r	2-63.5

Results and discussion

As can be seen in Table 2, all variables are important in determining the fracture energy. However, considering the variable sensitivity (S_i), the most important variables are strain rate (*r*), Young's modulus of the substrate (E_{sub}) , and span (*l*), whilst the least important variable is the Young's modulus of the adhesive E_{adh} .According to Fig. 2, the fracture toughness declines by increase in *r* and *l/p* whereas it increases by increase in *l* and E_{sub}. Based on Fig. 3, thickness ratio has higher interaction at higher strain rate. However, the effect of alteration of thickness ratio is negligible at low strain rate. The substrate with high Young's modulus has a high interaction with the lower strain rates and the longer crack length. The interaction of higher E_{sub} to thickness ratio (t_{sub} / t_{adh}) is considerable at lower substrate thickness and higher adhesive thickness.

Table 2 –Variables used in ANN modeling and the corresponding errors obtained by omitting each variable.

Variables→ / Error calculation↓	E_{adh}	σ_{adh}	ε_{adh}	E_{sub}	t_{adh}	*l*	l/p	t_{sub}/ t_{adh}	r	e_t
All variables	●	●	●	●	●	●	●	●	●	e_t= 12%
Corresponding error of each variable (e_i)	21	24.2	23.1	30	23	25.5	22.8	22.1	36.4	-
Corresponding variable sensitivity (S_i)	9	12.2	12.1	**18**	11	**13. 5**	10.8	10.1	**14.4**	-

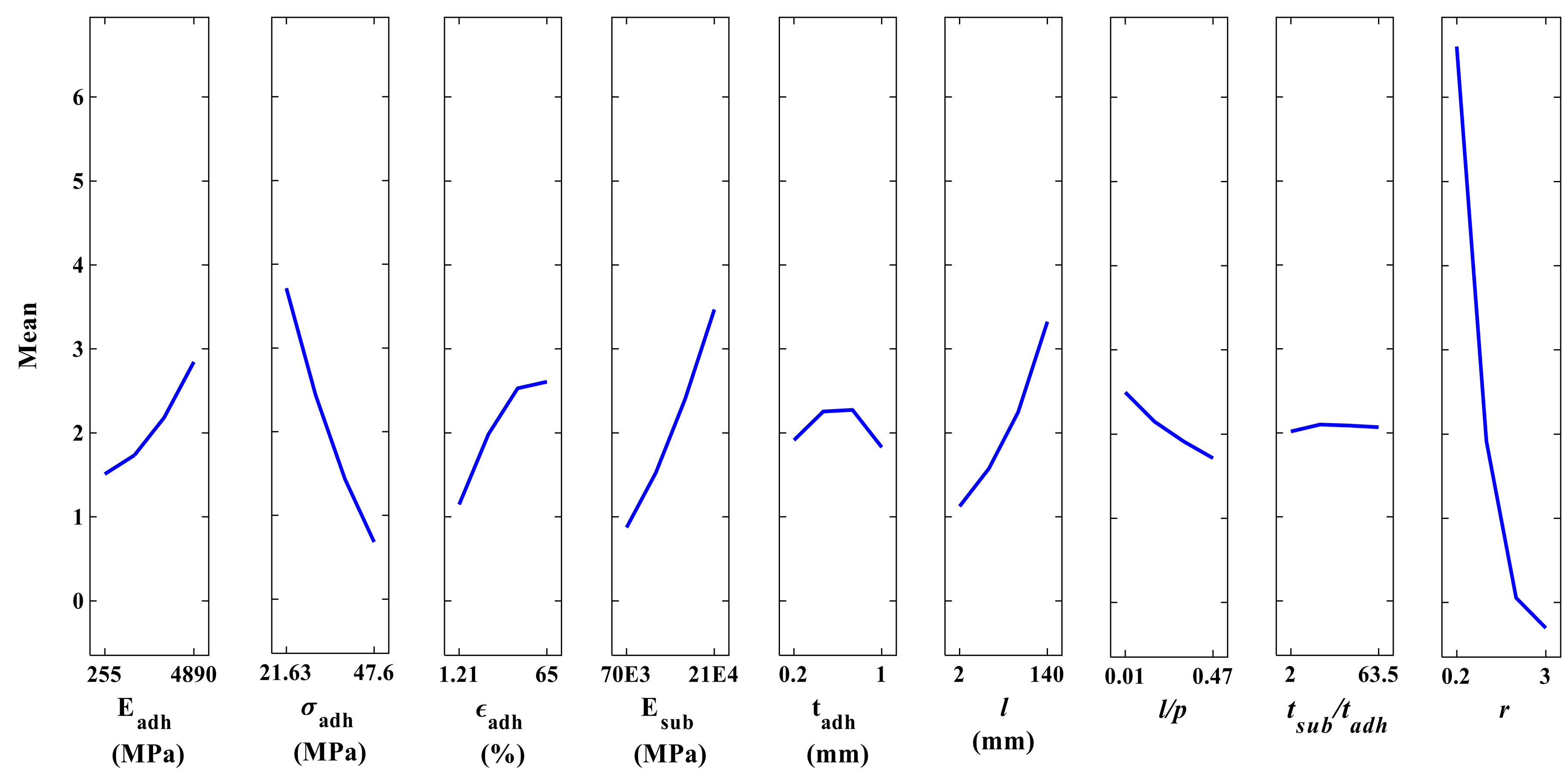

Figure 2 – Main effect plots for each variable.

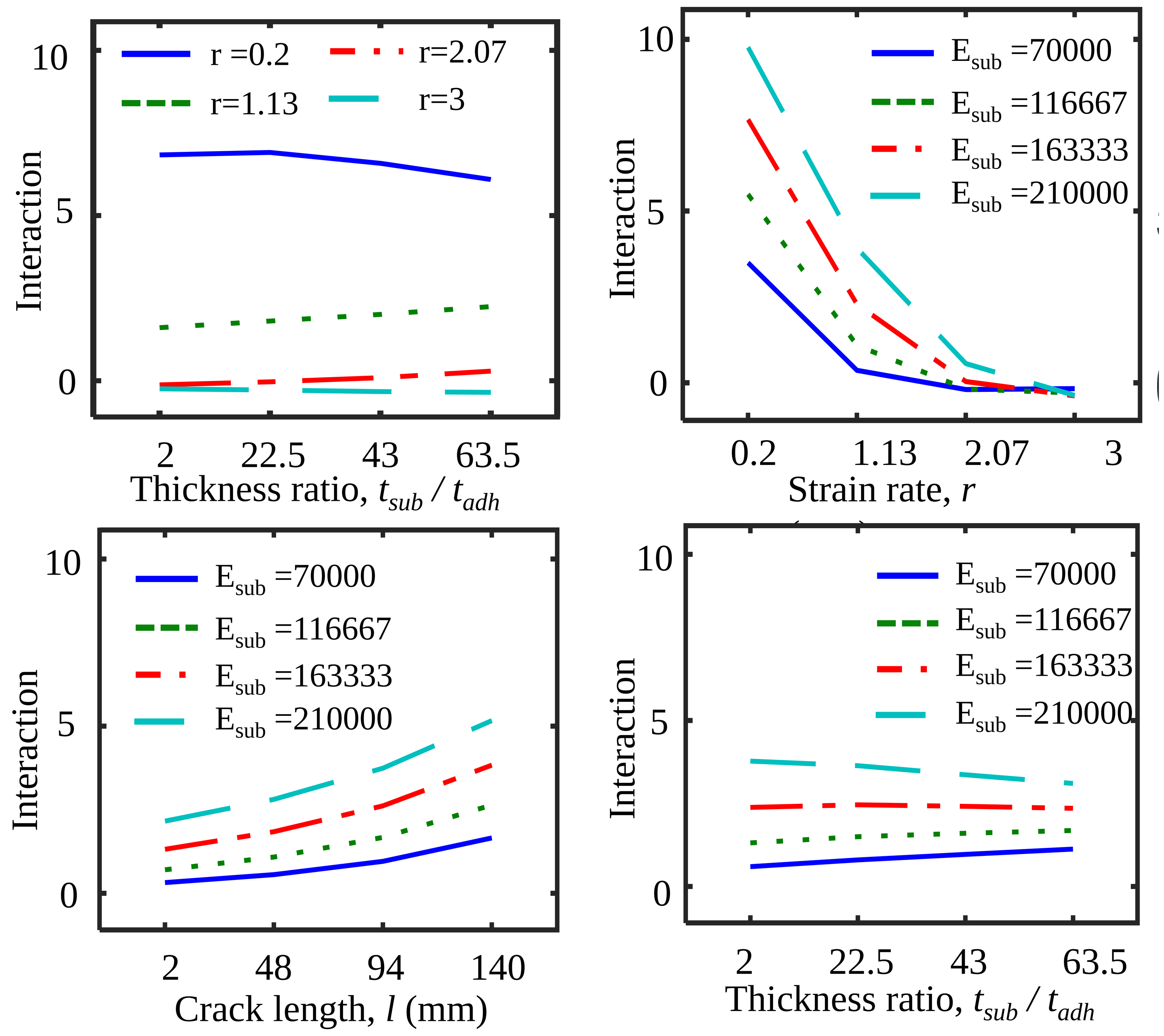

Figure 3 – Interaction plots of Young's modulus to other parameters.

Conclusions

G_{IIc} of different adhesives was collected from literature and analyzed by the aid of ANN. Although all parameters have impact on the G_{IIc}, fracture toughness is more sensitive to the strain rate and substrate stiffness. Therefore, this value is not only an adhesive property, but also it is a function of geometrical and testing condition. Based on the developed code it is possible to estimate G_{IIc} of adhesives by knowing the material properties and the joint geometry.

References

[1] Akhavan-Safar A, Salamat-talab M, Ajdani A, Ayatollahi MR, da Silva LFM. Mode II fracture energy characterization of brittle adhesives using compliance calibration method. Fatigue & Fracture of Engineering Materials & Structures.

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