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Table 1. Material evaluation criteria

Label	Concept
C_1	pH
C_2	viscosity
C_3	anionic active material
C_4	nonionic active material
C_5	total active material

Three decision-makers indicate the direction of causal relationships in three categories: positive, negative, null. Experts decide the degree of causal links by using linguistic variables; subsequently linguistic variables are transformed into fuzzy numbers. In this study, nine linguistic terms are used as negatively very strong (nvs), negatively strong (ns), negatively medium (nm), negatively weak (nw), zero (z), positively weak (pw), positively medium (pm), positively strong (ps), positively very strong (pvs). The corresponding triangular fuzzy numbers for these linguistic variables are reported in Table 2.

Table 2. Scale of Fuzzy Numbers [9]

Linguistic Term	Fuzzy Number
nvs	(-1,-1,-0.75)
ns	(-1,-0.75,-0.5)
nm	(-0.75,-0.5,-0.25)
nw	(-0.5,-0.25,0)
z	(-0.25,0,0.25)
pw	(0,0.25,0.5)
pm	(0.25,0.5,0.75)
ps	(0.5,0.75,1)
pvs	(0.75,1,1)

The matrices of power of causalities are given in Tables 3,4, and 5.

Table 3. Matrix of power of causalities according to Expert 1

	C_1	C_2	C_3	C_4	C_5
C_1	x	z	z	z	z
C_2	z	x	z	z	z
C_3	pm	pvs	x	pw	pm
C_4	pm	ps	pw	x	ps
C_5	p	pm	z	z	x

Table 4. Matrix of power of causalities according to Expert 2

	C_1	C_2	C_3	C_4	C_5
C_1	x	z	z	z	z
C_2	z	x	z	z	z
C_3	pm	pm	x	pm	pm
C_4	ps	pm	pw	x	pm
C_5	ps	pvs	z	z	x

Table 5. Matrix of power of causalities according to Expert 3

	C_1	C_2	C_3	C_4	C_5
C_1	x	z	z	z	z
C_2	z	x	z	z	z
C_3	ps	ps	x	pw	ps
C_4	pm	pm	ps	x	ps
C_5	ps	ps	z	z	x

The linguistic data that were collected from experts were converted into triangular fuzzy numbers according to the membership functions mentioned in Table 2. These triangular fuzzy numbers are aggregated via MAX aggregation, and then defuzzified by employing COG method, and the weight matrix is obtained as in Table 6. MATLAB fuzzy tool box is used for these operations. With regard to the weight matrix, FCM is constructed as in Figure 2.

Table 6. Weight matrix

	C_1	C_2	C_3	C_4	C_5
C_1	0	0	0	0	0
C_2	0	0	0	0	0
C_3	0.63	0.67	0	0.38	0.63
C_4	0.63	0.63	0.50	0	0.63
C_5	0.63	0.67	0	0	0

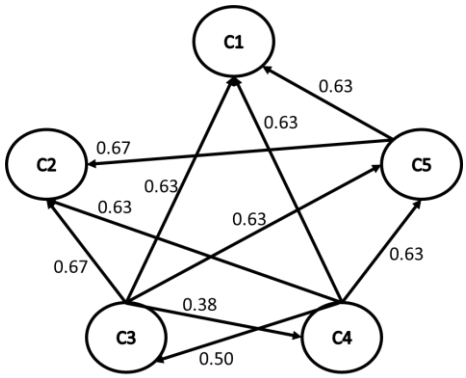

Figure 2 .FCM

In order to obtain concepts' values, the iterative formulation of FCM is run via FCMapper software. Concept values are given in Table 7.

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Table 7. The concepts' values of material evaluation criteria

Label	Concept	Concept's value
C_1	pH	0.9165
C_2	viscosity	0.9217
C_3	anionic active material	0.7544
C_4	nonionic active material	0.7354
C_5	total active material	0.8577

IV. CONCLUSION

In order to obtain the concepts' values of material evaluation criteria, factors are listed through expert opinions and the literature review. Experts decided whether there is causality or not. If there is causality between each pair of concepts, then they determine the sign of the relationship. After that the weight of outlined causal links was decided according to specified linguistic variables. These linguistic variables are converted into fuzzy numbers according to the associated membership function and they were aggregated by using MATLAB Fuzzy Toolbox. Finally, aggregated fuzzy numbers were defuzzified by using MAX and center of gravity methods to compose weight matrix. The result of FCMapper reveals that "viscosity" is the most important material evaluation criteria, which is followed by "pH" and "total active material".

Future research directions will focus on selecting the most appropriate material by employing a fuzzy multi-criteria decision making technique.

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