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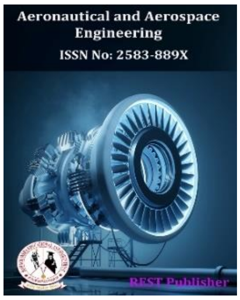

GRA methods are used to select penstock materials in small hydropower facilities

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Abstract: *Small hydropower (SHP) is expected to be a safe and dependable energy source. Choosing appropriate materials for different parts of SHP programmes in general, and the penstock in especially is one for the more challenging assignments because civil works components significantly increase the total cost of the endeavor. Because there is no organized and efficient strategy for selecting the most suitable material in the scientific literature, engineers must make this decision based on a variety of factors. In recent years, the realism of materials with various properties has increased rapidly, complicating the material selection process. A recent research found that "An effort has been made to solve the choice of materials problem for penstock in SHP installations using multiple criteria decision-making (MCDM) methods. The competency-based GRA technique is used to match Components to specific jobs. An illustration demonstrates the framework's feasibility. GRA, like Ideal Solution (GRA) approaches, is computationally effective, theoretically simple and easy to understand, and capable of assessing the relative performance of alternatives in the form of a methodical choice. COPRAS methods are implemented to select the finest material. Polyvinyl chloride (PVC), high density polyethylene (HDPE), glass reinforced polymer (GRP), and mild steel (MS) were considered as alternative materials, as were five assessment attributes/scales such as yield strength, durability, thickness, cost, and material and maintenance costs.". Case studies were investigated and integrated into the study. GRA methods are determined to be the best fit for penstock GRP when compared to other materials.*

Keywords: *Small hydropower*, *penstock material, GRA methods*

1. INTRODUCTION

In recent years, a wide range of substances have become available, and material selection is important in construction and other disciplines. It is difficult to choose materials that are both inexpensive and high-performance [1]. Material selection in any field necessitates an understanding of practical requirements as well as performance criteria. Decision-making processes become more laborious and complex as more materials become available [2,3]. The material selection process's goals are to find the best material for its cheap cost, long life, minimal upkeep cost, light weight, and high performance. An MCDM problem is able to be used to select an item from among multiple options and attributes/criteria. The penstock is an enclosed pipe that transports water from a forebay or overflow reservoir to the turbine. Penstocks are designed to endure high water pressure, particularly water hammers. They are extremely costly, but they are vital to the irrigation system. In accordance with the site conditions, penstock is laid on the ground, incorporated into concrete, or buried in the soil. Bends, joint expansion, manholes, fitting components, reduction or expander, and horn mouth intakes are all features of penstocks. The Darcy Weisbach equation is used to calculate losses in penstock movement.

$$\text{Headloss}=fLV^2(2gD)^{-1}\text{----------------}(1)$$

"where f is the material-dependent coefficient of friction of the penstock's interior surface, L is the length of the penstock (m), V is the velocity in the penstock (m/s), g is the gravity coefficient (m/s2), and D is the diameter (m)".

Small hydropower: Small hydropower is an environmentally friendly power technique that has been used in the country since the early 1900s. It is a tried-and-true source of energy. When a hydraulic turbine converts high pressure water into mechanical force, the resultant energy is utilized to power a generator, which generates electricity [6]. The useful power is proportional to the output of the head and exhaust. P represents the mechanical power generated on the rotor shaft. The primary components of a small hydropower endeavor are (i) building work and (ii) electrical equipment. Diverter and intake - needed to divert a river or stream flow to an intake channel - and aqueduct - supplied to convey rerouted water from the dam's back to the front via the outlet - are typical construction tasks for small hydropower projects. Boring Tank - To minimise water erosion, a large amount of alluvial soil is needed. Forbe - It is a simple structure that is installed at the end of a water conduit to meet the early water demand and absorb water. Unexpected power outage of generating machinery

Penstock - a pipe that connects the forebay to the turbine. Provisions for spillage - In the case of a flood or incomplete load, As quickly as feasible, the intake entry flow should be spilled. A power station building is a structure that generates electricity and a tailrace channel is a simple water conduit that transports and returns water produced by the turbine to the running stream. Inlet valves, turbines, draught tubes, barriers, generators, management and protection equipment, and substations for transferring electricity to transmission lines are the primary electromechanical components of a power plant.. The penstock, turbine, and engine are the most expensive components. As a consequence, penstock was proposed for screening to improve selectivity.

2. PENSTOCK MATERIAL

The penstock is a tube connecting the intake device to the hydro engine. Water's potential energy is converted to kinetic energy as it travels down the penstock. Penstock design considers factors such as girth, thickness, and losses [9]. Each of these is calculated separately. The penstock is designed to withstand maximum pressure under normal or unusual operating circumstances, primarily because water produces hammer. Penstock architecture incorporates steel and cast iron, reinforced concrete, precast plastic, and glass fibre-reinforced plastic. Penstock form and structure come in two varieties: single and double. A single has a single circulating and turning circuit, whereas a double has two continuous circulating and turning circuits. The single type is considerably less expensive, whereas the dual type offers more operational flexibility, resulting in a faster operational response when the turbine is required.

Penstocks are long pipelines that carry water from the hydroelectric reservoir to the power plant's generators. They are usually made of steel, and water is forced through the penstock at high pressure. A penstock is a pipe made of cement, polyvinyl chloride (PVC), or steel that has been properly computed for flow rate and head. Most small-scale companies and micro-hydro initiatives use medium-density polyethylene (MDPE), high-density polyethylene (HDPE), rigid PVC (poly-vinyl chloride), and mild steel pipes for penstock design. Their suitability, availability, and expense. For large head penstocks, only steel should be used, but the required steel strength should be determined. Lower heads can be constructed of wire-reinforced wood, laminated wood, fiberglass, plastic, concrete, or mild steel. A penstock is used to transport water from the source to the power loom's hydraulic engine. Because it converts potential energy in water into mechanical energy, it is an essential component of the micro hydro system. Depending on the inherent features of the property, penstock material, the outside temperature, and environmental issues, it can be exposed or buried beneath. Multiple variables such as diameter, thickness, water velocity, and cross-sectional area are taken into account when creating penstock. At various sites, penstock material selection, alignment, design, and implementation all add differently to project costs. It is primarily determined by geography, as well as construction method and material. As a result, the penstock material, as well as related parameters such as surface roughness, construction pressure, joining technique, pounds, and consideration is given to installation, availability, and upkeep [6,8].

Material selection is critical for mechanical, electrical, thermal, and chemical uses [9,10]. The selection of materials is critical in hydropower building. Many new materials are being used to reduce weight in modern living; lower costs and improved performance are available [11,12]. In hydropower engineering, an MCDM issue is optimal material selection from a large number of alternatives based on various properties. When selecting suitable materials, a variety of factors must be considered, Mechanical, electrical, and physical properties, as well as corrosion resistance and economic factors, are all considered. Hardness, toughness, thickness, rigidity, strength, and creep resistance are the most frequently encountered material characteristics [13-15]. This research makes use of material choosing and MCDM method analysis to determine the best technique and substance for penstock in SHP installations..

3. COPRAS METHOD

Deng invented the Gray Relational Analysis (GRA) method, which is now widely used to handle MCTM problems. All alternatives' GRA results must first be translated into a relative ranking. This grey relative stage is known as creation. A excellent destination the sequence is penalised according to these sequences. The grey correlation coefficient between the best target sequences is then computed for all comparison sequences. Finally, there is this grey communication. Gray correlation degree is calculated based on the coefficients for improved target order between each comparison sequence. A comparative sequence between the ideal goal line and itself was translated from an alternative. High levels of grey contact are the best option. We fix MCDM issues. We suggest an extended GRA method in which quantitative values are expressed as linguistic variables as interval values and quantitative weights are unknown. Are expressed as conventional GRA interval values Some optimisation models for determining criterion weights have been developed based on the fundamental idea. The computational Extended for MCDM Steps of GRA method, Sort the alternatives and pick the preferred one Interval-valued triangular fuzzy estimate are given. Summarize the GRA procedure. MCDM issues are described using Interval-valued with unknown weights. The GRA method was created in order to solve the proposed approach. To demonstrate compatibility, a numerical example including the application is investigated for a software business Select Computer Analysis Engineer. Gray Relational Analysis (GRA) is a term commonly used in Asia. It is a model of impact evaluation based on the degree of relationship between two orders. The degree of similarity or variation is measured. The goal of GRA is to investigate the variables that influence systems. It is data that is both independent and correlated and is founded on the discovery of relationships in series. GRC (Gray Correlation Coefficient) is used to determine reference series and relationships between series when using GRA.

The MCDM method generates a GRA based on linguistic factors and describes the abilities of available people to achieve a common set of organisational objectives. Create a talent-based GRA system and select the best materials based on his ranking. The analysis employs existing MCDM methods to determine the best penstock material. The integrated method's schematic flow to find the optimal choice for the most suitable option. The criteria for evaluation and alternatives for the decision process framework are given in the first step. Weights for the MCDM method are created and used using a decision hierarchy. In the second step, The pair-wise comparison matrices are built to calculate the criterion weights and to estimate the geometric mean from the values. Finally, the decision-makers approve the weights. GRA is used to identify and rank the best choices. Table 1 summarises the attributes/criteria for optimum material selection based on a review of the literature. Durability, thickness, functionality, and material upkeep were also taken into account in this study. Until recently, very few researchers investigated the expense of optimal material selection. This research looked at, "As stated below, five attributes/criteria for four alternative materials are investigated for penstock material selection. 1. Yield strength (YS): The most important parameter in penstock construction. 2. Life (L): The effective existence of the substance they service under all environmental conditions. 3. Thickness (T): The distance between the material's top and lower surfaces. The volume of the material rises as the thickness increases. 4. Expenditure (C): This is material purchase expenditure. 5. Maintenance Cost (MC): The cost of keeping it in good working order before a major defect arises".

4. RESULT AND DISCUSSION

TABLE 1. Given a data set

Materials	YS()Mpa	L(year)	T(mm)	C($/m)	MC($/m/year)
PVC	26	12	40	863.59	17.26
HDPE	34	25	46	1239.61	37.19
GRP	138	40	8	470.42	7.05
MS	252	50	9	630.65	37.84

The data collection for Penstock material is shown in Table 1. In the above table, the YS (Mpa), L(year), T(mm), C($/m) and MC($/m/year) of the return of "PVC, HDPE, GRP, and MS' are displayed. The other numbers are calculated using the above table.

TABLE 2. Normalized data

	YS()Mpa	L(year)	T(mm)	C($/m)	MC($/m/year)
PVC	1.0000	1.0000	0.1579	0.4889	0.6684
HDPE	0.9646	0.6579	0.0000	0.0000	0.0211
GRP	0.5044	0.2632	1.0000	1.0000	1.0000
MS	0.0000	0.0000	0.9737	0.7917	0.0000

Table 2 shown that the normalized data for YS ()Mpa, L(year), T(mm), C($/m)and MC($/m/year). These values are calculated using by formulas.

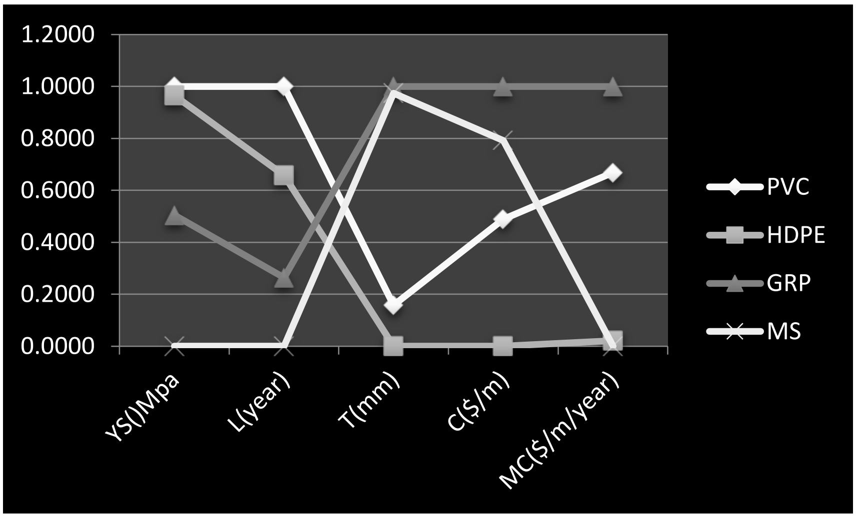

FIGURE 1. Gives the normalized data

Figure 1 shown that the normalized data for YS ()Mpa, L(year), T(mm), C($/m)and MC($/m/year). These values are calculated using by formulas.

TABLE 3. Deviation sequence

	YS()Mpa	L(year)	T(mm)	C($/m)	MC($/m/year)
PVC	0.0000	0.0000	0.8421	0.5111	0.3316
HDPE	0.0354	0.3421	1.0000	1.0000	0.9789
GRP	0.4956	0.7368	0.0000	0.0000	0.0000
MS	1.0000	1.0000	0.0263	0.2083	1.0000

Table 3 shown that the deviation sequence values and is calculated that the formulas.

TABLE 4. Grey relation coefficient

	YS()Mpa	L(year)	T(mm)	C($/m)	MC($/m/year)
PVC	1.0000	1.0000	0.3725	0.4945	0.6012
HDPE	0.9339	0.5938	0.3333	0.3333	0.3381
GRP	0.5022	0.4043	1.0000	1.0000	1.0000
MS	0.3333	0.3333	0.9500	0.7059	0.3333

A zeta value is constant and the values of 0.5. Table 4 is given for a grey relation coefficient.

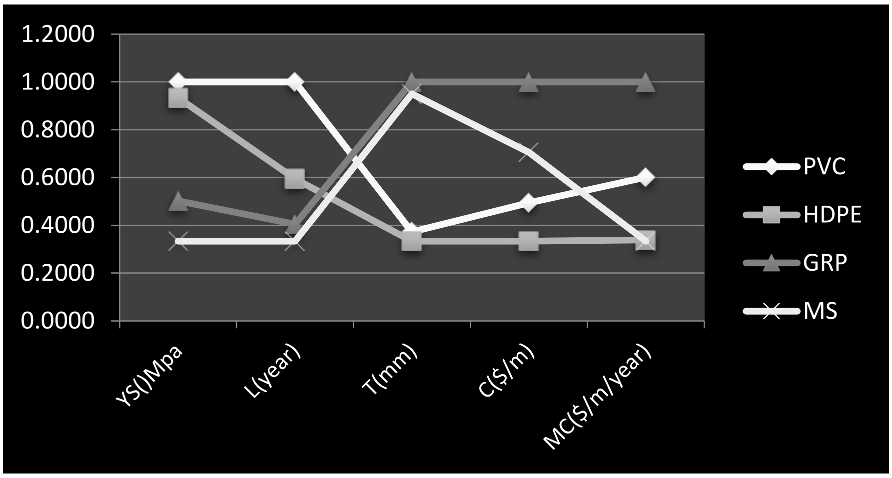

FIGURE 2. Grey relation coefficient

TABLE 5. GRG values

PVC	0.6937
HDPE	0.5065
GRP	0.7813
MS	0.5312

Table 5 Obtained by using formulas to calculate the GRG values, the result of the method was shown above.

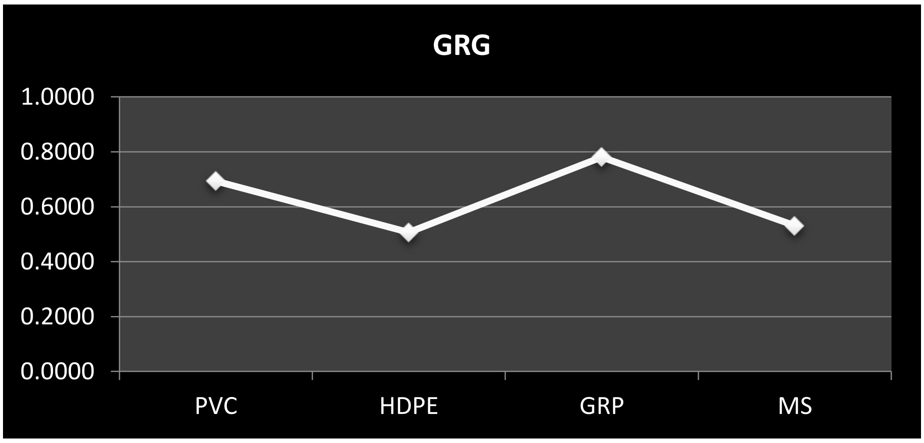

FIGURE 3. GRG values

TABLE 6. Ranking

Materials	**Rank**
PVC	**2**
HDPE	**4**
GRP	**1**
MS	**3**

According to Table 8, GRP is first, PVC is second, MS is third, and HDPE is fourth.

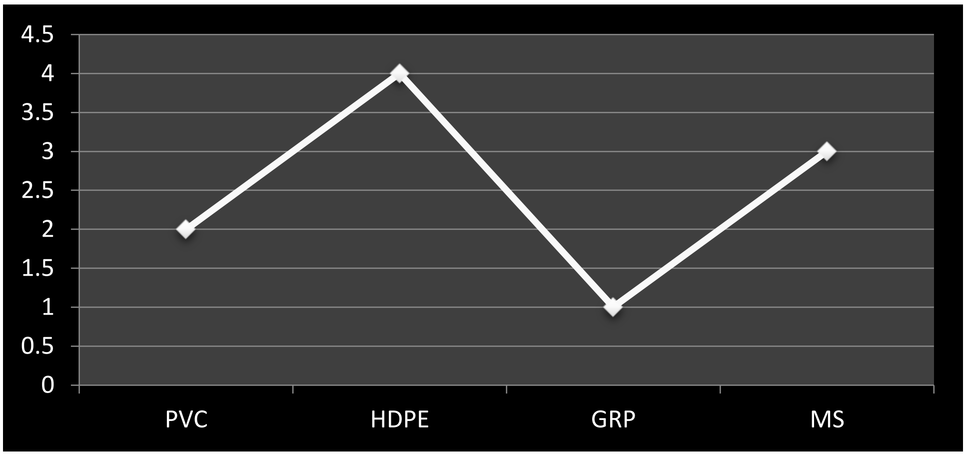

FIGURE 4. Ranking

Figure 4 shows that the GRP is first, PVC is second, MS is third, and HDPE is fourth. MCDM methods for ordering priorities were used to address the material selection problem for penstock within small hydropower projects. A method for optimal object ranking is created using GRA methods and Table 6 shows the outcomes of two case studies. Table 6 assigns numbers 1, 2, 3, and 4 to various materials such as PVC, HDPE, GRP, and MS. Table 6 shows that GRP is rated first in GRA methods. As shown in Table 7, To determine the best material, these results were compared to their scores/values obtained using various ways of ranking alternative materials. Figure 4 depicts a ranking representation of MCDM techniques.

5. CONCLUSION

SHP plays an important part in generating electricity for economic growth and development. Because it contributes significantly to installation, operating, and maintenance expenses, the choice of penstock materials for hydropower plants has a direct effect on power production over the plant's usable life. In this study, GRA MCDM techniques are used to determine the best material for penstock. To determine the ranking of the items, the amounts of weight for the attributes/criteria were calculated using the GRA method. The proposed method for integrating existing MCDM methods is found to be straightforward, appropriate, and capable of finding the best material among other choices. The suggested method is applicable to material selection problems in SHP and other disciplines. Nonetheless, the first and second-stage values/scores in the GRA technique are very close to each other. In contrast to other materials, GRP has a long life and maximum yield strength while being relatively thin and inexpensive. When material and maintenance expenses are evaluated, MS is an appropriate material. The proposed method clearly aids in the selection of the best penstock material.

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