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A Comparative Study of Non-Frost Refrigerator Over the Frost Refrigerator in Economical and Environmental Perspective

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Abstract
The study focuses on a comparative operation cost analysis between the non-frost and frost type refrigerator. Refrigerator is an essential equipment for food storage technique around the world. Both frost and non-frost refrigerators are widely used nowadays. However, their costing operations are not same. So the objective of this study was set to find out more economical refrigerator type that is either the frost type is economical or the non-frost type. A comparative analysis was done for both type refrigerators with the focus on the calculative results of initial cost (i.e. assembly cost, decoration cost, process cost), maintenance cost and the total 10 years' power consumption cost. The calculated results depicted that though initial cost is found higher in non-frost inverter refrigerator, the other cost like maintenance cost as well as the overall 10 years' power consumption cost was found to be cheaper in non-frost inverter refrigerator. Based on the experimental data it can be suggested that the non-frost with inverter type refrigerator is found to be more economical than frost type refrigerator. So it can be recommended that non-frost with inverter type refrigerator can be used in both domestically and industrially in the minimum costing rate.

Keywords: Refrigerator, Frost, Non-frost, Cost, Environmental Impact.

1. Introduction

Refrigerator is one of the mostly used home appliances around the world. It is more likely an insulated compartment having a heat pump (mechanical, electronic or, chemical) that transfers heat from its inside to its outer environment so that its inner compartment becomes cool to a temperature below the room temperature (BBC, 2009). One of best usage of refrigeration techniques is to preserve the food both in the domestical and industrial level. The other usage of refrigerator technique is storage of chemicals, storage of medicines, vaccines, etc. (Mehra, 2020).

2. How does a refrigerator Work?

A Refrigeration cycle consists of five basic components i.e. fluid refrigerant, the compressor that controls refrigerant flow, condenser coils on the outside of the fridge), evaporator coil (on the inside of the fridge) and last but not least something called the expansion device. The following points summarizes how these components interact to cool down the objects in the refrigerator (Sforza, 2012):

- The compressor constricts the refrigerant vapor that consequently raise the pressure, and thrust it into coils on the outer portion of the refrigerator.
- As soon as the hot gas within the coils meets the cooler air temperature of the kitchen, it turns to liquid form.
- Then the refrigerant cools down under high pressure since it the liquid flows into the coils inside of the freezer and the fridge.
- The refrigerant then absorbs the heat inside the fridge and subsequently cooling down the air.
- Lastly, the refrigerant evaporates into a gas and then flows turns back to the compressor where the cycle starts all over.

There are different types of refrigerators used in both industrial and domestic purposes. In this study we focused on frost (direct cooling) and non-frost (defrost) type refrigerator.

Like its name, the formation of ice happens in the frost refrigerator. Sometimes ice deposition can also be formed in the refrigerator compartment if the temperature becomes too cold. A frost refrigerator consists of direct cooling technology where chilling happens through natural conversion. This mechanism cools down the air and food items inside the refrigerator instantly. Air contains water in the form of moisture. When the air in direct cool refrigerator chills, the moisture turns into water and then accumulates. At freezing temperature, these water then turn into ice and deposit on the freezer. Ice accumulation can also be seen in the refrigerator if the temperature of it is not set properly (Clever Consumer, 2020).

On the other side, non-frost technology prevents the ice accumulation from outside air moisture. It does so by using a single motor for refrigerator and freezer section, single evaporator, ventilation device and an air treatment technique which makes the cooling using dry air. It also prevents the formation of odors of different food inside from the refrigerator. As ice does not accumulate on the freezer walls, it does not require manual defrost (Clever Consumer, 2020). A rigorous calculation was also done between these two types of the refrigerator on the basis of cost comparison. Thus, this study depicts to select the more economical refrigerator in home and commercial level.

3. Frost vs Non-frost

After the discovery of refrigerator with emerging French door and stainless facades era, a lot of transition has occurred in the modern refrigerator technology. This evolution is obviously the consequences of human preference and requirement. Frost and non-frost type are the two of that consequences that people are often seem to be confused to select which one would be better option to pick (Mehra, 2020).

Considering the frost refrigerator, natural convection process directly cools the air circulation process inside the fridge compartment. This type of refrigerator needs manual defrosting since water vapor on its internal surfaces freezes to ice and so does create the uneven temperature circulation. Most of the frost type refrigerator is single door type. However, this simple mechanism gets obsolete in consumers' level with time (Mehra, 2020). One of the common drawbacks of a frost refrigerator is freezer burn incidents due to formation of ice crystals on the stored food surface. The contaminated food tastes bad and frequently start to develop unpleasant texture (Kelsey, 2018).

Non-frost refrigerator developed to avoid the thick layer of ice that deposited on the inner body of traditional freezers. This design enables the non-frost model to work efficiently without having regular manual defrosting procedure and thus save the time, cost and physical efforts (Kelsey, 2018). So there are different functions are seeming to be in the non-frost refrigerator system. Since its name non-frost, this refrigerator keeps the consumer typically frost free. The electric fan is used to evenly circulate the cool air inside the refrigerator compartment through convection mechanism. There is no need of manual defrosting since ice does not form on its surface. This type of refrigerator typically come with double or triple doors nowadays (Mehra, 2020).

Traditional freezers result frost buildup since the water vapors generate around the coils turn into the liquid and starts to become freeze immediately. On the contrary, frost-free models prevent this water vapor formation automatically by defrosting the storage area on a regularly. Built-in timing cycle shut down the cold air compressor and turn on a small heater to melt down ice crystals. As soon as clearing of frost, the freezer shuts down the heater so cold air can remain food items stored at a favorable temperature (Kelsey, 2018).

4. Cost Analysis Data Result

Cost analysis was done on the basis of the assembly, decoration cost, 10 years' power consumption cost and maintenance cost. The analyzed data was collected from BOM List of Refrigerator Component, RFL Electronics Limited (2011-2012). However, the resultant cost might be changed in accordance with the price deviation of machinery parts availability and demand in the market.

Table 1. Initial Cost of Refrigeration Manufacture

	Door Assembly Cost		
Initial Cost	**Cost Item**	**Cost for Non-Frost Refrigerator with Inverter (BDT)**	**Cost for Frost Refrigerator (BDT)**
	Gasket Magnet	250	250
	Door Liner	745	745
	Door Trim	800	800
	VHB Tape	500	500

	Flexible Foam	100	100
	Chemical	550	550
	Door Glass	1,600	1,600
	Door Support	320	320
	Total	4,865/=	4,865/=
	Body Assembly Cost		
	Cabinet Lines	2,280	1,780
	U Shell	2,200	2,200
	Back Sheet	433	433
	Evaporator	2,150	2,150
	Condenser	520	520
	Hot Pipe	470	470
	Middle and Lower Crossbar	110	110
	Upper hinge and lower Support	70	70
	Reinforce Support	250	250
	Chemical (Poly Urethane)/ (Iso + Poly + C5)	1,500	1,500
	Cable	200	200
	Total	10,183/=	9,683/=
	Post Assembly Cost		
	Compressor	2,100	2,100
	Welding Cost	100	100
	Light and Holder	70	70
	Thermostat	550	450
	Cooling (Fan + motor) - (650 × 2)	1,300	-
	Heater (2 pcs) – (450×2)	900	-
	PCB Timer	850	-
	(Relay + PCTR + Capacitor)	750	600
	Gas Charge Cost	650	650
	Compressure Base Plate	200	200
	Inverter	1,500	-
	Total	8,970/=	4170/=
	Decoration Cost		
	Body Stand	700	700
	Plastic Drawer (5 pcs)	1,200	1,200
	Door Pocket	250	250
	Egg Pocket	250	85
	Egg Troy	85	-
	Com back Cover	80	80
	Wire Shelve	560	560
	Total	3,048/=	2,875/=
	Process Cost		
	Manpower Cost	700	500
Total		27,776/=	22,093/=

Table 2. Power Consumption Cost of Non-frost with Inverter and Frost Refrigerator

Power Consumption Parameters	Non-Frost Refrigerator with Inverter	Frost Refrigerator
Compressor Rated Power Appliance	80 Watt	100 Watt
Daily Operational hour	10 Hours	12 Hour
Daily Power Consume	0.8 Kw	1.20 kW
Monthly Power Consume	30×0.8 = 24 Kw	30 × 1.20 =36 kW
Yearly Power Consume	24×12= 288 Kw	36 × 12 = 432 KW
10 Year Power Consume	288 ×10= 2880 Kw	432 × 10= 4320 KW
BD Currency Units 1	5.61 Taka	5.61 Taka
Cost of Daily Power Consume	1 ×5.61=5.61 Tk	1.20 × 5.61 =6.73Tk
Cost of Monthly Power Consume	24×5.61=134.64 Tk	36×6.73=242.35 Tk
Cost Yearly Power Consume	288×5.61=1,615.68 Tk	432× 6.73 =2,907.36 Tk
Cost of 10 Years power Consume	2880×5.61=16,156.8 Tk	4320×6.73 =29,073.6 Tk

Table 3. Maintenance Cost Comparison

Cost Item	Cost for Non-Frost Refrigerator with Inverter (BDT)	Cost for Frost Refrigerator (BDT)
Gas Charging Cost	1,200	1,200
Leak Test	500	500
Fan motor problem Replies Cost	600	-
Thermostat and Relay Replace	-	450
Compressor Change	-	4500
Total	2,300/=	6,650/=

Table 4. Total Cost Comparison

Cost Item	Cost for Non-Frost Refrigerator with Inverter (BDT)	Cost for Frost Refrigerator (BDT)
Initial Cost	27,776	22,093
Power Consumption Cost	16,156.8	29,073.6
Maintenance Cost	2,300	6,650
10 Years Total Cost	46,232.8/=	57,816.6/=

Table 1 represents the initial cost of for both non-frost with inverter and frost type refrigerator manufacture. Though door assembly cost found same for both type refrigerator, body assembly cost, post assembly cost, decoration cost and process cost were found to be higher in non-frost with inverter type refrigerator. **Table 2** represents the 10 years' power consumption cost. The calculated result showed that the frost type refrigerator cost higher than non-frost with inverter type refrigerator. Again the **Table 3** represents the maintenance cost. This maintenance cost comparison indicated that frost type refrigerator was costlier than non-frost type refrigerator. Combining all of these cost, it can be concluded that non-frost inverter type refrigerator is more economical than frost refrigerator (**Table 4**).

5. Impact of Refrigerator on Environment

Refrigerators have multiple environmental impacts e.g. indirect impact like consumption of electricity results huge carbon emissions along with other harmful pollutants from fossil fuel based power plants. Another source of harmful

gases like Hydrofluorocarbons, HFC; and other fluorinated gases, F-gases could be generated from open disposal of refrigerant. Negative impacts of these gases e.g. some older F-gases can damage the earth's ozone layer; and many of them are responsible for global warming. Some F-gases are thousand times as harmful as CO_2. Both direct and indirect impacts are considered to be Total Equivalent Warming Impact (TEWI), that is measured in terms of the equivalence of carbon dioxide (CO_2e). Considering old designed frost type refrigerator, 60% of impacts depicts indirect emission and 40% found direct emissions. However, the emission proportions and total carbon dioxide concentration have found to be less significantly over the time with non-frost type. With environment-friendly hydrocarbon (HC) gases - that are used for refrigerant and foam-blowing agents - on the increase in the last couple of years (e.g. in the European Union, EU), the relative effect of direct emissions has shown to be lessen in the advanced non-frost type refrigerator.

Another safety related issue of refrigerator industry is improper handling of appliances and gases that pose both environmental and occupational health risk. However, in many countries F-gas induced refrigerants (especially frost type) are still popularly used in refrigerators, thereby impacting the nature. Indirect (energy related) impacts are found to be less than one third of what they were for older appliances. Study showed that developing countries with unregulated markets governed by old technology refrigerators can save energy up to 60%. Furthermore, refrigerators are high electricity consumers in household sector. The range of efficiency is variable. Old appliances like frost type refrigerators consume up to three times more energy when compare with the non-frost type and contain the environmental legacy of highly damaging GHG and/or ozone damaging gases (UN Environment, 2017; Koch, 2015).

6. Conclusion

A comparative study has been done between the non-frost type along with inverter refrigerator and frost type refrigerator. From both economic and environmental point of view, it can be concluded that non-frost type inverter refrigerator could be the most preferable appliance to use in both home and industry. \

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Authors Contribution

Md. Shawkut Ali Khan: Conceptualization, Validation, Supervision. Md. Iftakharul Muhib: Writing, Reviewing, Editing.

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