Development of Liquid Nitrogen Centrifugal Pump

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Abstract. Usually liquid nitrogen (LN₂) transfer from a container to a laboratory equipment takes place by applying pressure to the container to push out liquid or pouring liquid into the cryostat directly by lifting the container. In order to overcome inconvenience of pressuring or lifting containers, we have been developing a liquid nitrogen centrifugal pump which is small and less costly. Significant advantages of using such a pump are both reducing time to fill LN₂ and controlling the flow rate of liquid into the cryostat are obtained by introducing this pump. We have achieved the lift of about 800mm with the vessel’s opening diameter of 28mm.

1. Purpose

Liquid nitrogen (LN₂) pumps have been manufactured and widely used for LN₂ transfer from tank lorries to big storage tanks. However these large pumps doesn’t suit small equipments in laboratories.

LN₂ transfer from a container to a cryostat takes place by two methods: (1) Applying pressure to the container to push out liquid under the differential pressure, (2) Pouring liquid into the cryostat by lifting the container. In order to overcome these inconvenience, we have been developing a liquid nitrogen centrifugal pump which is small and less costly. Significant advantages of using such a pump are both reducing time to fill cryogen and controlling the flow rate of liquid.

Here we describe the current status of our development.

2. Assembly of the pump

Our goal is to develop a portable LN₂ centrifugal pump with easy manufacturing, good maintainability and low cost. Figure 1 shows the schematic view of the pump. Numbers in the figure correspond to as follows: 1: transfer tube, 2: reducer, 3: spacer, 4: casing, 5: motor, 6: spacer, 7: impeller, 8: casing cap with an inlet hole. The impeller(7) scatters cryogen continuously, then scattered cryogen flows the gap between the motor(5) and the casing wall(4).
Figure 1. Schematic view of the LN\textsubscript{2} pump A (longitudinal section). Pump B has the same components but the shapes and materials of the parts are different.

3. Test

3.1. Setup

We prepared two setups, A and B, to compare and clarify important factors in operating the pump. Pump A (with motor A, figure 3) and pump B (with motor B, figure 4) is used in setup A and B, respectively. Brief specification of each setups is summarized on Table 1.

Figure 3. Pump A. (A) With transfer tube. The length between the pump and the elbow is 800mm. (B) Overhauled.

Figure 4. Pump B. Overhauled.

In order to minimize abrasion and to acquire longterm durability, we chose DC blushless motors \textsuperscript{1}. Motor A has no mechanical grease around bearings. Motor B had the grease inside because it was originally designed for a room temperature use. Preliminary test showed that the motor B stopped rotating in LN\textsubscript{2} because the grease caked, so we washed the motor in ethanol.

\textsuperscript{1} Blushless motors generally have better durability than blush motors because the former don't have any contact surface.
and removed it. Impellers were made with polyoxymethylene (POM) resin by using 3D digital modeling machine\(^2\). POM has less density and better processability than other metals or resins.

| Table 1. Brief specification of setups |
|--------------------------------------|
| **Setup** | A | B |
| Motor’s power [W] | 6~8 | 15 |
| Rotation at test [rpm] | 9000~12000 | 10000~37000 |
| Impeller material | POM | POM |
| Number of blades | 6 | 6 |
| Impeller’s inner radius [mm] | 6 | 2.5 |
| Impeller’s outer radius [mm] | 11 | 8.0 |
| Height of a blade [mm] | 8 | 10.0 |
| Casing material | polyvinyl chloride (PVC) | alloyed aluminum |
| Casing inside diameter [mm] | 25 | 19 |
| Casing outside diameter [mm] | 26 | 24 |
| Casing length [mm] | 92 | 91 |
| Inlet hole diameter [mm] | 8 | 12 |
| Transfer tube material | PVC | glass insulated tube |
| Transfer tube inside diameter [mm] | 13 | 4 |
| Transfer tube outside diameter [mm] | 26 | 12 |
| Transfer tube length [mm] | 800~ | 1000~ |
| Storage tank material | alloyed aluminum | glass |
| Storage tank entrance diameter [mm] | 28 | 54 |
| Storage tank volume [L] | 50 | 22 |
| Target tank material | stainless | stainless |
| Target tank entrance diameter [mm] | 24 | 185 |
| Target tank volume [L] | 50 | 6 |

3.2. Result

Current result is briefly summarized on Table 2. Setup A (figure 5) transferred LN\(_2\) with the discharge volume rate of 4L/min at the input power of 6W, 12000rpm. It was also verified that the discharge volume rate was controlled with the input power control. As for setup B (figure 6), we tried some different shapes of the casing and the spacer (No.3 in figure 1). All of them lifted LN\(_2\) over 1000mm. The best and worst discharge volume rates were 1.8L/min and 0.3L/min, respectively. Furthermore, we found that the discharge volume rates of both of the setups gradually decreased after a certain period operation. In the case of setup A, the decrease began after transferring 30L of LN\(_2\).

\(^2\) Roland DG, 3D Plotter MDX-15
### Table 2. Result

| Setup     | Condition                   | Discharge volume rate [L/min] | Lift [mm] |
|-----------|-----------------------------|------------------------------|-----------|
|           | with spacer                 | 4.0                          | 800~      |
|           | w.o. spacer                 | 1.8                          | 1000~     |
| B-1       | with spacer (figure 7)      | 0.3~0.9                      | 1000~     |
| B-2       |                             |                              |           |

### 4. Conclusion and future plan

We have succeeded in development of the LN\textsubscript{2} centrifugal pumps. They have small radii and the enough total heads to transfer LN\textsubscript{2} without pressuring cryostats. Another favorable result is that each of pumps cost inexpensive, suggesting the pump would be commercial wares with a reasonable price for the laboratory use. It is our pleasure to have made prototypes of the adequate pumps for the laboratory which wants to conquer the inconvenience of LN\textsubscript{2} transfer. We also have a plan to apply the pump to liquid helium transfer in the future.

On the other hand, it should be notified that there are three points to be clear in order to analyze the reason why the discharge volume rate decreases during operation and to optimize the specification: (1) The characteristics of the discharge volume rate on the input power or motor rotation, (2) how the inside shape influences the discharge volume rate, (3) the flush loss of LN\textsubscript{2} during the operation. Detailed data and its analysis will be achieved soon.

### References

[1] KHK 2006 *High pressure gas safety techniques 3rd edition* (Tokyo: The high pressure gas safety institute of Japan) p319

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